The Optometric Management of Concussion

by

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A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Master of Science

in

Vision Science

Waterloo, Ontario, Canada, 2021

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Introduction

Traumatic brain injury is a major public health problem that affects millions of people annually and hundreds of people experience brain injury daily. Many of these individuals develop visual symptoms. Optometrists play a prominent role in the management of patients with concussion-associated vision deficits and persistent concussion symptoms. At present, there is no accepted optometric standard of care for individuals with concussion. Patients receiving optometric concussion related care would benefit from a standardized evidence-based concussion management process.

The purpose of this project was to determine the current assessment methods and prescribing practices of optometrists seeing individuals with persistent concussion-associated vision deficits in private practice and at a university academic optometry clinic.

Study 1

A retrospective review examined the frequency of visual assessments and management strategies at an academic university optometry clinic. A total of 238 patient files were examined. Of the 238 patient files, 119 individuals had persistent concussion symptoms (concussed group) and 119 individuals did not have concussion (non-concussed cohort). The frequency of visual assessments (ocular structure and visual function) and management strategies were determined. A chi square test was used to compare the frequency of assessments and management strategies between cohorts. In the concussed group, an emphasis on visual function and management strategies, for example assessments of vergence, saccades, pursuits and stereopsis were observed in comparison to the reference group. In non-concussed individuals, ocular structure assessments (e.g., posterior segment,

anterior segment and confrontation visual field) were more prevalent than in the concussed cohort. It is important to note that ocular structure assessments did not include assessments conducted by the referring optometrists. Diagnostic drugs, for example tropicamide and anesthetics, were used more commonly in the non-concussed group, while cycloplegia was more prevalent in the concussed group.

Study 2

A 6-question online survey was distributed to optometric provincial and national regulators and associations in Canada. Questions pertaining to visual assessments, prescribed medications and supplements, advice about daily living activity, appointment duration and appointment follow-up were asked. Analysis consisted of binning and determining the frequency of responses. Of the 199 responses received, 142 were completed and analysis was only conducted from these responses. A total of 128 optometrists managed concussion and 13 optometrists did not. The top reasons for optometrists who did not manage concussion was referral and no training. Ocular structure assessments were more prevalent than visual function and management strategies of concussion. Optometrists most frequently recommended Omega 3 (54%) and oral supplements (38%). The majority of optometrist's (64%) advice on daily living activity was to limit physical and cognitive activity, the second most common suggestion was to rest (12%). The majority of optometrists, 57%, employed 30 to 60-minute assessments and over one-fifth conducted follow-up appointments within 2-months.

Conclusion

This project informs optometrists on the state of concussion management in Canadian private practice and at a university academic optometry clinic.

Findings can be used to aid in the development of standardized strategies for the optometric management of concussion and related regulatory decisions. This can lead to reductions in persistent post-concussive symptoms, improved patient outcomes, and overall improved quality of life.

Acknowledgements

First and foremost, I cannot sufficiently thank my supervisors, Dr. Dalton and Dr. Irving, for not only giving me this opportunity, but for their ample support and guidance throughout my research studies. I appreciate your insight, encouragement, and kindness. I end my masters journey inspired - thank you Dr. Irving and Dr. Dalton.

I would also like to thank my committee members, Dr. Spafford and Dr. Christian for all their helpful suggestions, feedback and support.

I would like to thank Chris Mathers for his abundant help with REDCap. You made my experience with REDCap an easy and positive one.

Thank you to the grad coordinators, Holly Forsyth and Emily O'Connor, for all their hard work in keeping us, grad students, on track.

A special thank you to Yara Mohiar and Dr. Zoe Lacroix for your time and energy towards translating the survey and responses.

I would like to thank my lab mates, fellow grad students, faculty and staff for making my experience at the school a memorable one.

To my parents, thank you for your unconditional love and unwavering support. Thank you for teaching me that sky is the limit and to always dream big. A big thank you to my family who have always encouraged and cheered me on. Finally, to Cheri, thank you for all your support.

Dedication

This thesis is dedicated to my parents. Mom and Dad, thank you for all the sacrifices you’ve made.

Table of Contents

List of Figures

List of Tables

Chapter 1

Literature Review and Objectives

1.1 Concussion defined

Mild traumatic brain injury is one of three classifications of traumatic brain injury (TBI), the other classifications are moderate and severe TBI. Multiple definitions of mild TBI exist. The World Health Organization (WHO) Collaborating Center Task Force on Mild Traumatic Brain Injury reported 38 varying definitions and inconsistencies in terminology within the literature (Carroll et al., 2004; McCrory et al., 2018). The 5th consensus statement on concussion in sport also highlighted challenges surrounding the term sports related concussion (McCrory et al., 2018). It does not indicate grades of severity, the fundamental processes leading to brain impairment and does not incorporate new insights on persisting symptoms (McCrory et al., 2018).

Various groups have different definitions and criteria for concussion, below are some of the more commonly used definitions. The CDC describes TBI as, “a disruption in the normal function of the brain that can be caused by a bump, blow, or jolt to the head, or penetrating head injury” (CDC, 2017). A clinical criterion used in the diagnosis of TBI, the DSM-5, defines TBI as “brain trauma with specific characteristics that include at least one of the following: loss of consciousness, posttraumatic amnesia, disorientation and confusion, or, in more severe cases, neurological signs” (APA, 2013). The WHO defines mild TBI as “an acute brain injury resulting from mechanical energy to the head from external physical forces” (Holm et al., 2005). Mild TBI can also be described as a Glasgow Coma Scale (GCS) score of 13 to 15 and some author groups have further categorized it as complicated or uncomplicated (Permenter et al., 2021). Complicated mild TBI entails symptoms linked with computed tomography (CT) scan irregularities, namely, subarachnoid or subdural bleed, hematoma, fractures or midline shift (Permenter et al., 2021). Uncomplicated concussions comprise normal brain CT scans and increased likelihood of symptom resolution in less than three months (Permenter et al., 2021).

The high contact nature of many sports leaves athletes vulnerable to traumatic brain injury, accounting, in part, for the high prevalence of concussion (Clay et al., 2013). The Concussion in Sport Group, a group of medical experts on concussion, seek to provide consensus on definitions and management of sports-related concussion for healthcare providers. The Concussion in Sport Group defined sports related concussion (SRC) at the Berlin international Conference on Concussion as "a traumatic brain injury induced by biomechanical forces." Some traits of concussion that can be employed in defining concussion in clinic are that sports related concussions (SRC) are caused by a force to the body that transmits to the head and in most cases leads to a disruption of neurological function that often resolves in expected clinical recovery time frames (McCrory et al., 2018). Furthermore, the onset of SRC typically leads to signs and symptoms that may not always lead to loss of consciousness (LOC). In fact, Purcell et al. note that most concussion cases do not actually lead to a loss of consciousness (Purcell et al., 2013). Mild TBI and concussion seem to be used interchangeably, the first being more prevalent in a medical setting and the latter more commonly used in a sports medicine context (Lefeve-Dognin et al., 2021).

1.2 Persistent concussive symptoms defined

Persistent post-concussive symptoms (PCS), also known as post-concussion syndrome, describe the collection of symptoms that may persist after concussion (Permenter et al., 2021). Concussion is self-limiting and heals in approximately 85% to 90% of cases (Permenter et al., 2021). Signs and symptoms typically resolve within four weeks, however in some cases symptoms have been recorded to be prolonged by ten to thirty percent (McCrory et al., 2018). When symptoms persist past normal clinical recovery times, i.e., more than ten to fourteen days in adults and more than four weeks in children, the patient may be diagnosed with PCS (McCrory et al., 2018). Persistent symptoms are common in mild traumatic brain injury (Fraser and Mobbs, 2021). As new insights rapidly evolve on concussion, the terminology surrounding it is changing from post-concussion syndrome to persistent concussion symptoms to better reflect new knowledge of the injury. Persistent concussive symptoms may not be part of ongoing posttraumatic pathophysiology, but rather a group of non-specific symptoms that may be associated with pre-or co-existing factors (McCrory et al., 2018). Risk factors for PCS include age, sex, history of chronic pain syndromes, or psychiatric history (Dikmen et al., 2017). Unfortunately, researchers do not agree on a specific cause of PCS; based on the current understanding, PCS is thought to be caused by a combination of biological effects from the injury alongside factors in an individual's life (i.e. psychosocial factors, psychological factors and chronic pain) that pose as cumulative stressors (Iverson, 2005).

As previously discussed, a variety of terms are used to describe concussion in the literature. In this thesis, terminology consistent with the CIS group, namely concussion and persistent concussive symptoms, will be used, except when reporting previously documented research. When reporting previously documented research, the published terminology of the authors will be used.

1.3 Concussion pathophysiology

After a concussive head injury, a complex set of processes occur that affect neuronal function and result in signs and symptoms (Howell and Southard, 2021). These processes include microstructural, metabolic and physiological changes in the brain (Permenter et al., 2021).

Researchers hypothesize that the cascade of pathophysiological events are primarily the product of altered ion flux, reduced cerebral blood flow, energy reduction, neuromechanical deformation, and disrupted axonal function (Giza and Hovda, 2001). At the cellular level, after injury to the brain potassium (K^{+1}) flows out of the neuron while sodium (Na^{+1}) and calcium (Ca^{2+}) flow in (Giza and

Hovda, 2001). In an attempt to maintain homeostasis, the cell utilizes membrane ion pumps which require energy. With the increased energy demand due to the head injury and the limited ability to create new energy because of altered glucose and cerebral blood flow an energy crisis results (Giza and Hovda, 2001). This crisis can last for up to 10 days in animal models however the duration is unknown in humans (Giza and Hovda, 2001; Howell and Southard, 2021). On top of the energy crisis, neurons lose their form due to a collapse of microstructural components and microtubules. This is largely caused by calcium influx and axonal stretching (Giza and Hovda, 2001; Howell and Southard, 2021). Neuronal inflammation has also been observed, which further disrupts normal cell function and tissue, leading to the signs and symptoms observed in concussion (Howell and Southard, 2021).

1.4 Concussion epidemiology

Concussion is a major public health problem worldwide (Ciuffreda et al., 2020). An estimated 42 million individuals experience concussion annually (Gardner and Yaffe, 2015); however, the reported prevalence of concussion varies in the literature. This variation may be due to varying definitions of the term concussion (McCrory et al., 2018). An underestimation of the prevalence of concussion may also exist from underreporting. A minimum of 25% of concussion cases fail to receive medical help (Iverson, 2005). This may perhaps be due to the quality of health care systems available, concussed individuals not knowing they have experienced a concussion, or thinking their concussion is not severe enough to warrant medical attention. A Canadian study examining the occurrence of concussion at two university teaching hospital emergency departments in Montreal, Quebec found that 88.6% of those who experienced concussion were unaware of the injury (Delaney et al., 2005). The WHO reviewed studies and found a hospital treatment rate of 1 to 3 per 1000 individuals;

acknowledging that only a proportion of concussions are treated at hospital, the WHO estimated a concussion rate of 6 per 1000 people (Cassidy et al., 2004).

The annual incidence rate of concussion is higher in teenagers and young adults and studies indicate males experience concussion at around twice the rate of females (McCrory, 2001; Cassidy et al., 2004). Individuals who have had multiple brain injuries are at an increased risk of PCS (Permenter et al., 2021).

In Langlois et al's 2004 study investigating the rate of hospitalization, emergency department visits and death in relation to TBI in the United States, the leading cause of concussion was found to be falls (28%), followed by motor vehicle accidents (20%) and assault (11%). They found 'other' and 'unknown' reasons accounted for 32% and 9%, respectively. A 2019 study by Hon et al. (2019) reviewed the global perspectives on the prognosis, treatment, and epidemiology of concussion in children by reviewing randomized controlled trials, meta-analyses, clinical trials, and reviews. They reported that most publications were from Canada and the United States, and that common causes of concussion included sports injuries, motor vehicle collisions, bicycle accidents, falls and assaults. They also noted over 88% of concussion cases go unrecognized and that it is likely concussions are underdiagnosed in sports.

The CDC examined results from the 2017 National Youth Risk Behaviour Survey in the United States and reported that the prevalence of concussion was higher in men compared to females and more prevalent in athletes compared to non-athletes (DePadilla et al., 2018). A 2006 study described the epidemiology of reported concussion from the Canadian National Population Health Survey and found concussion to be most prevalent in individuals that were 'younger' and male (Gordon et al., 2006). Males were heavily represented between 16-34 years. The estimated annual incidence rate of concussion was 110 per 100,000, however it was noted that this approximation may be an underrepresentation of the actual population incidence rate. The incidence per 100,000 females and males between 0 – 14 years was 230 and 170, respectively (Gordon et al., 2006). Between 16-34 years, the incidence per 100,000 females was 60 and for males between 15-34 years it was 260 (Gordon et al., 2006). Finally, the incidence per 100,000 females and males 35 years and older was 50 (Gordon et al. 2006). Similar trends exist in other traumatic brain injuries. Langlois et al. (2004) reported males to be twice as likely to experience traumatic brain injury compared to females.

1.5 Concussion symptoms

It is common for cognitive, emotional, sleep and/or physical symptoms to present during the first 72 hours following concussion. (Permenter et al., 2021; Junn et al., 2015; Mayo Clinic, 2020). Acute symptoms like vomiting, loss of consciousness and seizure may require urgent care. Cognitive symptoms can include poor concentration, memory impairment and attention impairment (Junn et al., 2015). Emotional symptoms include depression, anxiety, moodiness and irritability (Mayo Clinic, 2020). Sleep symptoms consist of drowsiness, sleeping more or less than usual and/or troubles falling asleep. Physical symptoms involve headache, nausea, balance issues, noise sensitivity and vision problems (Mayo Clinic, 2020).

Commonly reported visual symptoms include but are not limited to blur, photophobia, double vision, vision loss, and issues tracking, reading and focusing (Pillai and Gittinger, 2017). Up to 69% of adolescents with concussion have vision symptoms and as many as 88% of adolescents with persistent concussion-associated visual symptoms have been shown to have vision or vestibular problems (Master et al., 2016; Master et al., 2018). Response to injury may differ between developing adolescent and adult brains, which could potentially lead to adolescents being at greater risk for persistent symptoms, but the pathophysiology of persistent symptoms is still unknown. Figures as high as 90% of individuals with traumatic brain injury have been reported to suffer from visual deficits (Ciuffreda et al., 2007).

1.5.1 Visual acuity, visual field and refractive status

Trouble seeing is a common symptom after concussion. While visual acuity is typically maintained in mild TBI, testing can be limited due to other symptoms like photophobia (Pillai and Gittinger Jr., 2017). A retrospective analysis found 50% of individuals with concussion were diagnosed with photosensitivity compared to 10% of healthy individuals (Truong et al., 2014). Glare disturbances have also been reported, but research on glare is largely in the cataract population and it is unknown if measuring glare acuity would be beneficial in concussion treatment (Pillai and Gittinger Jr., 2017). Vision loss is more prevalent in moderate and severe TBI compared to mild TBI and is thought to occur following trauma to the optic nerve or chiasm (Suchoff et al., 2008; Atkins et al., 2008). A 2008 study examined the frequency of visual field defects in ambulatory outpatients with acquired brain injury accompanied with visual symptoms and found 46.36% (102/220) of individuals with ABI suffered some type of visual field defect (Suchoff et al., 2008). The ABI population consisted of 160 TBI patients and 60 cerebral vascular accident patients. In the TBI group, scattered defects were most prevalent (22.5%) (Suchoff et al., 2008). Findings from Sabates et al. (1991) reported 35% of closed head injury patients had visual field defects. Confrontation visual field and automated perimetry can be used to assess visual field defects in this population (Pillai and Gittinger Jr., 2017).

Refractive status can be altered following a concussion. Leslie (2009) documented individuals with traumatic brain injury, with no existing history of myopia, who presented with myopia between 1 and 2 diopters following head injury. Ciuffreda et al. (2016) also noted increased myopia as a result of dysfunction in the sympathetic nervous system in mild TBI patients. In another study examining 161 patients with head injury, 19% were reported to have pseudomyopia, an uncontrolled accommodation of the eye caused by ciliary spasm or overstimulation (Kowal, 1992; Khalid et al., 2021).

1.5.2 Pupils

Because the pupillary light reflex is conventionally examined using a penlight, interpretation is dependent on the observer. While pupil abnormalities, including anisocoria (inequal pupil sizes) may be obvious in severe TBI cases, pupil abnormalities in mild TBI are typically subtle and not always recognized using a penlight (Pillai and Gittinger, 2017).

Research using infrared pupillometry, a device that objectively examines pupil reflexes, showed that concussed military personnel had slowed pupil constriction and dilation responses compared to a non-concussed cohort (Capo-Aponte et al., 2013). Similarly, a 2016 study also found that a mild TBI group had slower velocities and longer constriction latencies compared to non-concussed individuals (Truong and Ciuffreda, 2016). Interestingly, when comparing minimum and maximum pupil sizes to baseline scores, no changes were noted (Capo-Aponte et al., 2013), which suggests that mild TBI affects the dynamic properties of the pupils more than their static aspects.

1.5.3 Saccades and Pursuits

Eye movements can be impaired following concussion (Suh et al., 2006; Heitger et al., 2009). Saccades are rapid conjugate eye movements fundamentally used by foveate animals to scan their visual environment and are also employed in tasks like reading. When reading, concussed individuals have experienced difficulties moving from one line to the next, skipping words or losing their place in text which may be due to saccadic dysfunction or misalignments of the eyes (e.g. a decompensating vertical phoria) resulting in symptoms like diplopia (Pillai and Gittinger Jr., 2017). Abnormalities in memory-guided saccades, antisaccades and visually cued saccades have also been reported (Pillai and

Gittinger Jr., 2017). A 2014 project found saccadic gain to decrease in concussion patients by 10% to 20%; the same trend exists for pursuit gain (Ciuffreda et al., 2016; Thiagarajan, 2014).

Smooth pursuits, conjunctive reflex tracking eye movements, keep a moving stimulus on the fovea accurately. Patients with concussion have reported difficulties with tracking objects and studies have verified that concussed individuals have increased error in eye position (Pillai and Gittinger Jr., 2017). A review on the visual effects of acute concussion reported abnormalities in smooth pursuit alongside abnormalities in convergence and accommodation in patients who had their initial injury at least 3 months prior (Fraser and Mobbs, 2021).

1.5.4 Binocular vision

Binocular vision involves the utilization of information from both eyes to perceive a single image and is commonly affected following concussion (Howell et al., 2018). Increased binocular dysfunction was shown in a 2017 retrospective study reviewing the prevalence of visual dysfunction in 500 concussed US military personnel. Capó-Aponte et al. (2017) concluded that binocular dysfunctions, for example vergence (88%) and version (57%) issues, were the most common. In agreement, Gallaway et al. (2017) found 82% of concussed individuals in two private practice settings had an oculomotor deficit diagnosis. In the Gallaway et al. study, oculomotor deficits consisted of binocular vision deficits (e.g., convergence insufficiency, convergence excess, and fusional vergence dysfunction), accommodative issues, and eye movement disorders. Binocular vision deficits, which included but were not limited to convergence insufficiency, convergence excess and vertical deviations, were the most common at 62.3% (Gallaway et al., 2017).

A 2015 cross-sectional study by Master et al. (2016) examining 100 concussed adolescents reported 69% to have one or more of the following deficits: accommodative disorder (51%), convergence insufficiency (49%), and saccadic dysfunction (29%). Gallaway et al. (2017) also found a prevalence of 54.2% in accommodative disorders and 21.6% in saccadic dysfunction. The criteria they used to define saccadic dysfunction was either a ratio score or error score of one or more below the mean on the Developmental Eye Movement Test (DEM). Interestingly, 41.9% of accommodative disorders were attributed to accommodative insufficiency (Gallaway et al., 2017). This same study also found convergence insufficiency and convergence excess prevalence to be 47.5% and 7.8%, respectively (Gallaway et al., 2017).

Although spasm of the near reflex typically presents from an underlying emotional disorder, is functional in nature, and rarely comes from organic causes, it has been documented in case reports following head injury (Knapp et al., 2009; London et al., 2003). It is characterized by intermittent miosis, convergence spasm and pseudomyopia (Knapp et al., 2002; Chan and Trobe, 2002). Symptoms in a case report were managed by a cycloplegic agent paired with distance and near spectacles (Knapp et al., 2009). Other authors have reported difficulties in the management of pseudomyopia because of its continuance even after medical intervention. Prospective measures contemplated include accommodative facility exercises, near addition lenses and cycloplegic agents (London et al., 2003).

Stereoacuity requires alignment of images on the fovea of both eyes and visual processing; decreased functionality has been documented in a cohort of concussed military personnel (Pillai and Gittinger, 2017; Capó-Aponte et al., 2017). In accordance, a 2020 study evaluating stereoacuity as an objective test to detect concussion found significant differences between a concussed and reference group (Kara et al., 2020). A virtual reality program depicted 3D rotating soccer balls in different positions of the visual field and subjects were instructed to pick the soccer ball that appeared elevated from the screen as quickly as they could. The response times of the mild and moderate TBI groups were longer compared to the reference group primarily due to defective fusion. The moderate TBI subjects also had a longer response time compared to the mild TBI group. While central fusion remained intact, 9 of 19 mild TBI patients and 9 of 11 moderate TBI patients displayed fusion impairment while gazing to the left and right, immediately after hospitalization (Kara et al., 2020).

1.5.5 Extraocular Motility

Extraocular motility issues in head trauma have been documented as early as the late 1900s. An early study examining 161 patients with head trauma found motility disorders were common, mainly cranial nerve palsies (third, fourth and sixth nerve). Other less common disturbances included comitant esotropia, exotropia and inferior oblique palsy (Kowal, 1992). Rosner et al. (2016) analyzed the effectiveness of treating concussion-related vertical heterophoria with neutralizing vertical prisms to reduce symptoms following concussion. Prismatic lenses were found to indirectly be an effective treatment of anxiety, headache and dizziness in PCS patients by primarily treating underlying binocular vision symptoms like eye strain, blurred vision and "losing your place while reading" (Rosner et al., 2016). A subjective improvement of symptoms surrounding vertical heterophoria was also documented.

1.5.6 Balance abnormalities

The vestibular system helps maintain equilibrium and spatial orientation and works closely with the ocular system to carry out the vestibulo-ocular reflex (VOR) (Leigh and Zee, 1999). The VOR is a robust system that allows gaze stabilization when the head moves. In a scenario where the head is moving, the eyes move in an equal and opposite direction of the head to allow the eyes to clearly fixate on an image (Broglio et al., 2015). Vestibular impairment can lead to balance and equilibrium issues whereas, dysfunction of the vestibulo-ocular system can lead to nausea, dizziness, vertigo, and blurred vision (Broglio et al., 2015; Furman et al., 2010). Oculomotor and vestibular dysfunction have been reported to occur in around 60% of athletes after a sports-related concussion (Mucha et al., 2014). Interestingly, vestibular issues have been documented to be predictive of prolonged vision symptoms (Lau et al., 2011; Master et al., 2018).

Another condition that can lead to balance abnormalities is midline shift syndrome. A scoping review by Labreche et al. (2019) concluded that midline shift syndrome can occur after a cerebrovascular event, despite the literature's lack of agreed upon terminology, pathophysiology, assessment, and management. While Labreche et al.'s work demonstrated there is some consensus on the existence of midline shift syndrome in the post-stroke population, there is less consensus about midline shift syndrome in the post-concussion population. A 2015 study that examined 36 subjects with balance issues and presumed midline shift syndrome reported that 10/36 participants had concussion (Padula et al., 2015). Yoked prisms are prisms in the lenses that refract the image in the same direction by the same degree and may be an intervention for individuals suffering from visual midline shift syndrome (Padula et al., 2009). Although some researchers have observed improvements using yoked prisms on individuals with presumed visual midline shift, Barton and Ranalli (2020b) contradict this stance and report a lack of clinically significant proof on the efficacy of yoked prisms treating balance issues. They recommend additional research on both visual midline shift syndrome and its treatment.

1.6 Concussion Management

1.6.1 Recognition

The nature of concussion is complex, signs and symptoms may not immediately present following injury, and injury can evolve making the recognition of concussion a difficult task (McCrory et al., 2018). Parachute's 2017 guidelines state that if an athlete sustains significant impact to the brain during a sporting event, a concussion should be suspected in their sideline assessment. The goal of the sideline assessment should be to screen for potential concussion as opposed to diagnose concussion; the latter can only be done after a medical assessment (McCrory et al., 2018; Parachute, 2017).

Sideline evaluations should include assessment of symptoms, balance, cognition, and cranial nerve function (McCrory et al., 2018). Effective evaluation of concussion should include multidimensional testing that has also received expert consensus, for example the Sport Concussion Assessment Tool – 5th edition (SCAT 5) which is further discussed in an upcoming section (McCrory et al., 2018).

One objective screening measure is the King-Devick test, a quick and portable sideline test. Baseline scores are required for this screening tool and are compared to scores following a neurological event. King-Devick is designed to capture impairment of attention, language, fixation and eye movements (Galetta et al., 2015b; Ciuffreda et al., 2016). An additional, objective screening tool is the Vestibular/Ocular Motor Screening (VOMS) which incorporates five domains (smooth pursuit, saccades, convergence, vestibular-ocular reflex [VOR] test and visual motion sensitivity [VMS]) to detect signs and symptoms of a concussion (Mucha et al., 2014). A preliminary study examining consistency and sensitivity of the VOMS in 64 concussed patients and 78 control patients supported its use in concussion detection (Mucha et al., 2014).

The CISS, Convergence Insufficiency Symptom Scale is a 15-point validated subjective symptom survey that detects convergence insufficiency. Research by Master et al. (2016) aimed to determine if CISS could be used as a screening tool for adolescents with vision diagnoses post mild TBI. A score above 16 on the CISS indicates an individual may have convergence insufficiency. Participants with vision diagnoses following concussion were identified with CISS making it a possible detection tool for vision diagnoses after a concussion (Master et al., 2016). It is important to note that CISS can identify multiple conditions, therefore it is not a specific symptom scale. The inclusion of CISS baseline testing may increase the precision of the survey in detecting concussion.

1.6.2 Assessment and Diagnosis

Concussions result from neuropathological disturbances. Signs and symptoms reflect a functional disruption rather than a structural injury, so conventional imaging like CT and magnetic resonance imaging (MRI) are not largely recommended as the functional disruptions typically go undetected (Hon et al., 2019; McCrory et al.,2018; McCulloch et al., 2020). Because a common feature of concussion is the absence of abnormalities on standard structural imaging, a criterion that could be set for a concussion to be diagnosed is that the MRI is normal (McCrory et al., 2018). Advanced neuroimaging of fluid biomarker analyses like cerebral blood flow assessment could detect biological disruptions; however, their overall use in clinical practice is low (Howell and Southard, 2021). As per the most recent consensus statement on concussion, clinical symptoms, physical signs, cognitive impairment, neurobehavioral features, and sleep/wake disturbances should all be assessed in patients with suspected concussion. When symptoms or signs are present on three or more of the clinical domains described above, then it is much more likely a person has a concussion; however, the final diagnosis of a concussion is a medical decision based on clinical judgment (McCrory P, 2018). Due to the heavy reliance on patient symptoms, concussion diagnosis is less precise than injuries diagnosed objectively (Howell and Southard, 2021.

As described above, currently, there is no single test that detects concussion. Subjective symptom surveys are largely used in the diagnosis of concussion by health care providers and typically include questions on cognitive impairment, visual symptoms and physical complaints. Below are some commonly used symptom scales described by Laukkanen et al., 2017 and Subotic et al, 2017.

The Rivermead Post Concussion Symptoms-Questionnaire is a self-reporting 0 – 4 scale that measures the severity of post-concussion symptoms (King et al., 1995). The Post Concussion Symptoms Scale is a 22-question form asking patients to rate symptoms over the past two days on a

7-point Likert subjective scale (Heinmiller and Gunton, 2016). An additional self-administered symptom 0 – 4 scale is the Brain Injury Vision Symptoms Survey (BIVSS), which focuses on vision namely, eyesight clarity, visual comfort, double vision light sensitivity, dry eyes, depth perception, peripheral vision and reading.

The Standardized Concussion Assessment Tool (SCAT), developed by the Concussion in Sport Group, is perhaps the most commonly used tool internationally (Echemendia et al., 2017). The SCAT, currently on version 5 (SCAT5) evaluates athletes suspected to have sustained concussion across a variety of domains. Variables like orientation, memory, and concentration are assessed alongside cognitive and physical examinations, and individual symptoms (Davis et al., 2017; McCrory et al., 2018; Echemendia et al., 2017; Heinmiller and Gunton, 2016). In addition to its usefulness in acute concussion diagnosis, this tool can also be used to gather baseline data for future comparison and has some utility in monitoring concussion recovery.

There is a significant amount of research being done to develop objective tests for concussion diagnosis, including research on eye movements, pupil function, vestibular function, and blood biomarkers (Zahid et al., 2020; Podolak et al., 2019; Harris et al., 2021; McCrory et al., 2018). While research on objective tests appears to be promising, none are currently accepted as standards of care and more research is required.

1.6.3 Management

Most concussions resolve on their own and complete recovery occurs within 1- 4 weeks (Parachute, 2017; McCrory et al., 2018). Acute rest for 24 to 48 hours followed by a gradual return to cognitive and physical activity is recommended following a concussion (McCrory et al., 2018). Parachute (2017) outline activity progression in their guidelines for returning to school and work that are intended to help concussion patients safely re-integrate into ‘normal’ lifestyle again.

In a clinical setting, the management of concussion should be individualized as each patient has a unique combination of symptoms and management should focus on alleviating injury burden and restoring base line function (Heinmiller and Gunton, 2016; McCrory et al., 2018; Wolter and Pizzimenti, 2017). A careful assessment from clinicians is required in determining if persistent symptoms are a result of neurological pathophysiology or other processes, such as pre-existing conditions (Bramley et al., 2016).

Several authors have provided suggestions on assessment measures based on symptom prevalence and/or effectiveness found in concussion management. Master et al. 2016 suggest that a comprehensive visual examination be conducted to aid in the evaluation of adolescents with concussion after discovering prevalent oculomotor dysfunction, mainly convergence insufficiency and accommodative insufficiency, in this population.

Ciuffreda et al. 2016 proposed a 4-tiered conceptual pyramid of vision care for concussion that assesses concussed individuals from the bottom up. At the base of the pyramid, a basic vision examination including ocular health status, refractive status and binocular status should be conducted. This exam should be followed by an assessment of oculomotor based-vision problems including assessments of accommodation, version and vergence (pyramid level 2). Next, an analysis of non-oculomotor vision problems should be conducted, namely visual field defects, photosensitivity, vestibular dysfunction, motion sensitivity, visual information processing (pyramid level 3). Finally, an assessment on non-vision-based problems should be completed, including depression, attentional problems, neurological problems, cognitive problems and behavioral problems (pyramid level 4). When non-vision-based problems do not relate to optometric management, referral to a specialist is suggested. Recommended visual interventions include prisms, occluders, tints, lenses, and vision therapy (Ciuffreda et al., 2016). Vision rehabilitation exercises are recommended if visual deficits do not subside by 4 weeks in adolescents and 2 weeks in adults (Carrick et al., 2017).

Vision therapy is an individualized rehabilitation program that can be implemented to alleviate concussion-related vision deficits (Thiagarajan and Ciuffreda, 2013; Gallaway et al., 2017). A 2014 project encouraged oculomotor-based vision therapy because saccadic gain decreased by 10% to 20% post-concussion, but after oculomotor-based vision therapy, saccadic gain was reported to increase significantly (Thiagarajan, 2014).

In a 2017 study, exercises that train components of the binocular and oculomotor systems were assigned to patients. Gallaway et al. (2017) then examined convergence insufficiency, accommodative insufficiency, and saccadic dysfunction after vision therapy in two private practice settings and found vision therapy had a successful or improved outcome in the majority of those that completed therapy. The criteria for 'success' for convergence insufficiency was a near point of convergence (NPC) below 6 cm for all three trials, base out (BO) greater than 20 diopters or pass Sheard's criteria, and a score below 16 on the CISS (Gallaway et al., 2017). The criteria for 'improved' outcomes were a minimum CISS ten score improvement and improved NPC by more than 4 cm or a 10 diopter increase in BO results (Gallaway et al., 2017). Accommodative insufficiency success was satisfaction of the following three criteria, normal accommodative amplitude, monocular accommodative facility (MAF)/ binocular accommodative facility (BAF) greater than six, and a score less than 16 on CISS (Gallaway et al., 2017). Accommodative insufficiency was considered improved when patients could achieve normal accommodative amplitude or when MAF/BAF was greater than six (Gallaway et al., 2017). Saccadic speed and accuracy were measured using the Developmental Eye Movement (DEM) Test and saccadic dysfunction was considered successful when scores were greater than or equal to the 50th percentile and improved outcomes occurred when either ratio or error scores were greater than the 50th percentile (Gallaway et al., 2017). While the results of this study are promising, it was significantly limited because it did not include a control group. Ongoing randomized controlled trials on concussion management exist; however, more randomized clinical trials are needed specifically relating to the optometric management of concussion.

1.7 Limitations

As mentioned above, the literature reveals differences in the definition, terminology, and diagnostic criteria of mild TBI, posing difficulties in comparing research and clinically managing concussion.

More specific to this project, there is no optometric standard of care for concussion and the literature reveals limitations in optometric management of concussion. Clinicians have reported challenges in the management of pseudomyopia following head injury because of the uncertainty in determining a treatment intervention (London et al., 2003). Further research is required on the management of pseudomyopia after head injury. Additionally, Ciuffreda et al. (2016) have documented visual deficits relating to concussion going undetected because of inadequate assessments being selected during assessment.

1.8 Objectives

The purpose of this project was to determine the current assessment methods and prescribing practices of optometrists seeing individuals with persistent concussion-associated vision deficits. The results of these studies will provide important insight on the current optometric management of concussion patients with persistent symptoms.

Research Questions

- How are concussion patients managed at an academic optometry setting?

- How does the optometric management of concussed individuals compare to the optometric management of non-concussed individuals, at an academic optometric setting?
- How do optometrists in private practice assess and prescribe for the visual deficits following concussion?

1.9 Hypotheses

- Optometric management at a university clinic will emphasize reducing visual symptoms relating to concussion.
- The selection and frequency of assessments will be less in the optometric management of the non-concussed group compared to the concussed group.
- There is no established treatment protocol for concussed individuals, therefore optometric management in private practice across Canada will vary and focus on relieving vision-related symptoms.

Chapter 2

The Optometric Management of Concussion at a University Academic Optometry Clinic

2.1 Abstract

Purpose

The purpose of this study was to examine the frequency of different types of assessments conducted at a university optometry clinic by optometrists examining patients with persistent vision deficits relating to concussion. A secondary objective was to compare the optometric assessment and management of concussion patients with non-concussed patients.

Methods

A retrospective review examining the health records from at an academic University optometry clinic was conducted. Data were collected from concussed and non-concussed individuals. The concussed group consisted of 119 individuals, with concussion or persistent concussive symptoms (PCS). The non-concussed cohort was generated through a randomized age and sex match based on the concussed group. The visual assessments and management strategies collected included age, sex, health history, refraction, spectacle prescription, visual acuity and binocular vision. Analysis consisted of determining the frequency of assessments and management strategies conducted in each appointment. The chi square test was used to compare assessment frequencies between the concussed and non-concussed cohorts; p-values < 0.05 were considered to be statistically significant.

Results

There was no significant difference in frequency of health history, full eye exam and accommodation between concussed and non-concussed cohorts. All other frequency comparisons indicated a statistically significant difference. The top three statistically significant differences in assessment and management between cohorts was vision therapy, oculomotor control panel (fixations, saccades and pursuits) and vergence.

The concussed cohort received a wider selection and overall higher frequency of visual function assessments, including but not limited to the oculomotor control panel, vergences and stereopsis compared with the non-concussed group.

The top three most statistically prevalent assessments conducted in the non-concussed group compared with the concussed group were posterior segment, anterior segment and confrontation visual field.

Regarding diagnostic drugs, tropicamide use was the largest percent difference between groups. Tropicamide and anesthetics were more frequently used in the non-concussed cohort.

Conclusion

Overall, assessment and management strategies pertaining to non-concussed individuals focused on ocular structure assessments and there was a higher frequency of functional assessments in the concussed group. Frequency of diagnostic drugs showed that tropicamide was used more frequently in the non-concussed group compared to the concussed group.

2.2 Introduction

Mild traumatic brain injury (mTBI) falls under the umbrella of traumatic brain injury. Additional classifications of traumatic brain injury (TBI) include moderate and severe TBI. Mild TBI and concussion are often used synonymously. While varying definitions exist among organizations and author groups, concussion is generally explained as an external force to the brain leading to disturbances in normal brain function (Carroll et al., 2004; McCrory et al., 2018; Holm et al., 2005; CDC, 2017). Injury to the brain typically leads to signs and symptoms. In most cases (85 - 90%) symptoms are self-limiting and resolve within four weeks in children and ten to fourteen days in adults (Permenter et al., 2021; McCrory et al., 2018). When symptoms continue past these clinical recovery times, individuals may be diagnosed with persistent concussion symptoms (PCS) (McCrory et al., 2018). Concussion individuals may present a collection of symptoms that can be explained under four categories, emotional, cognitive, sleep and physical (Junn et al., 2015; Mayo Clinic, 2020; Permenter et al., 2021). Symptoms include but are not limited to memory and attention impairment, depression, irritability, sleeping more or less than usual, headache and vision problems (Junn et al., 2015). Much of the brain's circuits are associated with the visual system, consequently visual deficits can develop after a neurological event (Fraser and Mobbs, 2021). Vision and vestibular symptoms are common in adolescents with concussion and have also been shown to be predictive of prolonged recovery (Master et al., 2018). Convergence insufficiency, abnormalities in accommodation and saccadic dysfunction are prevalent visual deficits after concussion and can manifest as blurred vision, diplopia, difficulty reading and visual discomfort (Fraser and Mobbs, 2021; Gunasekaran et al., 2019). Mares et al. (2019) report photophobia and headache to be the most prevalent symptoms in PCS. Midline Shift Syndrome may also occur following a neurological event and can lead to issues in balance and posture (Tong et al., 2016; Labrache et al., 2020). A 2016 retrospective study determined the prevalence of Visual Midline Shift Syndrome in a TBI group (including mild TBI) to be 93%

(Tong et al., 2016). In a scoping review, Labreche et al. (2020) report that while there is consensus on the occurrence of midline shift, ambiguities on pathophysiology, terminology and management of midline shift remain.

Concussion-related visual deficits have been well reported in the literature. Some authors have provided some recommendations on the visual assessments that should be included in the management of concussion (Ciuffreda et al., 2016; Master et al., 2016); however, there is no standard of care for the optometric management of concussion. Limited studies document how optometrists currently are managing concussion in clinic, but some researchers have provided advice on clinical concussion management strategies (D'Angelo and Tannen, 2015; Ciuffreda and Ludlam, 2011; Tanen et al., 2016; Ciuffreda et al., 2016)

2.3 Purpose

The purpose of this study was to determine the frequency of different types of assessments conducted by optometrists, at a university academic optometry clinic, seeing patients with persistent concussion-associated vision deficits. An additional aim was to compare the assessment and management of concussed individuals to the assessment and management of non-concussed individuals. The academic university optometry clinic was chosen for this study because it has both a specialized brain injury clinic that provides care to post-concussion patients and a primary care clinic that provides care to non-concussion patients.

2.4 Methods

2.4.1 Study design

A retrospective review was conducted examining health records from the Optometry Clinics at the University of Waterloo. Files of patients who provided consent to access to their files for research purposes were recruited from the Electronic Medical Records database, Visual-Eyes (Chong, 1996) Data were collected from two groups of participants: a concussion group and a non-concussion group (control group).

Group 1

The concussion group, comprised of 119 individuals who had PCS and were being treated in one of three University of Waterloo's Optometry Clinics from 2018 to 2019: Brain Injury Clinic, Binocular Vision Clinic, and Sports Vision Clinic. The first concussion appointments at the academic clinic were examined, in some cases the first appointment dated back before 2018.

Group 2

The control group included 119 non-concussed individuals managed at two of the University of Waterloo's Optometry Clinics: Primary Care Clinic and Binocular Vision Clinic. The control group was produced via an age and sex matching exercise to the concussion group. For each concussed patient record, non-concussed records that matched the age and sex were generated and matches were selected at random, allowing for the same demographic proportions between groups. Most non-concussed patient records were extracted from their most recent examination (conducted between 2019 to 2021) rather than patients first ever eye exam at the clinic .

2.4.2 Data collection

Approval from the University of Waterloo's Office of Research Ethics was received before data collection commenced. All patient files were coded to safeguard patient identity. Data were extracted from the medical records of concussed and non-concussed patients. The list of assessments for data collection, shown in Tables 2.1 and 2.2, was largely selected from the assessments and prescribing methods that correspond to the visual deficits that arise following concussion reported in the literature. The assessments extracted included age, sex, health history, refractive status, spectacle prescription, visual acuity, binocular vision assessments, ocular health assessments, and diagnostic drug use. Spectacle prescription data will be analyzed separately, thus not included in the results presented here.

For the purposes of this thesis, a full eye exam was defined based on protocols from the Canadian Association of Optometrists (CAO). Concussed individuals often received initial basic concussion evaluations and/or full eye exams from other external eye care providers and were subsequently referred to the specialized university Optometry Clinics. If the initial assessment or full eye exam was done externally, the data were recorded as an external full eye exam because the details of all the specific tests done in each external assessment were not always included in the referral letter. If the full eye exam was done at one of the university Optometry Clinics, then the details of the specific tests included in the assessment were recorded.

Ocular Structure Assessments
Full Eye Exam
External Full Eye Exam
Health History
Dry Refraction
Pupil Reflex
Pupil Dilation
Anterior Segment
Confrontation Visual Field
Posterior Segment
Wet Refraction

Table 2. 1. List of ocular structure assessments.

Information from the first concussion appointment was examined. In some cases, multiple concussion appointments were required. A reason for a second appointment included but was not limited to highly symptomatic patients with low tolerance for visual examination. Extended concussion appointments were indicated on the record and data from both appointments were documented. Concussion appointments occurring after 2 months from the initial assessment were flagged and examined only if they were a continuation of the initial appointment.

Visual Function Assessments and Management Strategies	
Assessment	Oculomotor CP
Accommodative Accuracy	Stereopsis
Accommodative Amplitude	Tint trial
Accommodative Facility	Vergence
Broad H	Vergence Facility
Commitancy	Visual Acuity
Cover Test	Worth 4 Dot
Maddox Rod	**Management**
Midline Shift	Vision Therapy
Near Point Convergence (NPC)	Yoked Prisms

Table 2. 2. List of visual function assessments and management strategies.

2.4.3 Analysis

Cause of concussion was taken from the case reports in each file, responses were binned and the frequency of each cause of concussion was determined. Analysis consisted of calculating the frequency of tests conducted during each appointment. The frequency of tests conducted during concussion appointments and non-concussion appointments were compared using a chi square test to determine statistically significant differences in frequencies between groups. A p-value of less than 0.05 was considered significant.

2.5 Results

2.5.1 Demographics

A total of 238 patient files were examined in the present study. They consisted of 119 concussed patient records and 119 non-concussed patient files, a reference group. There was a total of 84 females and 35 males in each group averaging 39 years and ranging from 10 to 81 years. The median age was 41 years. In this study's sample population, concussion most frequently occurred from age 51

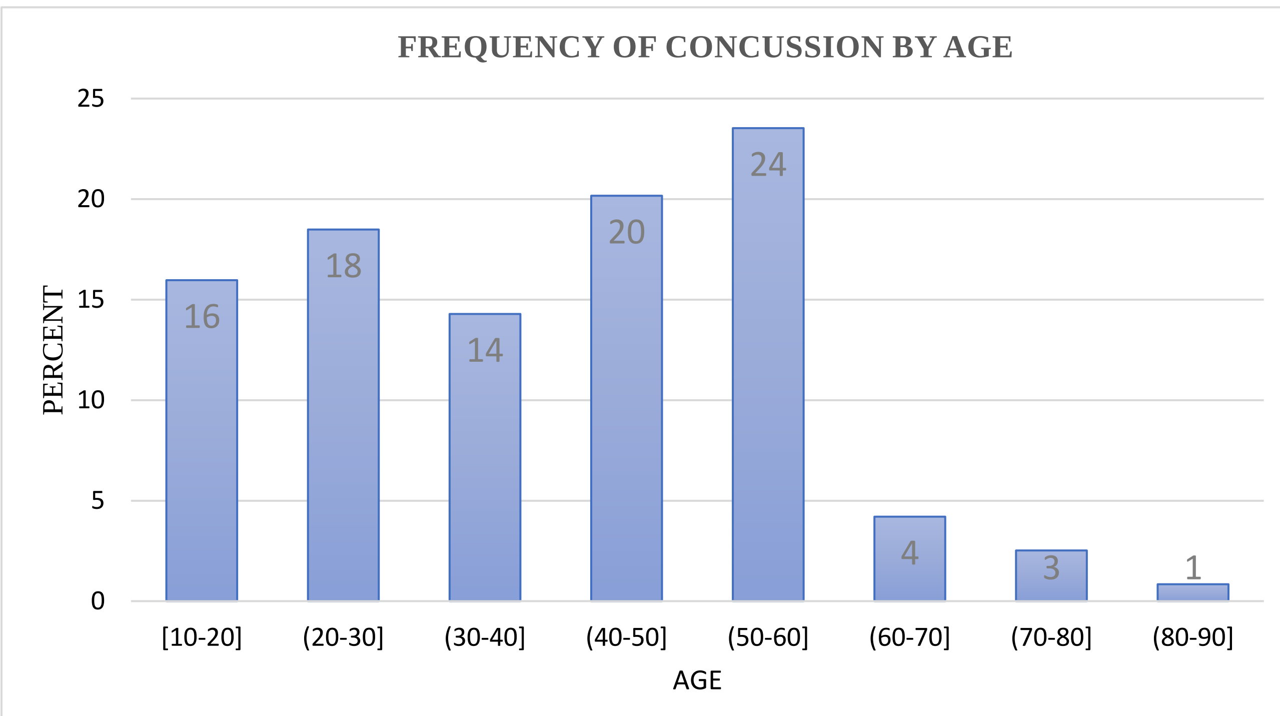

Figure 2. 1. Frequency of concussion by age.

to 60 years (24%) followed by 41 to 50 years (20%). The least number of concussions occurred between 80 to 90 years of age. See Figure 2.1 for concussion frequency by age group. The causes of concussion in the study population fell into six categories: motor vehicle accident (MVA), accidental blow, fall, sport, intentional blow and unknown. Intentional blow entailed assault cases, for example, domestic violence while accidental blow involved causes that were unintentional, for example, walking into an object. The most common cause of concussion was MVA (29%), followed by accidental blow (24%). Figure 2. 2 depicts the complete distribution of concussion causes from 119 concussed individuals.

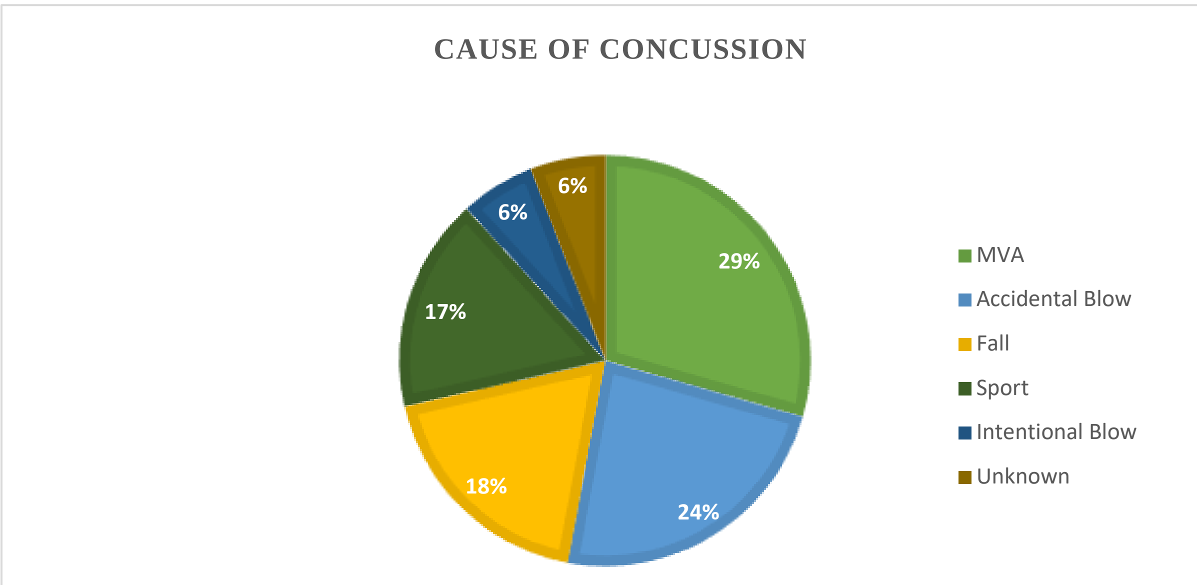

Figure 2. 2. Cause of concussion. Data collected from 119 concussed individuals.

2.5.2 Ocular structure examinations

All non-concussed individuals received a full eye exam and the vast majority of concussion patients received a full eye exam either from an external referring clinician or the university academic clinic. A minority (1%) of concussed individuals did not receive a full eye exam and this was due to patient absenteeism at the follow-up appointment scheduled to be a continuation of the first concussion appointment. A majority (61%) of full eye exams were conducted by the referring clinician and in these cases a full eye exam was typically not repeated during the concussion appointment at the university academic clinic.

With respect to the ocular structure assessments completed, there was no statistically significant difference in the frequency of health history, X^2 (1, N = 238) = 2.02 p = 0.156 and full eye exams, X^2 (1, N = 238) = 1.0, p = 0.316, between concussed and non-concussed appointments. All other assessments indicated a statistically significant difference in test frequencies between cohorts. See Table 2.3 for chi square test results.

The results demonstrated that assessments performed on the non-concussed group largely consisted of full eye exam assessments. Pupil reflex, pupil dilation and dry refraction were the top conducted assessments that were statistically more prevalent in the non-concussed group compared with the concussed group. Pupil dilation was determined based on the dilating drugs documented on record (namely Tropicamide and Cyclopentolate). Dry refraction was conducted over 60% of the time in both groups, while wet refraction (cycloplegic refraction) was conducted under 25% of the time in both cohorts. Wet refraction was conducted significantly more frequently in the concussed group (19%) compared with the non-concussed group (3%), X^2 (1, N = 238) = 15, $p < 0.001$. See Figure 2. 3 for a summary of the percent of the ocular structure tests conducted between both cohorts.

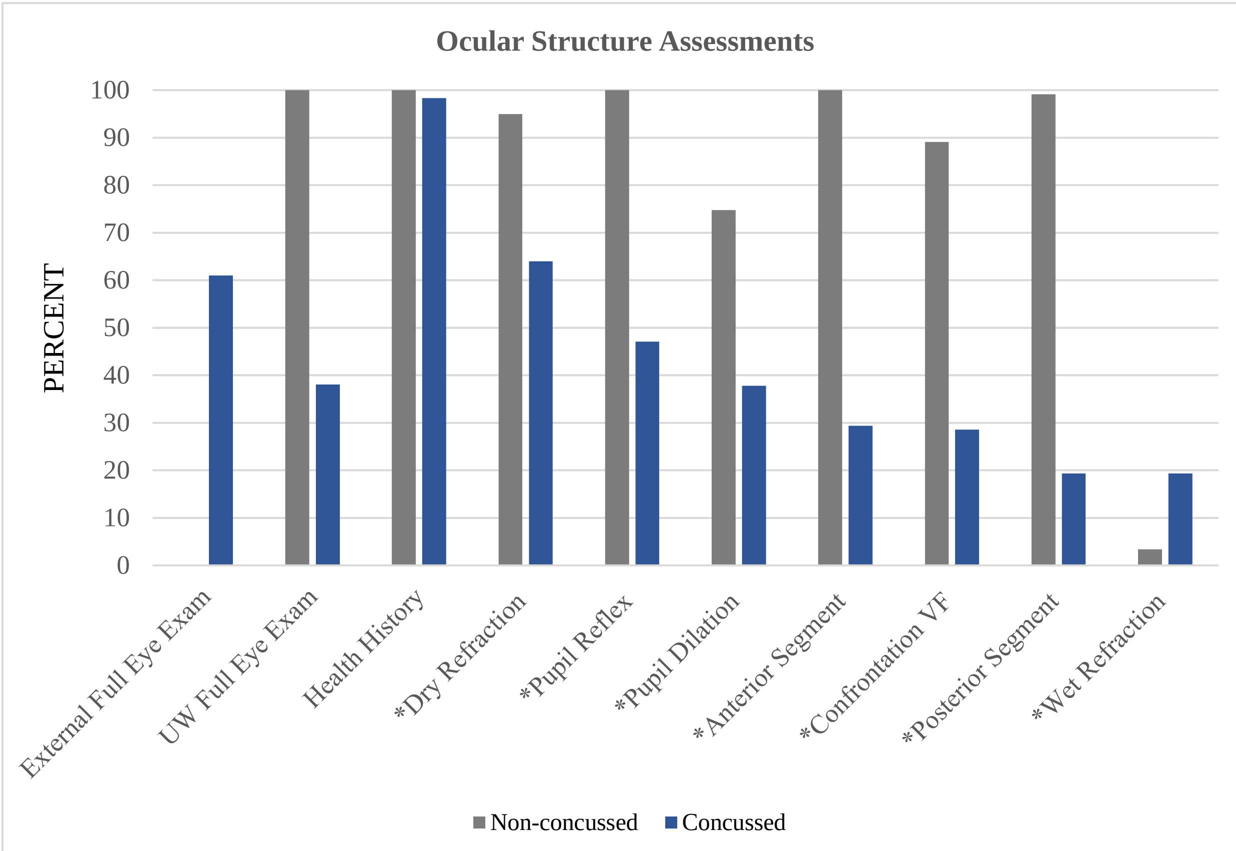

Figure 2. 6. Percent of ocular structure assessments conducted.

Data collected from 119 files per group. Grey represents the non-concussed group and blue represents the concussed group. 'UW full eye exam' displays full eye exams conducted at the university academic optometry clinic. 'External full eye exam' demonstrates full eye exams that were solely conducted by the referring optometrist in the concussed group.

****Confrontation VF stands for confrontation visual field & *UW Full Eye Exam stands for University of Waterloo Full Eye Exam***

****Represent statistical significance ($p < 0.05$)***

Ocular Structure Assessments	Chi Square Value (x^2)	P-value	% Difference (Non-concussed–Concussed)
Posterior Segment	157.05	< 0.001	79.83
Anterior Segment	129.82	< 0.001	70.59
Confrontation Visual Field	89.93	< 0.001	60.50
Pupil Reflex	85.68	< 0.001	52.94
Dry Refraction	35.18	< 0.001	31.09
Pupil Dilation	33.06	< 0.001	36.97
Wet Refraction	15.08	0.001	-15.97
Health History	2.02	0.156	1.68
Full Eye Exam	1.00	0.316	0.84

Table 2.3. Chi square test results on ocular structure assessments.

Frequencies between the tests conducted on concussed and non-concussed groups were compared for significance.. The degree of freedom was 1 for all assessments. (p=0.05)

2.5.3 Diagnostic drugs

Diagnostic drugs like dyes and stains were not statistically significant between groups, X^2 (1, N = 238) = 3.7, p = 0.055. All other categories of diagnostic drugs had a significant difference with the use of Tropicamide, a dilating drug, having the largest percent difference between groups, X^2 (1, N = 238) = 50.91, p = < 0.001. See Figure 2.4 for a summary of findings on diagnostic drug use and Table 2.4 for the results of the chi square test run on administered diagnostic drugs between the concussed and non-concussed cohorts.

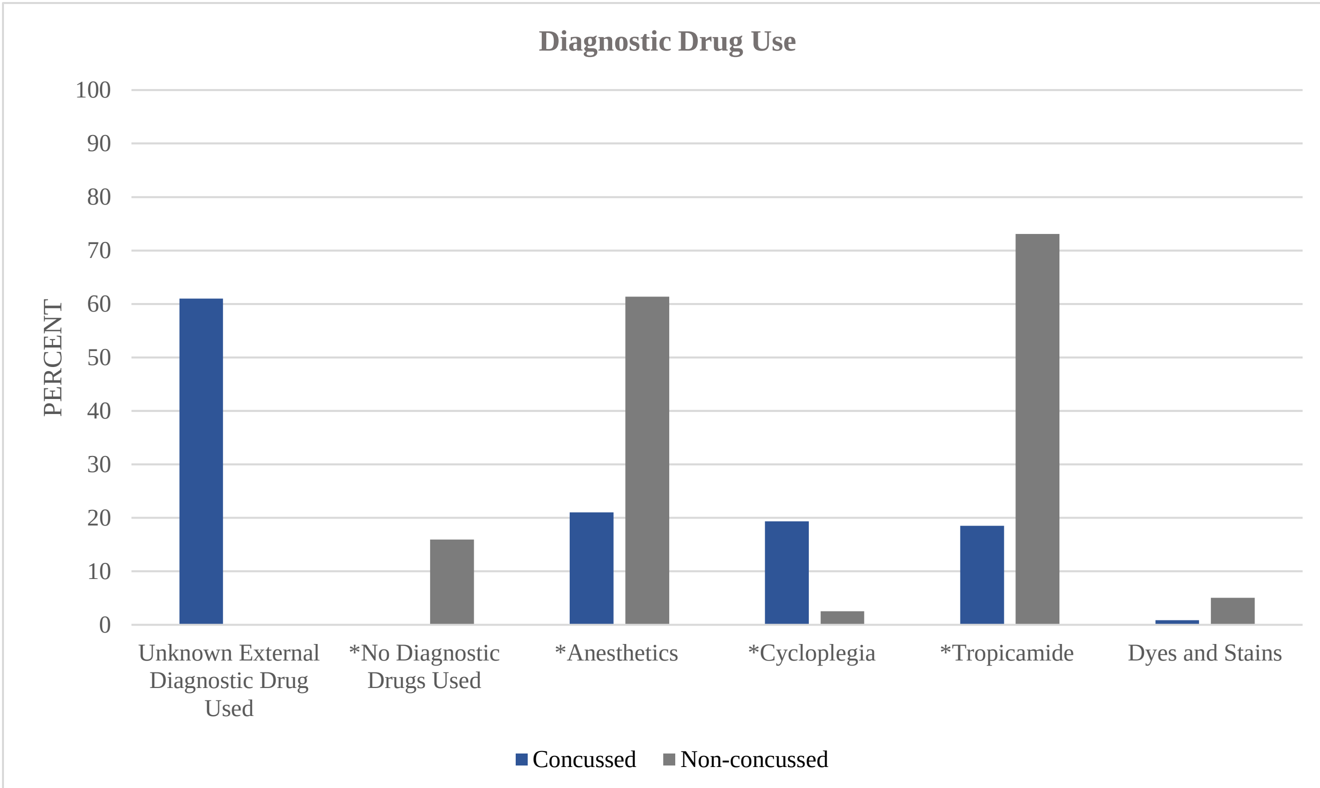

Figure 2. 11. Diagnostic drug use.

Data was collected from 119 files per group. Grey represents the non-concussed group. Blue represents the concussed group. 'Unknown external diagnostic drug used' demonstrates the unknown drugs that may have been administered by the referring optometrist. Anesthetics account for Proparacaine, Tetracaine, Alcaine and Benoxinate. Tropicamide was combined with Phenylephrine 2.5% in 8 cases. Dyes and stains comprise of Fluorescein.

****Represent statistical significance. ($p < 0.05$)***

Diagnostic Drug Use	Chi Square Value (x^2)	P-Value	Percent Difference (Non-concussed– Concussed)
Dilating Drugs	71.51	< 0.001	54.62
No Diagnostic Drug Used	48.31	< 0.001	-43.70
Anesthetics	39.97	< 0.001	40.34
Cyclopentolate	16.13	< 0.001	-15.97
Dyes and Stains	3.68	0.055	4.20

Table 2.4. Chi square test results on diagnostic drug use.

Frequency of tests conducted between concussed and non-concussed groups were compared for significance. The degree of freedom was 1 for all assessments. (p < 0.05)

2.5.4 Visual function examinations

Figure 2.5 shows the differences in frequency of the various functional assessments and management strategies between the groups. The top three statistically different test and management frequencies between groups were vision therapy, X^2 (1, N = 238) = 197.72, p = < 0.001, oculomotor control panel, X^2 (1, N = 238) = 129.82, p = < 0.001 and vergence, X^2 (1, N = 238) = 106.97, p = < 0.001. The oculomotor control panel consisted of fixations, saccades and pursuits of left and right eyes. See Table 2.5 for chi square test results on visual function assessments.

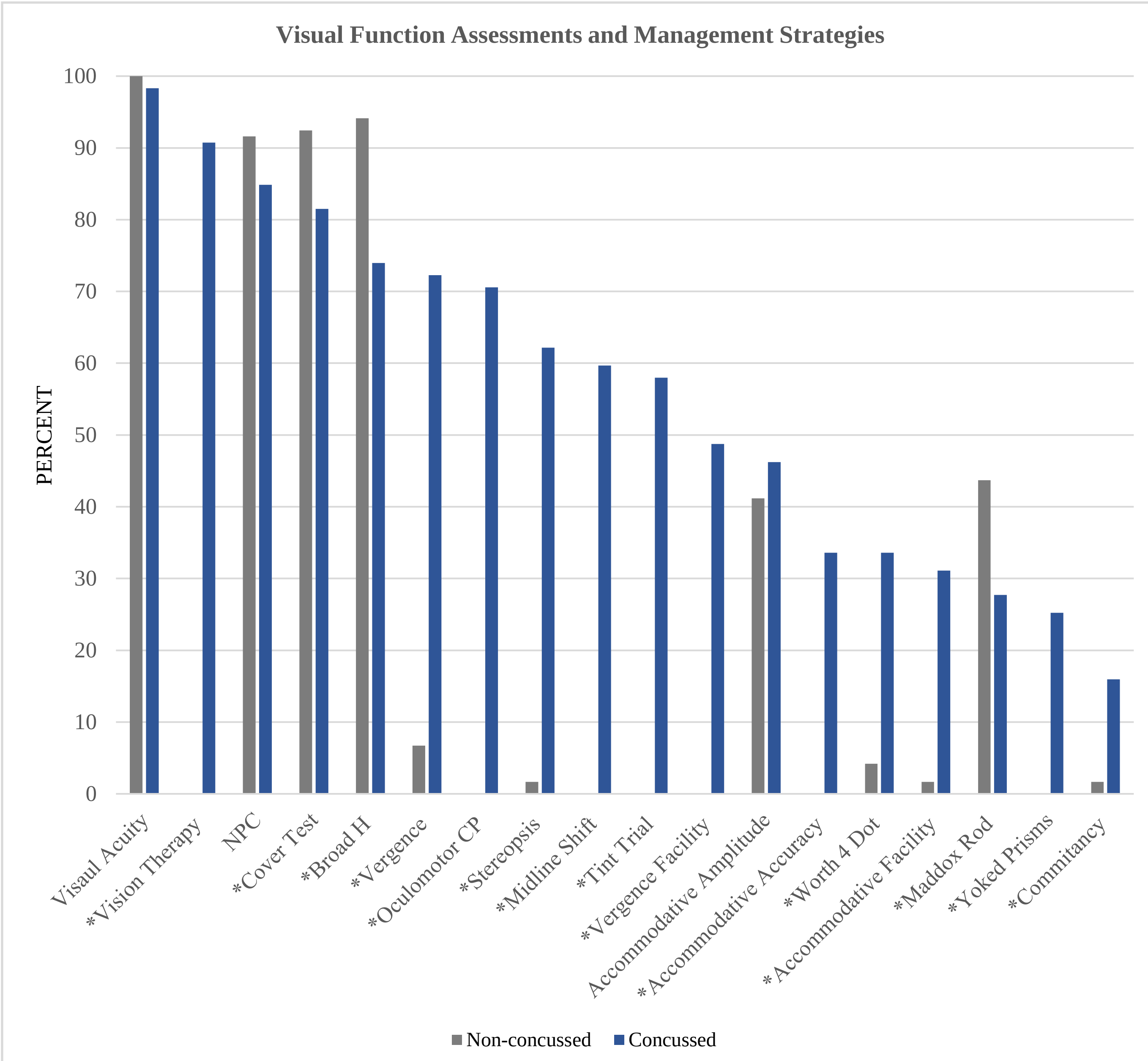

Figure 2. 13. Percent of visual function assessments conducted.

Data collected from 119 files per group. Grey represents the non-concussed group and blue is the concussed group. *Oculomotor CP stands for oculomotor control panel and consists of fixations, saccades, and pursuits.

****Represent statistical significance ($p < 0.05$)***

Visual Function Assessments	**Chi Square Value (x^2)**	**P-value**	**% Difference (Non-concussed – Concussed)**
Vision Therapy	197.72	< 0.001	-90.76
Oculomotor CP	129.82	< 0.001	-70.59
Vergence	106.97	< 0.001	-65.55
Midline Shift	101.19	< 0.001	-59.66
Stereopsis	100.21	< 0.001	-60.50
Tint Trial	97.17	< 0.001	-57.98
Vergence Facility	76.69	< 0.001	-48.74
Accommodative Accuracy	48.08	< 0.001	-33.61
Accommodative Facility	37.57	< 0.001	-29.41
Yoked Prisms	34.33	< 0.001	-25.21
Worth 4 Dot	33.57	< 0.001	-29.41
Broad H	18.04	< 0.001	20.17
Commitancy	15.09	< 0.001	-14.29
Maddox Rod	6.61	0.010	15.97
Cover Test	6.27	0.012	10.92
Near Point Convergence	2.59	0.108	6.72
Visual Acuity	2.02	0.156	1.68
Accommodation	0.61	0.433	-5.04

Table 2.5. Chi square test results on visual function assessments.

Frequencies between the tests conducted on concussed and non-concussed groups were compared for significance. The degree of freedom was 1 for all assessments. (p=0.05)

Assessments conducted on the concussed group reflected increased extensive binocular vision and oculomotor assessments. Assessments including oculomotor control panel (fixations, saccades, and pursuits), vergences, stereopsis and vergence facility were among the assessments that were more predominantly performed in the concussed group in relation to the non-concussed group.

2.6 Discussion

2.6.1 Epidemiology of a concussed cohort

Definition and terminology diversity in the literature pose challenges when comparing the epidemiology of concussion. Some differences in the frequency of concussion by age and sex exist when the present study is compared with previously reported findings. In our retrospective review, the concussed cohort consisted of 84 females and 35 males. In the literature traumatic brain injury historically has been reported to be more common in males. A 2003 American study summarized surveillance data from health departments across 14 states in the United States and reported the concussion rate was doubled in males compared to females (Langlois et al., 2003). In agreement, a 2017 study calculated estimates of TBI emergency department and hospitalization visits and found males to have a higher age-adjusted rate compared with females (Taylor et al., 2017). The WHO Collaborating Center Task Force of Mild Traumatic Brain Injury conducted a best-evidence synthesis and determined that men have twice the risk of concussion compared with their female counterparts (Cassidy et al., 2004). However, in a 2013 systemic literature review of concussion in sport, Clay et al. reported that the incidence of female concussion was more prevalent compared to males in the majority of sports (Clay et al., 2013). A retrospective study of 759 varsity athletes from their 2008/2009 to 2010/2011 season reported concussion in 13.08% of females and 7.53% of males (Black et al., 2017). Veliz et al. (2021) investigated self-reported concussion in 52,949 students in grade eight, ten and twelve and reported 50.3% of concussed individuals were girls. A 2016 descriptive epidemiologic study also reported female athletes sustained concussion at an overall incidence rate 1.4 times higher than their male counterparts in the same sport (Covassin et al., 2016). Finally, a higher concussion incidence rate was reported in women’s ice hockey, basketball, baseball/softball and soccer than men (Covassin et al., 2016). Overall, it appears concussion prevalence in general is higher in males compared with females, but specific to sex comparable sports, like soccer and basketball, many authors agree that the prevalence of concussion is higher in females compared to males (Clay et al., 2013; Black et al., 2017; Veliz et al., 2021; Covassin et al., 2016). Variance in incidence rates between sexes may be attributed to differences in risk-taking behaviour amongst other factors that may lead to males having a higher injury rate than females (Dick, 2009; Mollayeva et al., 2018). Different traditional societal activities and roles placed on females and males may also be a factor in why males have higher incidence rates in concussion than females (Mollayeva et al., 2018). More specific to the differences relating to sex prevalence found in our study compared with other studies, our study population consists of individuals with persistent concussion symptoms and the majority of studies examine acute concussion patients. Additional factors for differences in sex prevalence in our study matched with others may be the different help-seeking behaviors and symptom load between males and females may play a role in the arrival of the aforementioned findings. It has been reported that females tend to seek medical attention more often than males after concussion. A 2016 study reported greater symptom reporting intention in females than males based on survey responses from college athletes in the United States (Kroshus et al., 2017). Increased symptom loads following work-related concussion has also been observed, from clinical data, in females compared with their male counterparts. Fatigue, alertness and daytime sleepiness were compared between sexes and females demonstrated more severe fatigue, lower alertness and higher daytime sleepiness following concussion (Mollayeva et al., 2018; Mollayeva et al., 2017). Further research on the sex related incidence rates on individuals with PCS that present in clinic is required.

The concussed group examined from an academic optometry clinic showed the top three age ranges in order of descending prevalence were 51 - 60 years, followed by 41 - 50 years, and 21 - 30 years old. These findings differed from the literature. In our study, young adults had the third highest age prevalence whereas other studies found young adults and 'younger athletes' to be the most common age group that reported concussion. Cassidy et al (2004) reported concussion to be most prevalent in teenagers and young adults. Others also reported 'younger athletes' having increased concussion incidence (Clay et al., 2013; Guskiewicz et al., 2000). Differences between our study and other research findings, with respect to age prevalence, may be attributed to the older population being a risk factor, particularly for PCS. It is important to note that the current study does not capture concussion prevalence rather PCS, which may have a higher risk with age. Pre-existing age-related issues in combination with persistent visual deficits may propel individuals aged 41-60, the most prevalent ages in our study, to more frequently report symptoms following concussion compared with other age groups. This may contribute to the differences observed in our study compared to other findings. Further research on the risk age may pose on PCS is required.

The causes of concussion within the concussed cohort in our retrospective review are like what is reported in the literature: MVA, accidental blows, and falls were the most common. Cassidy et al. (2004) reported that falls and MVAs are the most frequent causes of concussion. Other studies have documented sports related injuries, MVA, bicycle crashes, falls and assaults to be common causes of concussion (Hon et al., 2019; Cassidy et al., 2004; Gordon et al., 2006; Ropper and Gorson, 2007). We also found sporting injuries and intentional blows, for example domestic abuse, occurred in our data set. It is important to note that intentional interpersonal harm is unacceptable, and awareness of its prevalence is necessary to facilitate change.

2.6.2 Visual assessments

The CAO indicate that evaluation of the existing prescription, examination of the eye and visual system should be included in full eye exams (CAO, 2021). More specifically, a full eye exam includes a case history, visual acuity, color vision, neurological assessment, glaucoma screening, refractive status, analysis of visual needs and binocular vision assessment (CAO, 2021). Binocular assessments focus on coordination of both eyes, motor alignment, and sensory fusion while oculomotor assessments examine the ability to keep a desired object on the fovea during eye movements and involves fixations, saccades, pursuits, vestibular and optokinetic movements (Leigh and Zee, 1982; The 1986/87 Future of Visual Development/Performance Task Force, 1988). Many of the components of a full eye exam incorporate ocular structure assessments. For the purposes of this thesis ocular structure assessments were defined as refraction, ocular alignment, pupil reflex, visual field and ocular health assessments. Ocular health examinations included anterior segment, posterior segment and pupil dilation. It is important to establish normal ocular structure first, then graduate to assessments relating to visual function. Visual function examinations in this study included visual acuity, vergence, accommodation, oculomotor control, stereopsis and photosensitivity.

The university academic optometry clinics that examine concussion largely receive patients based on referral from other optometry clinics. Patients will have either had a full eye exam conducted at the Optometry Clinic for which complete data are obtained or prior to being seen for concussion either at the University of Waterloo Optometry Clinics or by the referring clinician. The referral letters do not always specify every test that was done with their respective scores. In the current study, assessments scores were taken from the concussion appointments.

The majority of full eye exams conducted in concussed patients were conducted by an external referring clinician. In these cases, the full eye exam was typically not repeated during the concussion appointment at the university academic clinic. Signs and symptoms of concussion for example light sensitivity, vestibular issues, headache and irritability may decrease examination tolerance for the concussion patient (Junn et al., 2015). Therefore, clinician discretion should be applied when determining whether to repeat assessments previously conducted by another clinician.

In our study, a significant difference in the frequency of structural assessments existed between groups. Most non-concussed individuals (at least 75%) received structural assessments, except for wet refraction (3%). In contrast, only health history, visual acuity, and dry refraction were conducted frequently (>60% of the time) in the concussed group. Ocular structure assessments such as pupil reflex, ocular health assessments (i.e., pupil dilation, anterior segment and posterior segment), confrontation visual field and wet refraction were conducted in less than 50% of these patients at the academic optometry clinic. The differences in ocular structure assessments between groups is likely due to these tests being conducted by external referring clinician in the concussed group but given the current referral system we have no way to verify this.

Based on our findings, it is proposed that concussion patients receive a structural assessment of the eye. Conducting full eye exams (including ocular structure examinations) is supported by the literature. Master et al. (2016) suggest a comprehensive multilevel assessment for persons with concussive brain injury. In agreement Ciuffreda et al. recommend a basic vision examination consisting of refractive, ocular health and binocular status (Ciuffreda et al., 2016). A difference in the functional assessments between non-concussed individuals and concussed individuals was observed. In the concussion group, we found assessments pertaining to visual function were conducted more frequently in the concussion cohort. Some of the tests include visual acuity, vergence, oculomotor control panel and stereopsis. Our study also showed that the assessment of oculomotor and binocular vision deficits in the concussed group was more extensive and covered a wider range of visual function assessments compared to the non-concussed group. These findings could suggest that the higher prevalence of oculomotor and binocular vision assessments received by the concussed group is associated with oculomotor and binocular vision deficits that arise following concussion. Alternatively, these findings could be interpretated that the non-concussed cohort did not receive sufficient oculomotor and binocular vision assessments and interventions like vision therapy. Several assessments and management strategies were not conducted in the reference group, namely oculomotor control panel, vergence facility, accommodative accuracy, midline shift, yoked prisms, and tint trial. Because photophobia, midline shift, vergence, accommodation and oculomotor issues are prevalent following concussion it would seem logical that these visual assessments are more prevalent in concussion management compared with non-concussion management (Pillai and Gittinger, 2017; Heinmiller and Gunton, 2016; Jenkins, 2020; Ventura et al., 2016).

Binocular vision assessments like NPC, cover test, broad H and Maddox rod appear to have higher frequencies in the non-concussed cohort in relation to the concussed group. This is because these tests belong to a battery of assessments regularly conducted in full eye exams at the university academic optometry clinic which largely overlap with recommendations provided by the CAO. All other binocular vision assessments for example stereopsis, von Graefe and Worth 4 dot were conducted at considerably higher frequencies in the concussed population compared to the non-concussed group. The increased functional assessments carried out in the concussion group likely relate to the visual deficits that present following concussion. A study by Scheiman et al. (2021) examined the frequency of vision diagnoses. They found four to twelve weeks post-concussion that 70% of individuals (7 to 11 years of age) had one oculomotor diagnosis (i.e., accommodative, convergence and saccadic disorders) and 47% had multiple oculomotor diagnoses. Scheiman et al. (2021) also found clinician detection methods using CISS, accommodative amplitude and NPC underperform, and the authors emphasize the need for a comprehensive oculomotor examination. Brahm et al. (2009) also noted dysfunctions in saccades and pursuits. Another report documented saccadic intrusions, or involuntary saccades that disrupt fixation, in pediatric concussion patients (Cochrane et al., 2020).

The results of our study demonstrated a significant difference between concussion and non-concussion assessment practices at a university academic clinic. Concussion care showed the administration of extensive oculomotor and binocular vision related assessments.

A 2021 study noted instances of only accommodative amplitude and near point of convergence being conducted in concussion assessment and found that these tests alone failed to identify 50% of individuals with accommodative insufficiency and a third of those with convergence abnormalities (Scheiman et al., 2021). Others have recommended the inclusion of oculomotor testing including vergence, version and accommodation assessments, in the assessment of concussion which is supported by findings from optometrists at a university academic optometry clinic (Scheiman et al., 2021; Zasler et al., 2019; Ventura et al., 2016; Poltavaski & Biberdorf, 2014; McDevitt et al., 2016).

Dry refraction was done in 95% of non-concussed individuals and 64% of concussed individuals in our study. The difference in the frequency of dry refraction between groups may be attributed to dry refraction having already been performed in a full eye exam prior to the referral to the academic university clinic. Additionally, the difference could be related to the fact that more cycloplegic refractions were done in the concussion group. Correcting previously uncorrected refractive error in post-concussion patients may be an effective treatment for concussion-associated vision deficits. A 2017 pilot study examined eight patients with prolonged concussion symptoms and assessed reading performance, visual symptoms and binocular function prior to and subsequent to spectacle treatment (Johansson et al., 2017). Near work and reading symptoms were assessed using the Convergence Insufficiency Symptoms Survey (CISS) and reading performance using an eye tracker (Johansson et al., 2017). Functional assessments included but were not limited to visual acuity, refraction, near point convergence, cover test and stereo acuity (Johansson et al., 2017). It was concluded that spectacle treatment directed at improving near task visual function, increased reading performance and decreased symptoms in 50% of patients (Johansson et al., 2017). However, this study is significantly limited by the lack of a control group. Further research on the potential role spectacle prescription can play in the management of concussion is required.

2.6.3 Diagnostic drug use

Diagnostic drugs were utilized in 40% of concussion appointments compared to 84% of non-concussion appointments. Again, this difference is likely related to most full eye exams for concussion patients being previously assessed by the referring clinician. Our study found a statistically significant difference in cycloplegic refraction between groups. Cycloplegic agents inhibit accommodation allowing evaluation of refractive status without the interference of accommodation. While limited studies discuss the role cycloplegic refraction plays in concussion management, our study showed 19% of concussion appointments utilize cycloplegic refraction. Cycloplegic refraction may be beneficial in management considering the prevalence of accommodative issues and pseudomyopia that have been found in populations following mild traumatic brain injury (Porcar and Martinez-Palomera, 1997; Knapp et al., 2002; Chan and Trobe, 2002). More research is required to determine the efficacy of cycloplegic refraction in concussed individuals.

2.6.4 Management

Treatment interventions for individuals with mild traumatic brain injury typically include but are not limited to vision therapy and optical devices, including spectacles. In our study, most patients (91%) received vision therapy as treatment to improve components of functional vision. The literature exhibits evidence-based studies that suggest the effectiveness of vision therapy. A 2017 study monitoring the success rate of individuals who completed vision therapy found 85% and 33% of patients with convergence and accommodative insufficiency, respectfully, showed improvements and individuals with saccadic dysfunction also exhibited improvements (Gallaway et al., 2017). The reduced success rate for accommodative insufficiency through vision therapy compared to convergence insufficiency may be because prescription of plus lens is typically the primary treatment of accommodative insufficiency. Vision therapy is a secondary treatment option for accommodative insufficiency. A limitation to the Gallaway et al. study was that there was no control group to isolate the effect of vision therapy. Additionally, plus lenses were not investigated as a treatment for accommodative insufficiency. Research on the use of plus lenses for accommodative dysfunction following concussion should be conducted.

Optical devices like, yoked prisms were used in 25% of concussion patients in our study. Yoked prisms act to “induce a change in the perception of space by shifting image location as well as by inducing greater” distortion (Errington et al., 2013). They can be applied therapeutically in abnormalities of spatial localization, visual midline shift and postural problems (Ciuffreda et al., 2016). Barton and Ranalli (2021b) have reviewed proposed treatment approaches for managing visual deficits following concussion. Concerning the management of midline shift, which the literature is unclear on if or why it occurs after concussion, with yoked prisms Barton and Ranalli highlight the uncertainty of yoked prisms influencing balance that will lead to improved quality of life. Additionally, they highlight the lack of data clarifying the use of yoked prisms specifically after concussion. Additional research is required on the effectiveness of yoked prisms as an intervention following concussion.

Photophobia is commonly reported in concussion patients (Pillai and Gittinger, 2017; Heinmiller and Gunton, 2016). Tint trial was conducted in more than half of concussed individuals in our study (58%) and in none of the non-concussion appointments. Tints can be prescribed to alleviate photosensitivity (Young et al., 1982; Huang et al., 2011), however more research is needed to determine how tints should be prescribed in this population.

2.6.5 Limitations

As mentioned earlier, the university academic clinic that manages concussion is one that receives patients based on referral. The referring clinician typically conducts a full eye exam and does not always list all the assessments done and their results in the referral letter. The frequency of assessments documented in our study do not reflect the assessments conducted by the referring clinician and presumably account for lower-than-expected frequencies of ocular structure assessments in the concussed group.

2.6.6 Conclusion

The relationship between the management of concussed and non-concussed individuals at a university academic clinic differed. Non-concussion appointments were directed largely at ocular structure assessments with the inclusion of some binocular vision assessments including but not limited to NPC, Cover Test and Broad H. Concussion appointments focused on visual function assessments and included an extensive list of binocular and oculomotor assessments. Most concussed individuals received ocular structure assessments, often from the referring clinician. The management of visual deficits following concussion entailed vision therapy and ocular devices. It is likely spectacle prescriptions were also used for management purposes; however, the use of spectacle prescriptions was not examined in this study. This study does not report on the efficacy of optometric management following concussion either. However, it seems logical that the standard of care for optometric management should build on the strengths of what is currently being done. Based on this study’s findings, the inclusion of extensive visual function assessments including vergence, accommodation, oculomotor control, stereopsis and tint trial assessments alongside vision therapy and ocular devices, when needed, should be included in the optometric management of concussion. It is suggested that clinicians ensure ocular structure assessments are conducted on concussed individuals.

Chapter 3

The Optometric Management of Concussion in Canadian Private Practice

3.1 Abstract

Purpose

The purpose of this study was to determine the current prescribing and assessment practices of optometrists in Canada seeing patients with persistent concussion-associated vision deficits.

Methods

A 6-question survey in REDCap (Harris, 2009) a secure web application for building and managing online surveys, was distributed to provincial and national associations and regulators of Optometry in Canada. Questions pertaining to vision assessment, prescribing practices, daily living advice, appointment duration and follow-up appointment(s) were included. Analysis consisted of categorizing and binning similar responses and analyzing the frequency of responses provided within each category.

Results

A total of 199 responses were received of which there were 142 completed responses (including 1 blank response). Of these, 13 optometrists indicated that they did not manage concussion. Some reasons given for this were they referred to a specialist (31%), lacked training (23%) and lacked time (8%).

Of the 128 optometrists who indicated that they managed concussion, 98% conducted a full eye exam. Visual acuity was assessed 96% of the time. Other frequent assessments were dry refraction (91%), pupil dilation (80%), and full binocular vision assessments (78%). Less frequently conducted tests were automated perimetry (73%), confrontation visual field (62%) and tint trials (50%). Less

than half the time, optometrists indicated that they prescribed yoked prism (41%), did vision therapy (41%), or midline shift assessments (38%). Only 30% of optometrist reported doing a cycloplegic refraction.

A minority of optometrists (26) recommended supplements. The most recommended supplement was Omega 3, (54%). Most respondents, 116, indicated that they provided advice on daily living activity and the most frequent advice was to limit activity (64%).

Responses were offered by 121 optometrists on appointment duration. Most frequently, optometrists stated concussion appointments lasted between 30-60 minutes (57%). Responses on follow-up were given by 119 optometrists and the most frequent follow-up was 1-2 months (23%).

Conclusion

There is no set standard of care for the optometric management of visual deficits following concussion; however, the results from this study provide insight on how optometrists in private practice are managing patient symptoms following concussion. Further research on treatment effectiveness is required to develop an optometric protocol for the management of concussion associated vision deficits.

3.2 Introduction

Concussions are a significant public health concern. Each year an estimated 42 million individuals experience mild Traumatic Brain Injury (mTBI) worldwide (Gardner and Yaffe, 2015). Many individuals with concussion develop visual symptoms. Optometrists play a prominent role in the management of patients with concussion-associated vision deficits and persistent concussion symptoms. Unfortunately, there is no consistent standard of care for individuals with these types of injuries.

Concussion is a type of mTBI that arises from acute impact to the brain (McCulloch et al, 2020). Acute impacts to the brain can occur when the brain is jarred against the skull resulting in an adverse change in the brain's chemical status (CDC, 2017). The most common causes of mTBI are falls and motor vehicle accidents (Management of Concussion/mTBI Working Group, 2009). Other causes include sports-related accidents or strikes by/against an object (Kushner, 1998). While concussions typically resolve within four weeks in children and ten to fourteen days in adults, concussion symptoms can persist in up to 30% of individuals resulting in prolonged concussion recovery, also known as persistent concussion symptoms (McCrory et al., 2018).

Concussion cannot be detected with conventional clinical neuroimaging techniques and is thought to be caused by metabolic disturbances in the brain (Howell and Southard, 2021). Consequently, the diagnosis and management of concussion is still based on patient symptoms. Concussion symptoms typically fall under four main categories; cognitive, emotional, sleep, and physical (Mayo Clinic, 2020; McCrory, 2018; McCulloch et al, 2020). Visual deficits are considered physical symptoms. It has been reported that up to 90% of individuals with TBI (including concussion) suffer from visual deficits (AOA). A 2007 article found up to ninety percent of individuals with traumatic brain injury suffer from oculomotor dysfunction; and in 2018, 88% of children with concussion were found to have vision and vestibular deficits (Ciuffreda et al., 2007; Master et al., 2018). Visual deficits also appear to be predictive of prolonged concussion recovery or persistent concussion symptoms. A retrospective study conducted by Master et al. (2018) examined a cohort of pediatric patients experiencing concussion. They found time to clinical recovery was the main outcome measure and issues with balance, smooth pursuits, vestibulo-ocular reflex (VOR), and accommodative amplitude were predictors of prolonged recovery time. Common concussion-associated vision deficits include, but are not limited to light sensitivity, visual discomfort, convergence insufficiency, ocular motility issues and decreased visual acuity (Ciuffreda et al., 2016; London et al. 2003).

Optometrists have an essential role to play in the management and recovery of visual deficits following concussion, but there are still challenges in the optometric management of concussion. Clinicians have reported pseudomyopia following traumatic brain injury and have felt conflicted in deciding whether to re-establish baseline refractive error or prescribe lenses (London et al., 2003). A pilot investigation found that spectacle correction focusing on improving near tasks in concussed patients reduced symptoms in 50% of patients (Johansson, 2017). It is also possible that undiagnosed conditions, such as uncorrected astigmatism or latent hyperopia, that were asymptomatic prior to injury, may obstruct a patient's ability to cope following injury. Correcting uncorrected refractive error in post-concussion patients may be an effective treatment for concussion-associated vision deficits; however, it is unknown how refractive error corrections are used in the management of post-concussion patients. Finally, Ciuffreda et al. (2016) found eye care practitioners selected "relatively low-yield" visual assessments (i.e., visual acuity and refractive correction at distance) resulting in concealment of visual deficits following traumatic brain injury.

Currently, there is no recognized consistent optometric standard of care for individuals with these types of injuries. The purpose of this study was to determine the current assessment and prescribing practices of optometrists who manage post-concussion patients. The results of this study provide important insight on how Canadian optometrists in private practice are managing concussion.

3.3 Methods

3.3.1 Study design

A 6-question online survey investigating the assessment and prescribing practices of optometrists seeing individuals with concussion symptoms was built and managed on REDCap, an electronic data capture tool, hosted at the University of Waterloo (Harris et al, 2009). Questions pertaining to vision assessment, prescribing habits, daily living advice, appointment duration and scheduling of follow-up appointment(s) were included, and participation took approximately 5-10 minutes. The study received ethics clearance from the University of Waterloo's Research Ethics Office.

Upon opening the survey, participants were taken to an information link followed by consent to participation and a request to use of anonymous quotations. If respondents consented to participation, then the survey instrument appeared and after completion an appreciation note was presented. If consent was not provided an appreciation note appeared and the survey would come to an end. In the situation that respondents no longer wanted to participate in the study, they could exit the web-browser. The survey was administered anonymously, participants were not asked for any identifying information and IP addresses were not stored.

3.3.2 Subjects and recruitment

Practicing optometrists in Canada who have or have not managed patients with visual deficits following concussions were eligible to complete the survey. An email was sent to the provincial and national professional associations and regulators of optometry in Canada asking them to distribute the survey to their members on behalf of the researchers. Attached to the email was a recruitment letter with a link to either an English or French version of the survey. There are approximately 5,959 practicing optometrists across Canada (Shah et al., 2020). Assuming a 5% participation rate from Canadian optometrists, an approximate sample size of 300 participants was anticipated. As the purpose of this study was to understand the current concussion practice patterns of optometrists, other eye-care practitioners, such as ophthalmologists and opticians, were excluded from participation in this study.

3.3.3 Analysis

Data were compiled in REDCap and analyzed. This consisted of categorizing verbal responses and analyzing the frequency of responses provided. Initial binning was conducted by the student investigator. The resulting bins were then reviewed by the principle investigators (student's supervisors); additional modifications were made by the principal investigators as needed.

3.4 Results

A total of 199 surveys were started. Of these 142 were submitted. Although REDCap receives responses that were not submitted, only those that were submitted were included in data analysis. These were considered complete responses. Of the 142 submitted complete responses, 128 optometrists managed concussion, 13 did not manage concussion and 1 response was blank.

Of the 13 optometrists that they did not manage concussion, the top explanation was they referred concussion to others (31%), they lacked training (23%), their practice was "limited" (23%), they provided no reason (15%), or they reported watchful waiting (8%) which meant closely monitoring conditions without giving treatment. Limited practice refers to optometry clinics that do not offer all services, including concussion management. Some responses included in this category were optometry clinics not specializing in concussion management or not having interest in concussion management.

The characteristics of visual assessments conducted by optometrists are summarized in Figure 3.1. Of the 128 optometrists who indicated that they managed concussion 98% reported doing a full eye examination and 78% reported conducting a full binocular vision assessment. The 3 tests most frequently performed were visual acuity (96%), dry refraction (91%), and pupil dilation (80%). Only 30% of optometrists reported doing a cycloplegic refraction.

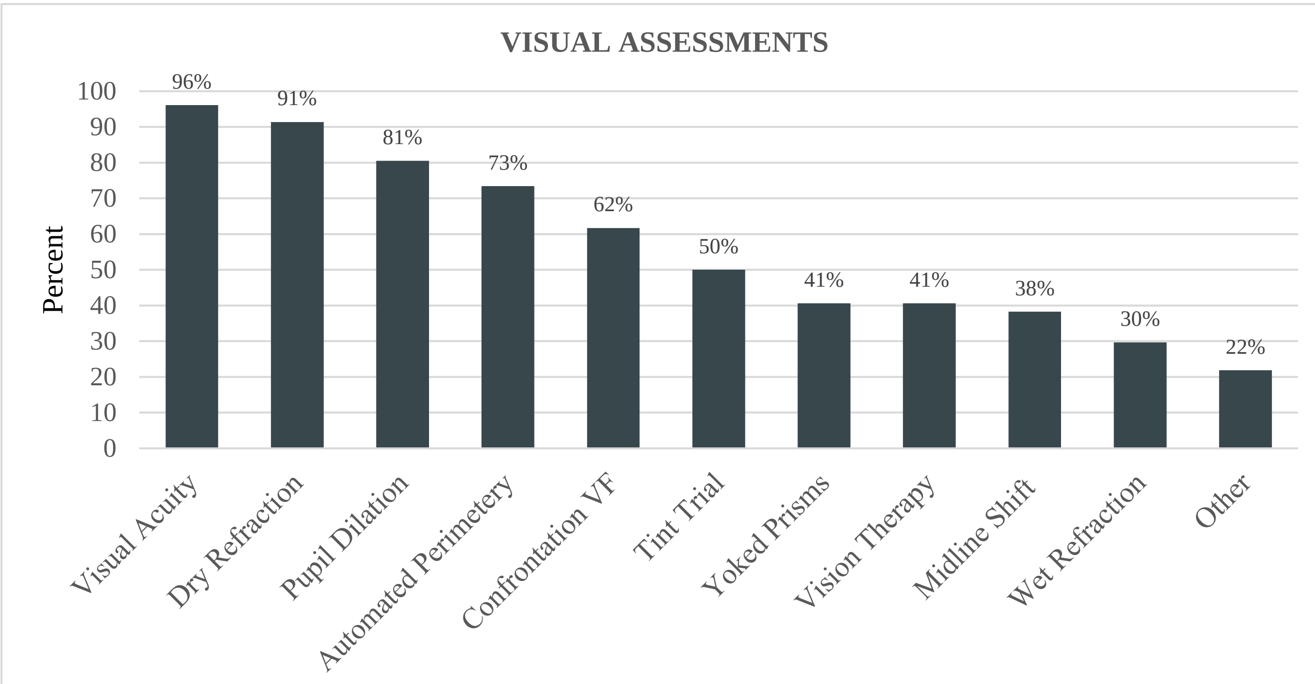

Figure 3. 1.Visual assessments.

Responses from 128 optometrists. Confrontation VF stands for Confrontation Visual Field. 'Other' tests included syntonics, imaging (i.e. Optical coherence tomography and Optomap), dry eye assessment, VOR (vestibulo-ocular reflex) testing and non-optometric recommendations (i.e. diet change, postural change and counselling).

A minority of optometrists (26) recommended supplements. The most recommended supplement by these optometrists was Omega 3 (54%). This was followed by other oral supplements (vitamins, minerals and herbal teas), with 38% of optometrists recommending them. Lubricating drops were suggested by 23% of optometrists who recommended supplements. Pain medication and topical steroids (Loteprednol) were suggested by 12% and 4% of optometrists, respectively, while water and ‘other’ (Tecamex) were suggested by 4% of optometrists. The results from optometrists’ recommendations on management of daily living activities are listed in Table 3.1. Most respondents (116) indicated that they provided advice on daily living activities and the most frequent advice was to limit cognitive and physical exertion (64%).

Limiting exertion included responses such as limit or moderate activity, gradual increase, do not overstimulate, reduce screen time, pacing and planning, minimize near work, minimize cognitive tasks and take breaks. Rest (12%) and ‘case dependent’ (10%) were the next most frequent pieces of advice on daily living activity from optometrists.

Advice on Daily Living Activity	**Frequency**	**Percent**
Limit	74	64%
Rest	14	12%
Case dependent	12	10%
Referred	9	8%
Watch/Be aware	7	6%
Follow specialist advice	7	6%
Tinted lenses	7	6%
Emotional support	5	4%
Educate/explain	3	3%
Positive health behavior	2	2%
Document symptoms	1	1%
Increase anti-inflammatory intake	1	1%
No advice	1	1%

Table 3. 1. Advice on daily living activity. Responses from 116 optometrists.

The responses offered by 121 optometrists on appointment duration is summarized in Figure 3.2. Most frequently optometrists stated concussion appointments lasted between 30-60 minutes (69/121). Less commonly 5% of optometrists indicated appointments to be less than 30 minutes (Figure 3. 2).

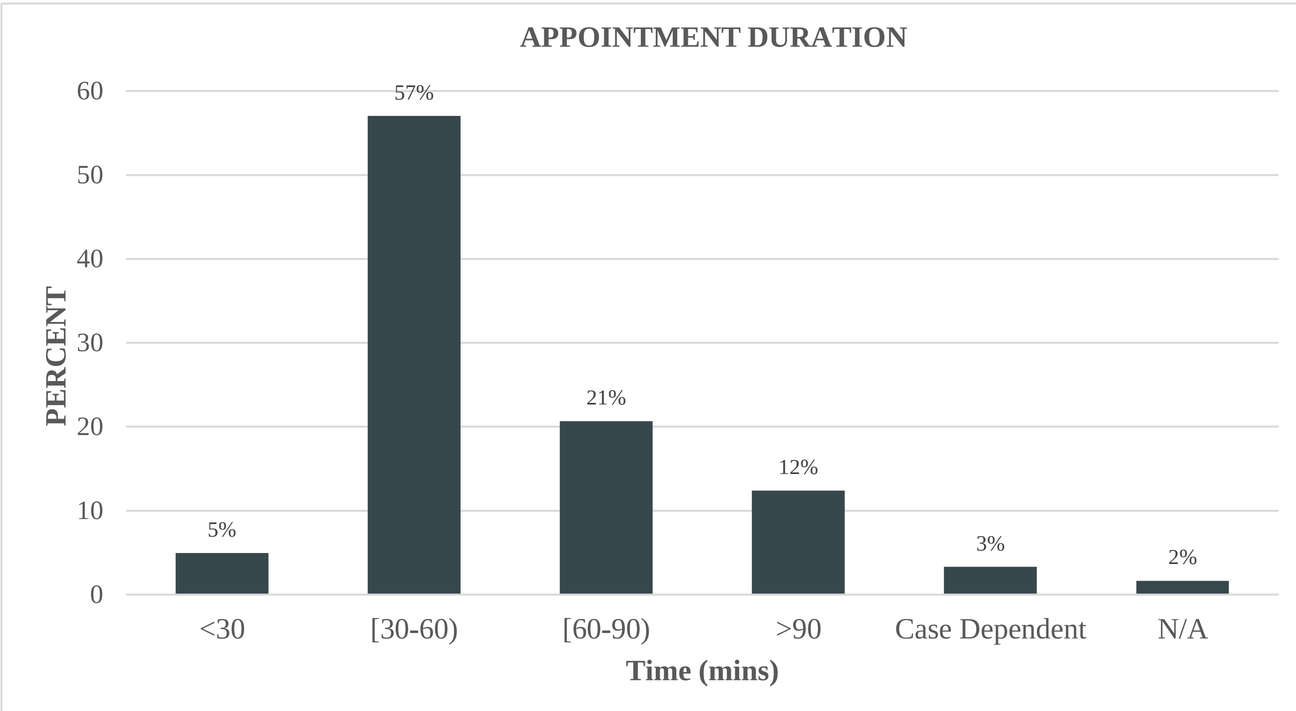

Figure 3. 4. Appointment duration. Responses from 121 optometrists.

Responses on scheduling of follow-up appointments were given by 119 optometrists and the results are summarized in Figure 3.3. The most frequent response was 1-2 months (27/119). Less commonly, later follow-up appointments (up to 6 months after the initial appointment) were reported. 23.53% of optometrists said follow-up was case dependent (Figure 3.3).

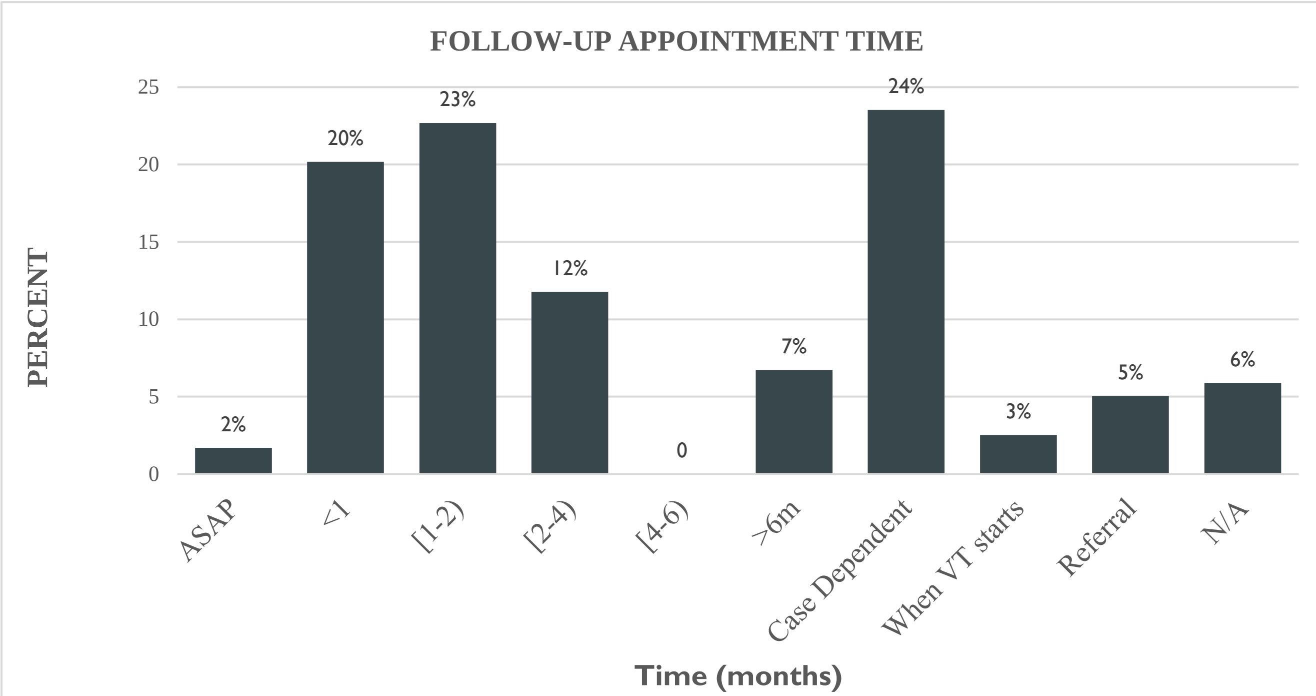

Figure 3. 5. Scheduling follow-up appointment. Responses from 119 optometrists.

3.5 Discussion

Clinical practice protocols are important in delivering quality health care because they facilitate effective diagnosis and management. Currently there are no standardized guidelines for the optometric management of concussion. This study examined the current concussion management practices of a sample of Canadian optometrists.

The study at present had a response rate of approximately 2% of optometrists across Canada. In this study, a proportion (9%) of optometrists did not manage concussion. Reasons given such as no training (23%) and "watchful waiting" (8%) emphasize the need for protocols and training to provide optometrists with the guidance required for the optometric management of concussion.

Ciuffreda et al. (2016) proposed a 4-tiered conceptual pyramid of vision care for concussion. The conceptual model of vision care emphasizes the importance of comprehensively conducting assessments on each tier before proceeding to the next in order to avoid subsequent tests being "held in possible question and with uncertainty". At the base of the pyramid, a basic vision examination encompassing refractive (including dry and/or cycloplegic refraction), binocular and ocular health status is recommended. In agreement, a study by Master et al. (2018) emphasized the importance of conducting a comprehensive multidomain assessment for concussion patients. It appears from our data that optometrists managing concussion are consistently completing the base level assessment, perhaps except for cycloplegic refractions.

In the higher levels of the post-concussion vision care pyramid, Ciuffreda et al. recommend assessing oculomotor-based vision problems including version, vergence, and accommodation assessments. Based on their study that found prolonged concussion recovery in children can be predicted by vision and vestibular system dysfunction Master et al. (2018) also suggested that saccades, smooth pursuits, accommodative amplitude and near point convergence be included in concussion assessments. Our study found that 98% and 78% of optometrists conduct a full eye exam and binocular vision exam, respectively. Both full eye exams and binocular vision exams incorporate oculomotor-based assessments. According to the Canadian Association of Optometrists a full eye exam encompasses a case history, analysis of the patients' visual needs, visual acuity test, refractive status, binocular vision and a health assessment (CAO). Health assessments are colour vision tests, eye health evaluation and a neurological assessment of the visual system (pupil and ocular muscle reflexes and peripheral vision assessment) (CAO). Common binocular vision assessments include tests of accommodation, vergence, ocular motility and tracking and binocular vision deficits identified with these assessments can often be managed through vision therapy (Advanced Vision Therapy Center, 2021). A study by Gallaway et al. (2017) found that 82% of concussion patients had oculomotor problems, most frequently accommodative issues, binocular problems, and deficits in eye movements. Vision therapy was suggested for most patients (80%) and of the 54% who completed vision therapy, significant statistical and clinical changes were seen in positive fusional vergence, near point convergence, and accommodative amplitude (Gallaway et al., 2017). In our study, the majority of optometrists conducted full eye exams and binocular vision assessments, while only 41% utilized vision therapy. Less than 50% of optometrists in private practice applied vision therapy and this may be the result of limited awareness on the efficacy of this treatment intervention. Research groups have provided clinical and scientific support for the efficacy of vision training in treating visual deficits (Cornsweet and Crane, 1973; Cooper and Duckman, 1978; Wold et al., 1978; Haynes and McWilliams, 1979; Grisham, 1980; Daum,1982; Daum, 1984; Hung et al., 1986; The 1986/87 Future of Visual Development/Performance Task Force, 1988; Ciuffreda and Ludlam, 2011). When applicable, vision therapy should be considered by optometrists as a management option for concussion-associated visual deficiencies.

The third level of the pyramid recommends examining “non-oculomotor” problems which entail assessments related to visual field processing, motion sensitivity, photosensitivity, visual field defects, and vestibular dysfunctions, which can manifest as visual symptoms like blur due to the tight correlation between the vestibular and oculomotor systems, as observed in the vestibular-ocular reflex (Crampton et al., 2021). Our study showed that 73% of optometrists conducted automated perimetry and 62% confrontation visual field, however other “non-oculomotor” assessments such as tint trials, yoked prisms, and midline shift assessments were conducted less commonly.

At the top of the pyramid, non vision-based problems should be considered. These include assessments such as cognitive impairment, behavioural issues, postural problems, neurological problems, attentional problems, fatigue, and depression (Ciuffreda et al., 2016). Although not much can be done by the eye care practitioner to manage these types of impairments if they are identified, recognition and referral to specialists by optometrists is recommended (Ciuffreda et al., 2016). A minority of optometrists who did not manage concussion (31%) referred. It is important to highlight the importance of referral to other health care professionals, including referrals to other optometrists as appropriate, to optimize patient outcome. Our study revealed that appointment duration for most optometrists (57%) is between 30 to 60 minutes. Appointment time largely depends on symptom severity and patient tolerance, as well as the number of tests conducted. Increased appointment duration may be required for highly symptomatic patients and / or to complete all the recommended assessments.

Visual interventions suggested by Ciuffreda et al. include prisms, occluders, tints, near lenses, and vision therapy (Ciuffreda et al., 2016; Ciuffreda et al., 2011). Barton et al. in their review expressed concerns with the use of occlusion, filters, prisms, and vestibular therapy due to limited evidence on effectiveness (Barton and Ranalli, 2021b). In contrast, a 2018 scoping review on vision rehabilitation treatment after concussion concluded prisms, glasses, vision, and oculomotor therapy to be promising interventions based on results from peer-reviewed literature generated from four electronic databases (Simpson-Jones et al, 2019). Due to limited evidence on these interventions, additional research is required to determine their efficacy before guidelines for their use (or not) can be adopted.

The management of concussion concentrates largely on reducing symptoms to re-establish baseline function (Heinmiller and Gunton, 2016). However, clinicians who only manage apparent symptoms may overlook assessments that reveal additional deficits (for example focusing on binocular vision problems and overlooking refraction or vice versa). It has been reported that some eye care practitioners have selected assessments that rarely lead to a definitive finding like visual acuity and miss some concussion-related vision deficits (Ciuffreda et al., 2016). In this study, most Canadian optometrists (78%) reported conducting a full binocular vision assessment and a minority of optometrists employed tint trial (50%), yoked prisms (41%) and vision therapy (41%) as a management strategy.

Pharmacologic treatments can be administered for the management of specific symptoms or altering primary pathophysiology of an ailment. Currently there are no specific pharmacotherapies for treatment in concussion and insufficient evidence on the effect of medical therapies for concussion to provide strong clinical recommendations for their use (McCrory et al., 2017; Hunt and Asplund, 2010). In the present study, Omega-3 was the most recommended supplement by optometrists (54%). While there are limited human studies proving the efficiency and efficacy of Omega-3 in concussion patients, studies report that DHA, (docosahexaenoic acid) a type of omega-3 fatty acid, has the potential to improve cognition in concussion individuals (Barret et al., 2014; Lewis et al., 2013). Animal- based research using rodents reported Omega-3 protects against decreased plasticity, offers resistance to oxidative stress from concussion, and decreases the effect concussion has on the brain (Wu et al., 2004; Wu et al., 2011; Bailes and Mills, 2010). Many optometrists in our study (38%) also suggested oral supplements such as vitamins, minerals and herbal teas. Animal based research on Vitamin C, D, and E suggest potential benefits for concussed individuals, however human studies are non-existent. A decrease in neurological deficits from vitamin E intake was reported in concussed rats (Yang et al., 2013) and a study using rodents showed that vitamin D combined with progesterone reduced neuronal loss post-concussion (Trojian et al., 2017). In vitro studies have reported some herbs (i.e., S. baicalensis) alleviate symptoms quicker after concussion by decreasing neuronal oxidative stress and apoptosis of cortical neurons (Miao et al., 2014; Zheng et al., 2014). Randomized clinical trials are clearly needed to determine the efficacy of these potential treatments in humans who have experienced a concussion before guidelines recommending for or against their use can be implemented.

Pain medication was suggested by 12% of optometrists in our study. and the effectiveness of pain medication in concussion management is supported by studies in the literature. While there may be some disagreement or controversy around a direct role of optometrists in pain management, one would expect them to ensure the patient was seeing a physician to manage their pain through recommendation or referral, particularly if over the counter pain medications were insufficient. In concussion, prescription medications are mainly administered in cases where specific criteria are reached and when symptoms persist beyond the effectiveness of standard care (Jones and O'Brien, 2021). Headache is a common symptom post-concussion, and it is recommended to treat it according to type and characteristic (McConnell et al., 2020; Harmon et al., 2013; Lucas, 2015). Acetaminophen and NSAIDs (nonsteroidal anti-inflammatory drugs) can be used primarily to minimize existing disruptive symptoms (DiTommaso et al., 2014). Antiepileptics and tricyclic antidepressants can be used as a preventative treatment plan for individuals with consistent daily headaches (Meehan, 2011; Langdon and Taraman, 2018; Mittenberg et al., 2001; Jones and O'Brien, 2021).

Most optometrists in this study advised patients limit activity (64%) and rest (12%). This is supported by suggestions from the 2016 International Consensus Conference on Concussion in Sports in Berlin. Initial rest during the acute phase, 24-48 hours after injury, followed by gradual increase in activity while not surpassing the threshold of symptom worsening was recommended (McCrory et al., 2018). Lun Hon et al. (2019) warn that prolonged rest could potentially worsen concussion outcomes (Lun Hon et al., 2019). In this study, most optometrists advised habits surrounding daily living activity was consistent with the previously mentioned guidelines.

Only 2% of optometrists advised positive health behaviour in this study. A 2021 study emphasized the importance of sleep hygiene in concussed individuals (Jones and O'Brien, 2021). Sleep hygiene entails reducing screen time, sleeping in a cool and dark room, exercising, avoiding alcohol and caffeine intake, reducing daytime napping and limiting noise (Jones & O'Brien, 2021; Irish et al., 2015). Responses regarding advice on daily living activity included, referral, emotional support, educate/explain and positive health behaviour. The initial medical help received by concussed individuals is likely not an optometrist. However, referral to an eye care provider can be pivotal for positive patient outcomes, likewise referrals from an optometrist to other specialists can be critical for improving patient outcomes. A randomized clinical trial study reported that adolescents who received collaborative care had less post-concussion symptoms at the 3- and 12-month marks and increased health-related quality of life compared to a group receiving typical care (McCarty et al., 2021). A large part of the optometrist's role is to recognize, refer and provide information consistent with other health practitioners. In clinic, educating within their area of expertise, showing concern for patient overall wellbeing, and validating the patient's emotional concerns are necessary and play an important part in management. Evidence suggests that concussed individuals are highly receptive to patient-centered interactions, reassurance, and education (Hunt and Asplund, 2010; King et al., 1997; Mittenberg et al., 2001). Because the scope of optometric management is largely confined to vision-based problems, it is recommended that non-vision-based issues be referred to the appropriate health care provider after the concussion appointment (Ciuffreda et al.2016; McCarty et al., 2021).

3.5.1 Limitations

Only 9% (13/142) of optometrists in this study did not manage concussion. It is possible that this survey disproportionately attracted optometrists who manage concussion compared to those who do not. The survey title, 'Optometric Management of Visual Deficits Following Concussion' could have deterred optometrists who do not manage concussion from participating. Additionally, because the survey was public and anonymous, no personal identifying information was collected and IP addresses were not stored, it is possible that participants could have submitted multiple surveys. That being said, there is no reason to believe that anyone would want to or go to such lengths in order to deliberately skew the results. Lastly, there was only a 2% response rate from optometrists in Canada.

3.6 Conclusion

There is no set standard of care for the optometric management of visual deficits following concussion, however it seems that Canadian optometrists typically complete a full eye exam and a binocular vision assessment that includes a midline shift assessment. It seems logical that the standard of care for optometric management build on the strengths of what is currently being done. In this study, management of visual deficits entailed tint trial, yoked prisms, and vision therapy; these interventions should be considered in the management on visual deficits after concussion. Recommendations around daily living activity should largely be to limit activity. It seems appointment duration should be around 30 to 60 minutes and follow up appointments should be booked within the range from under one month to two months. Further studies on treatment efficiency are required. Until evidence-based standards can be determined this study will inform optometrists, and other eye care providers, on how colleagues are currently managing concussion.

Chapter 4
Comparing The Optometric Management of Concussion in Private Practice to an Academic Optometry Clinic

4.1 Purpose

The purpose of this chapter was to compare the optometric management of concussion in private practice to an academic optometry clinic. Comparing populations will provide insight on differences and similarities on the optometric management of concussion between private practice optometrists and academic optometrists. In turn, this comparison can inform the optometric management of concussion. The sample population of optometrists from an academic optometry clinic and private practice are the same groups previously examined in this thesis project. The private practice cohort consisted of 128 optometrists and 18 optometrists composed the academic optometry clinic group; both cohorts managed concussion. See Chapter 2 and 3 for study design and data collection procedures.

4.2 Analysis

The percent of optometrists that conducted a particular assessment was examined and compared between groups. See Figure 4.1 for all assessments investigated. In Chapter 2, the retrospective review examined the frequency of assessments conducted in 119 appointments while Chapter 3, the survey study, investigated the frequency of optometrists that conducted a particular assessment from 128 respondents. To allow for comparison between studies the retrospective review needed to be examined from the perspective of frequency of optometrists that conducted a particular assessment, as opposed to the frequency of assessments conducted. The number of each assessment and number of appointments conducted by each optometrist from 119 appointments was documented. The number of assessments conducted by each optometrist was divided by the total number of appointments that optometrist conducted. A threshold of 1% or over was applied to ascertain if an optometrist was considered to generally administer a particular assessment. In other words, if an optometrist conducted a particular assessment more than 1% of the time the optometrist was considered to generally utilize that assessment when treating concussion patients. The optometrists that conducted an assessment above a 1% threshold were tallied and the percent of optometrists that conducted each assessment was calculated by dividing the number of optometrists that conducted a given assessment by the sample size.

The academic optometry clinic appeared to contain two subgroups within its cohort: 1) optometrists that regularly carried out concussion appointments (n=8) and 2) a group of optometrists that conducted one concussion appointment (n=10). Collectively the group of eight optometrists conducted 109 concussion appointments and the group of 10 optometrists conducted 10 appointments. The private practice group consisted of 128 optometrists from across Canada. Comparative statistics were run between groups using the three by two chi square test. A p-value less than 0.05 was considered significant.

4.3 Findings

Optometrists that regularly conduct concussion appointments at an academic optometry clinic had the highest frequencies across all assessments, except for visual acuity which was equal with the academic optometry clinic group that conducted one appointment. Additionally, all investigated assessments were conducted by over 85% of optometrists who frequently managed concussion, except for wet refraction which was conducted by 50% of optometrists in this cohort. Wet refraction was also conducted at the lowest frequency in all three groups. The optometric management in the private practice cohort was more similar with the academic optometry clinic group that only conducted a concussion appointment once in comparison to the academic optometry clinic cohort that regularly conducted concussion appointments.

A three by two chi square test showed that dry refraction, confrontation visual field, visual acuity and pupil dilation had no significant difference between the three cohorts. A statistically significant difference was observed in midline shift, vision therapy, yoked prism and tint trial in order of descending chi square value. See Table 4.1 for chi square results.

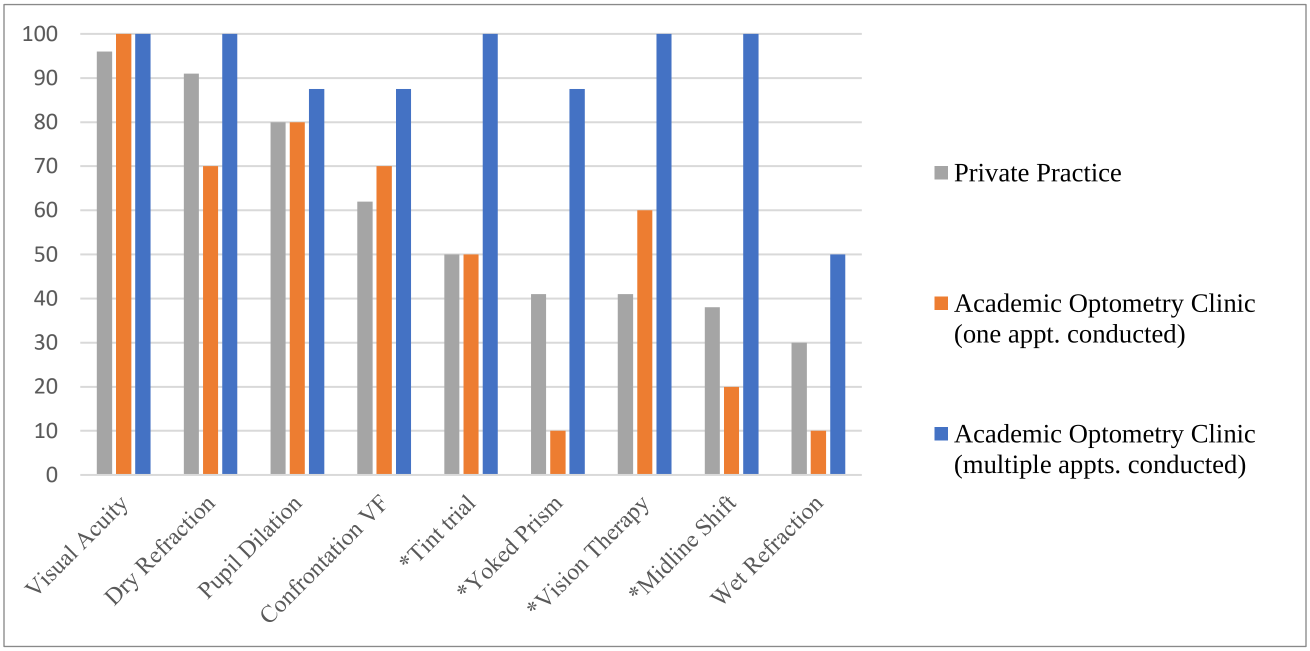

Figure 4. 1. The percent of optometrists that conducted assessments.

Private practice (n = 128), Academic optometry clinic - one appt. (n = 10) & academic optometry clinic – multiple appts. (n = 8)

****Confrontation VF stands for Confrontation Visual Field.***

****Represents statistical significance. (p<0.05)***

The findings showed that optometrists at an academic optometry clinic who saw concussed individuals frequently performed management strategies relating to visual function, namely vision therapy, tint trial, and, yoked prisms. These findings could indicate that the academic optometry clinic cohort that frequently deals with concussion patients has established a strategy that focuses on restoring binocular vision in the concussed patient.

Optometrists in private practice and optometrists that only conducted a concussion appointment once generally conducted full eye exam components at higher percentages compared to management pertaining to visual function namely, vision therapy. Tint trial was conducted by 50% of optometrists in both private practice and optometrists that only managed concussion once at an academic optometry clinic, compared to 100% of academic optometrists who managed concussion frequently. These results suggest that private practice optometrists and optometrists who do not often manage concussion in this study focused more on conducting the components of a full eye exam rather than providing visual function management for concussion patients.

Comparable Assessments	**Chi Square Value (x^2)**	**P-value**
Midline Shift	13.77	0.001
Vision Therapy	11.66	0.003
Yoked Prism	11.12	0.004
Tint trial	7.58	0.023
Dry Refraction	5.80	0.055
Wet Refraction	3.45	0.178
Confrontation Visual Field	2.35	0.309
Visual Acuity	0.73	0.695
Pupil Dilation	0.24	0.885

Table 4. 1. Chi square test results – comparing studies.

Frequencies between optometrists in private practice, optometrists who only conducted one concussion appointment, and optometrists who conducted multiple concussion appointments. p=0.05

In summary, optometrists who regularly manage concussion in an academic optometry clinic conducted assessments more frequently compared to other groups and nearly all assessments were conducted by the majority (over 85%) of optometrists in this group. The other two groups largely focused on ocular structural assessments and a minority of these optometrists conducted assessments or employed management strategies relating to visual function and photosensitivity.

4.4 Limitations

It is unknown what criteria each optometrist in the survey study used to determine if they consider themselves to conduct a particular assessment in concussion management, therefore a threshold value for the optometrists at an academic optometry clinic had to be assumed. A threshold of 1% or higher was implemented and necessary for comparing cohorts. This assumption may not correspond to the threshold used by optometrists in private practice. A higher threshold (i.e., 50%) was examined and demonstrated decreased frequencies across all assessments. However, a 1% threshold was decided upon based on reasoning that a 1% threshold might best reflect the criteria that private practice optometrists used when participating in the survey. If optometrists conducted an assessment once on a concussed patient, they may presumably answer ‘yes’ to incorporating that particular assessment as part of their concussion management strategies. In addition, the survey study was designed to get a general idea of how optometrists are managing concussion in private practice. The survey study does not capture the same level of detail as the retrospective review and poses limits on specificity when comparing both studies. Finally, the sample sizes between cohorts were unequal which may lead to a loss of statistical power.

Chapter 5
Discussion, Limitations, Future Studies

5.1 Summary

In general, both optometrists in a university academic setting and in private practice showed that the optometric assessment and management of binocular vision was an approach in the evaluation of concussion. In private practice, our survey results showed an emphasis on the examination of structural assessments. The retrospective comparison of the optometric management of non-concussed to concussed individuals in an academic optometry clinic revealed that visual function assessments were typically more extensive in selection and frequency in the concussed cohort compared to the non-concussed group. Vision therapy while employed by optometrists in private practice, was not as prevalent compared with optometrists who frequently managed concussion in an academic optometry clinic.

5.1.1 Optometrists who do not manage concussion

In private practice, many optometrists referred patients to specialized health care providers, and this was a top reason provided for optometrists who did not manage concussion (31%). Referring patients to other health care providers aligns with recommendations provided in the literature. Not only is referral for a medical assessment beneficial in a scenario where a healthcare professional is absent at the scene of concussion, but it is also important amongst health care providers to collectively provide optimal care for the concussion patient (Parachute, 2017). The Canadian Guideline on Concussion in Sport created by Parachute notes that individuals with PCS can benefit from referral to a multidisciplinary concussion clinic with experts specializing in concussion care or a physician specializing in concussion if the first is not accessible (Parachute, 2017). Joint care provided by multiple health care providers strengthens the care the patient receives by allowing various areas of concern to be addressed by corresponding health care specialists. Regrettably, our survey was not designed to determine what health care providers, private practice optometrists referred their concussion patients to. Future research should examine the referral patterns of optometrists and other health care providers who provide concussion management.

5.1.2 Visual assessments

Vision deficits are common following concussion (Master et al., 2016; Storey et al., 2017; Master et al., 2018; Gallaway et al., 2017; Capó-Aponte et al., 2017; Ciuffreda et al., 2016; Merezhinskaya et al., 2019; Wiecek et al., 2021). In a clinical setting, vision assessments are important for the diagnosis of any visual deficits (Tator, 2013). In private practice, it was reported that optometrists more frequently conducted assessments that make up ocular structure assessments. Dry refraction, pupil dilation, automated perimetry and confrontation visual field were conducted by over 60% of optometrists. The results from private practice clinicians regarding the administration of ocular structure assessments align with suggestions from other studies in the literature (Master et al. 2016 Ciuffreda et al., 2016). In a university academic optometry clinic, 70% of optometrists that managed concussion conducted structural assessments, namely dry refraction, pupil dilation and confrontational visual field. Others have suggested the inclusion of a full eye exam in the assessment of visual deficits following concussion. Master et al. (2016) suggest a comprehensive examination may be beneficial in the evaluation of adolescent concussion patients. Ciuffreda et al. (2016) propose a conceptual model of care as a 'roadmap' for the clinical assessment of visual deficits and suggest the incorporation of a basic vision examination consisting of refractive, binocular, and ocular health status. Subsequent to a basic vision examination, the examination of oculomotor-based vision, involving examination of version, vergence and accommodation should be conducted (Ciuffreda and Ludlam, 2011; Ciuffreda et al., 2016). In a study examining NPC in children following concussion

Master et al. (2016) highlighted the need for NPC assessments to be conducted as concussion surveys may not always be sensitive in identifying visual deficits in children. Scheiman et al. (2021) document cases where NPC and accommodative amplitude failed to detect a third of convergence disorders and over half of individuals who had accommodative insufficiency. Therefore, it was suggested that adolescents with PCS receive a thorough examination for accommodative, vergence and saccadic dysfunction (Scheiman et al., 2021).

At an academic clinic, when comparing the frequency of assessments conducted between a concussed and non-concussed group, a difference in the frequency of assessments was observed. Ocular structure assessments included but were not limited to visual acuity, dry refraction, pupil reflex, anterior segment, pupil dilation and confrontation visual field and were conducted more frequently in the non-concussed group. Vision function assessments included but were not limited to vergence, oculomotor control panel and stereopsis, were also more prevalent in the assessment of the concussed group. It is important to note that the academic optometry clinic that the concussed cohort was pulled from is a clinic that largely receives patients based on referral. The referring clinician typically conducts and reports that a full eye exam was completed in the referral letter to the university academic optometry clinic. In the referral letter a full list of assessments and their respective scores were not always included and therefore not part of the frequency count. Presumably due to examination intolerance in typically highly symptomatic patients, optometrists at the university academic optometry clinic may avoid repeating assessments already conducted. These two above mentioned explanations likely contributed to the reason fewer structural assessments were documented in this population. A noteworthy point is that all individuals received a full eye exam either from the referring optometry clinic or at the university academic clinic and these should include the basic structural assessments with respect to ocular health and refraction. Although the assessments comprising a full eye exam were not always listed in the referral letter, the results from the survey of Canadian private practice optometrists demonstrated these optometrists primarily completed ocular structure assessments for post-concussion patients. Therefore, it is likely that ocular structure assessments were being conducted by optometrists that referred concussed patients to the academic optometry clinic.

Wet refraction was most frequently done by optometrists that typically managed concussion (50%), followed by optometrists in private practice (30%) and optometrists that conducted one concussion appointment (10%). Wet refraction should be conducted more frequently in concussion individuals as it may be beneficial when examining individuals with accommodative issues, for example spasm of the near reflex. Furthermore, administering a cycloplegic agent may be a management strategy for individuals presenting with spasm of the near reflex (Knapp et al., 2002).

5.1.3 Management

Management strategies such as tints, prisms, and vision therapy were conducted by many (40-50%) optometrists in private practice. Researchers have recommended the use of these management techniques; however, more research is required on their effectiveness in concussion management. The administration of spectacle prescription for the concussed individual was not examined in our study and its effectiveness should be explored in future studies. At an academic university clinic, management strategies in a concussed group included vision therapy (91%), tint trial, (58%) and yoked prisms (25%). The above listed management strategies were non-existent in the non-concussed group, presumably because patients in this cohort did not have visual deficits requiring these management strategies. Alternatively, it may also be because clinicians that managed non-concussed individuals failed to conduct binocular vision assessments and therefore failed to detect conditions requiring treatment. Additional research on the administration of binocular vision assessments in non-concussed individuals is required to address these research findings.

Ciuffreda et al. recommend that ‘non-oculomotor-based’ vision assessments be conducted by looking at abnormal spatial localization, photosensitivity, vestibular dysfunction, motion sensitivity, visual field defect and visual information processing dysfunction. Suggested management of some of the above listed deficits included occluders, prisms, tints, and vision therapy (Ciuffreda et al., 2016). It appears that private practice optometrists are functioning at level one of Ciuffreda et al.’s conceptual pyramid of care while optometrists who frequently see concussion patients at a university academic optometry clinic are functioning at level two or three. It is suggested that all optometrists refer (level four of the pyramid) to other health care providers when appropriate.

D’Angelo and Tannen (2015) reported success using prisms based on their clinical experience. Some researchers have reported the effectiveness of vision therapy for binocular vision restoration (Rollett and Morandi, 2019; Scheiman and Wick, 2008; Ciuffreda, 2002; Cohen, 1988). Conversely, Barton and Ranalli (2020a) note that while the efficacy of vision therapy for primary convergence insufficiency is supported by data, there is insufficient evidence on the pathology of oculomotor deficiencies following concussion. The authors also note the lack of knowledge surrounding the cause of oculomotor deficiencies following concussion. The origin of oculomotor deficiencies may arise from ocular motor damage, or it may be a secondary effect of cognitive issues, namely attention and ‘executive control’(Barton and Ranalli, 2020a).

5.1.4 Medications and supplements

There is limited evidence on the effectiveness of pharmacotherapy in concussion management and no pharmacotherapy yet has been proven to reduce concussion recovery times (McCrory, 2002; McCrory et al., 2018; Jones and O’Brien, 2021). In our survey study, the majority of responding optometrists in private practice (54%) suggested the use of Omega-3. There is continued research on the use of medications and supplements in concussion. Docosahexaenoic acid (DHA), an Omega-3 fatty acid, has been reported to potentially improve functional outcomes, for example learning and spatial memory. Further clinical research in humans is required to validate preclinical findings (Barret et al., 2014; Bailes and Patel, 2014; Lewis et al., 2013). Studies have reported an increased frequency of dry eye in individuals with traumatic brain injury and it is likely the major reason for private practice optometrists recommending Omega-3 (Lee et al., 2018). In support, a minority of Canadian optometrists in private practice did mention Omega-3 in conjunction with dry eyes in the survey study. Private practice optometrists frequently performed ocular structure assessments compared to visual function assessments. It is likely private practice optometrists did see and diagnose dry eye more often compared to optometrists at specialized academic optometry clinics where anterior segment in not part of the visual function assessment typically conducted.

Oral supplements (vitamins, minerals and herbal teas) and pain medication were also recommended by 12% of optometrists. Headache is a prevalent symptom following concussion, (McConnell et al., 2020). Jones and O'Brien (2021) note that majority of people with headache treated themselves with over-the-counter (OTC) medication. More research on the effectiveness of pharmacotherapy in concussion management is needed. Our retrospective review did not determine how optometrists prescribe supplements and this may be a worthwhile future study as the supplement prescription of optometrists at an academic optometry clinic has not yet been reported.

5.1.5 Advice on daily living activity

Our findings on advice given by private practice clinicians regarding daily living activity largely align with the recommendations provided by the Canadian Guideline on Concussion in Sport and the 5th Consensus Statement on Concussion in Sport. In our study, 64% of optometrists recommended to limit physical and cognitive activity followed by a gradual return to activity. Rest was recommended by 12% of optometrists. Rest for the first 24 to 48 hours is suggested before starting cognitive and physical activity (Parachute, 2017; McCrory et al., 2018). A stepwise progression for returning to sport and school was proposed by Parachute and in the 5th Consensus Statement on Concussion in Sport (McCrory et al., 2018; Parachute, 2017). A gradual return to school and sport is recommended and if worsening of symptoms or new symptoms arise the individual should revert to the preceding step (Parachute, 2017; McCrory et al., 2018). McCrory et al. (2018) note that each step of the stepwise progression should take 24 hours, however individuals with PCS may exceed this time.

Less prevalent advice on daily living activity in our survey study was to watch/be aware, follow specialists' advice, and carry out positive health behaviour, which incorporated good sleep and diet habits. Some common sleep-related symptoms following concussion are sleeping more or less than usual and difficulties falling asleep (Parachute, 2017). Positive sleep habits included consistent sleep and awakening time, implementing a bedtime routine, and avoiding naps after the acute phase of concussion (Ontario Neurotrauma Foundation, 2018). According to the Ontario Neurotrauma Foundation (2018), diet recommendations include but are not limited to avoiding alcohol, caffeine, and sugar near bedtime, and eating foods that help with the production of melatonin (i.e., foods containing iron and magnesium) (Barlow et al., 2019).

Under 5% of optometrists reported providing emotional support and education on concussion in our study. An essential part of the management of concussion is the education, reassurance, and comfort that clinicians provide their patients. Identification of non-vision-based problems, including emotional problems such as depression or anxiety, should be followed up with a referral to a specialist. Parachute (2017) emphasized the continued need for concussion awareness and education for all individuals associated with sports for example athletes, coaches, parents, teachers, and trainers.

Concussion education includes but is not limited to the definition, mechanism of injury, signs and symptoms, preventative measures, proper medical assessments, and medical clearance requirements for returning to sport (Parachute, 2017).

5.1.6 Appointment duration and follow up appointment

There is limited documented information on concussion appointment duration. Therefore, a broader search on the estimated duration of full eye exams for non-concussed individuals in private practice optometry clinics was conducted. Variation in appointment duration exists amongst patients and between clinics. Concussion appointment duration is dependent on factors including but not limited to age, symptom severity and pre-existing medical conditions. Most optometrists in private practice (57%) reported concussion appointment durations ranged from 30 to 59 minutes, followed by 60 to 89 minutes. A minority of optometrists (5%) informed that appointments were under 30 minutes. Decreased concussion appointment duration, while not an absolute measure, can be an indicator of the potential need for more extensive examination of ocular structure and visual function.

In our survey study, private practice optometrists mainly responded that follow up appointments were case dependent (24%). Most optometrists reported follow-up appointments falling between 1 – 2 months (23%) and less than 1 month (20%). For individuals undergoing vision therapy D'Angelo and Tannen (2015) recommend a progress check every 10 to 12 sessions of vision therapy. For those who completed therapy D'Angelo and Tannen (2015), based on clinical experience, suggested to follow up at the six-week, three-month, six month and 12-month mark (D'Angelo and Tannen, 2015). Canadian optometrists seem to be loosely following this approach and are largely conducting follow up appointments before the 2-month mark.

5.2 Additional findings

In the academic optometry clinic, all patients received a full eye exam except for one patient in the concussed group that did not return to their scheduled follow-up appointment. Full eye exams were completed either at the referring clinic or at the academic optometry clinic. The majority of referring optometrists conducted a full eye exam, which largely overlaps with ocular structure assessments (61% of referring clinicians indicated a full eye exam was completed). Ocular structure assessments were sometimes but not always repeated at the academic optometry clinic. Avoiding repetition of ocular structure assessments may have been decided by clinicians in cases where patients were highly symptomatic and had low examination tolerance.

Lastly, it was observed that referral forms did not always include a complete list of visuals assessments conducted and/or included the respective findings of the assessments. Implementation of a standardized electronic referral form may be a potential resolution that allows for the optometrist to be fully informed on previously conducted vision assessments. See Appendix A for a proposed preliminary draft of a clinic referral form that can be utilized in the optometric referral process of concussion patients. This clinic referral form aims to capture both the assessments conducted by the referring clinician and their respective findings.

5.3 Limitations

In the retrospective review, the percent of assessments conducted did not include the assessments conducted by the referring clinician and so the findings were limited solely to the management of optometrists at an academic university clinic.

The survey study was designed to determine how Canadian optometrists are managing concussion, generally. Therefore, the specifics in terms of visual assessments conducted by optometrists were not captured from the survey. When comparing the findings from both projects, the survey study and retrospective review, there were limited comparable variables.

The study designs of both projects were different. The retrospective review looked at the frequency of assessments and management strategies conducted, and the survey study asked optometrists how they manage concussion. The criteria each optometrist, in the survey study, used to decide if they conduct a particular assessment is unknown. Therefore, a threshold of 1% or higher was assumed for the optometrists at an academic optometry clinic. A threshold of 1% or higher was chosen as we presumed that this might reflect the criteria used by optometrists the best, compared to other thresholds.

5.4 Future Studies

Wet refraction was used more frequently in the concussed cohort compared to the non-concussed cohort at a university optometry clinic and around a third of the time in private practice. Additional research is required on the role cycloplegia and refractive correction may play in concussion. Consensus on the use of prisms as a management strategy in concussion is pending and further research on this treatment option is also required. Limited studies exist on the use of spectacle prescriptions, although some preliminary studies have reported encouraging outcomes (Johansson et al., 2017). Further evidence-based research is required on the effect spectacle prescriptions can have on concussion associated vision deficits.

5.5 Conclusions

Visual deficits, including functional vision dysfunctions are reported to be common following concussion. However, there is no standard of care for the optometric management of these concussion-associated visual deficits. Results from this project reveal the status of optometric management of concussion in Canadian private optometry practices and at an academic optometry clinic and do not inform on the efficacy of visual assessments and management options for concussion. However, it seems rational that the optometric standard of care be developed based on the strengths of existing management strategies.

It is recommended to ensure that patients have received an ocular structural assessment and their functional vision status should be determined. Recommendations on ocular structure assessments include refractive status, visual field status, and the inspection of structures in and around the eyes. Based on our project findings, the examination of visual function which incorporates assessments of visual acuity, accommodation, vergence, oculomotor control, depth perception, and deviations of the eye appears to be conducted frequently in the concussion population and should continue to be conducted routinely until evidence suggests otherwise. In terms of the management of visual deficits following concussion, Canadian optometrists in private practice and at a university academic optometry clinic utilized vision therapy, tints, and prisms and these interventions should be considered. Finally, a standardized referral system is recommended for clinics that manage concussion. A referral system would help facilitate patient care and ensure that optometrists are fully informed of the assessments already conducted by referring optometrists, especially structural assessments.

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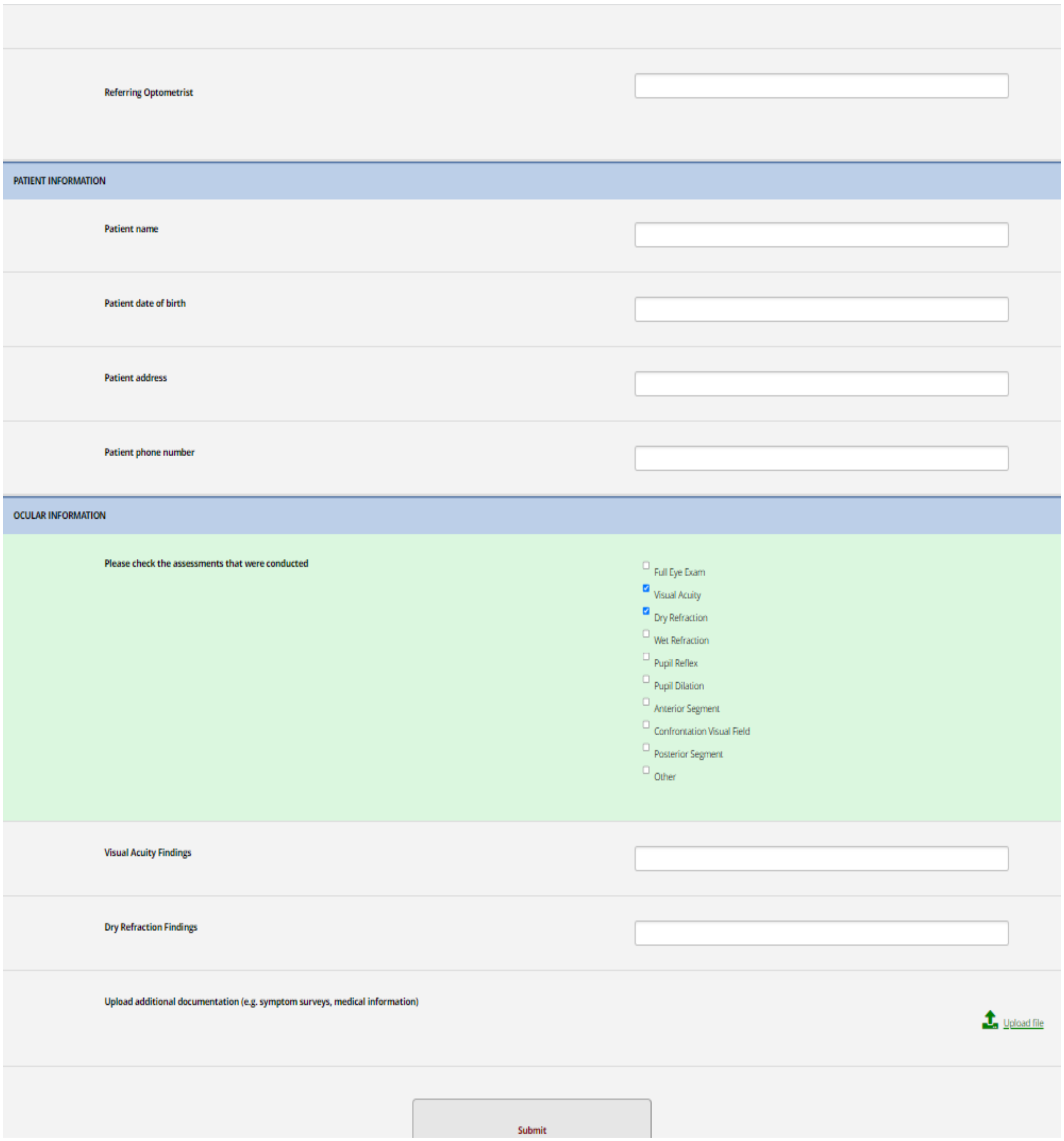
Appendix A – Standardized Optometry Clinic Referral Form



Referring Optometrist

PATIENT INFORMATION

Patient name

Patient date of birth

Patient address

Patient phone number

OCULAR INFORMATION

Please check the assessments that were conducted

- [ ] Full Eye Exam
- [x] Visual Acuity
- [x] Dry Refraction
- [ ] Wet Refraction
- [ ] Pupil Reflex
- [ ] Pupil Dilation
- [ ] Anterior Segment
- [ ] Confrontation Visual Field
- [ ] Posterior Segment
- [ ] Other

Visual Acuity Findings

Dry Refraction Findings

Upload additional documentation (e.g. symptom surveys, medical information)

Upload file

Submit