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**Canada**



**Concussions in Ice Hockey:  
Baseline Testing, Reporting Accuracy, and Cervical Functioning**

**by**

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**THESIS**

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in partial fulfillment of the requirements for**

**Master of Science**

**Wilfrid Laurier University**

**2010**

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**Abstract**

The purpose of this study was threefold: firstly, to demonstrate the utility of the SCAT2 as both a baseline measurement and a tool to aid in the decision making process following the occurrence of a concussion; secondly, to assess the accuracy of reporting and/or relaying a diagnosis of a concussion; and finally to attempt to measure a relationship between cervical spine functioning and past concussion occurrence. Eighty hockey players were assessed for cognitive, neuropsychological, and physical measures pertaining to concussive injuries within ice hockey. The results of the study showed a marked underreporting of concussions due to either fear of reporting, misdiagnosis, or simple lack of knowledge. The SCAT2 is demonstrated to be a useful and cost-effective tool for use as a baseline measure or for a means of following up post-injury. No significant findings appeared with regards to cervical functioning and past concussive injuries; recommendations for future research are offered.

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## Concussions in Ice Hockey:

### Baseline Testing, Reporting Accuracy, and Cervical Functioning

#### *Concussions: Background and Diagnosis*

Head and neck injuries in hockey, despite a great deal of attention by researchers, continue to pose a great challenge to those managing the injured athlete. Concussions have been especially troublesome due to their frequent occurrence, lack of understanding as to their exact pathophysiology, and varied course to recovery. Despite changes over the past decade to offer more protective equipment, stricter rules for players' safety, and awareness of head and neck injuries, the incidence of concussion continues to increase (1). Between 2002 and 2006 there was an increase in emergency room visits (14.4%) and hospitalizations (19.5%) due to traumatic brain injuries, including concussion, in children aged 0-14 years (2). In fact, the Center for Disease Control estimates that between 2001 and 2005 there were 207,830 cases of sports-related traumatic brain injuries in children aged 5-18 years reporting to the emergency room, of which males constituted 70.5% (3).

Concussion is defined as a traumatically induced physiological disruption of brain function with a short period of altered, or loss of, consciousness (4). In the "Summary and Agreement Statement of the First International Symposium on Concussion in Sport, Vienna 2001", concussion was defined as a "complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (5). In 2008, the Zurich symposium (6), offered an updated definition:

*Journal of Science and Medicine in Sport, 2009; 12: 340-351:*

Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function



- that resolves spontaneously.
3. Concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
  4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course however it is important to note that in a small percentage of cases however, postconcussive symptoms may be prolonged.
  5. No abnormality on standard structural neuroimaging studies is seen in concussion.

In the diagnosis of concussion, one must assess the somatic symptoms (e.g. headache, neck pain), the cognitive symptoms (e.g. confusion, feeling in a fog), and the emotional symptoms (e.g. depression, irritability). The athlete may experience “pressure in the head”, dizziness, or even nausea. Given the mechanism of the concussion, in the event of such severe symptoms, medical attention will be required to assess the risk of an intracranial hemorrhage or other medical emergencies. Additionally, physical signs such as loss of consciousness (LOC), amnesia, or poor coordination, as well as behavioural changes, such as moodiness or inappropriate responses must be assessed. Poor concentration and slowed reaction times are two examples of cognitive impairment that may exist following a concussion. Also, any form of altered consciousness, such as drowsiness, must be noted. In the recent Zurich statement (6), more emphasis was put on balance testing as the authors noted that current literature shows postural stability deficits for as long as 72 hours following a concussion in sport. Not all of these indicators need to be present for a diagnosis of concussion, but if even one of these are present, a concussion should be considered as a possible diagnosis and appropriate steps need to be taken (7). It may be noted that many of these symptoms may overlap with a variety of other coinciding conditions, or may be simply the effect of hormonal changes during puberty. As such, the continued monitoring of the athlete is essential, and should be done by someone with knowledge of the athlete’s typical demeanor. Because LOC is not required for the diagnosis and many concussions will occur

without LOC, careful assessment of an athlete is required if any suspicions arise. The duration of LOC has been found to be a predictor in outcome, and it was agreed that LOC greater than one minute should be a factor in modifying management (6).

Commonly, an athlete may be asymptomatic following the concussion or even hours later and basic testing procedures may yield negative results. Neuropsychological testing may reveal abnormalities that effect functioning. In the absence of overt physical symptoms, there may be countless neurological abnormalities occurring, such as axonal stretching and subsequent repair processes, impaired cerebral blood flow and glucose supply, delayed cell death, and numerous other ionic fluxes and neural disconnections (8). This will greatly tax the neurological structures and make them more vulnerable to further injury.

Giza and Hovda (8) proposed that when an athlete is subjected to a blow to the head, face, neck, jaw, or elsewhere in the body (if the force is transmitted to the head) there are immediate ionic fluxes occurring concomitant to the release of neurotransmitters. Specifically, glutamate (an excitatory neurotransmitter) will bind to a N-methyl-D-aspartate receptor, which will subsequently depolarize the neuron. Given that open ice collisions in hockey have been estimated at over 1800N of force (9), it is not surprising that following a hit, the neural membranes can be biomechanically disrupted within the brain and axons can be stretched. These factors will cause the opening of potassium channels, which will further disrupt the ionic balance surrounding the cell. As the neuron is depolarized there is a further outpouring of potassium ions and an inward surge of calcium. Functioning of glial cells also become impaired, which normally regulate extracellular potassium and glutamate, further contributing to the problem. These changes affect the normal nerve cell physiology, which will then effect the normal functioning of the neuron (8).

It is essential to note that under normal physiological conditions, cerebral blood flow is proportionally linked with neuronal activity. As such, when neurological demands increase, blood perfusion to related areas also increases. It has been demonstrated previously that cerebral blood flow may decrease to 50% of normal in animal models of head trauma (10-13) and recently researchers have postulated that this decreased flow is due to platelet activation and thrombus formation in the associated region of cerebral microcirculation (14); this is contrary to the assumption of a physiological vasoconstriction of the arterioles. Initially, due to the depolarization of the nerve and subsequent activation of the ATP-requiring sodium potassium pump, there is a period of hyperglycolysis to meet the demands of the pump. After a short period of time, the glucose available to supply ATP diminishes due to a lack of supply from the cerebral microcirculation and ionic balance will not be able to be maintained. Thus, an energy crisis ensues. This crisis is postulated to be the cause of increased vulnerability following a concussion due to the lack of resources within the brain to respond to a second insult (8). As such, it is essential to monitor an athlete with a suspected concussion for hours, if not days, following the event, even if the test scores are not indicative of a neurological injury. It is critical to be aware of the above-mentioned neurophysiological stresses, as they are the rationale for requiring physical and cognitive rest during the recovery period.

In the past, there have been several different grading systems used in the diagnosis of concussive injury, which has led to a great deal of confusion between those involved in its management (15). Peloso and colleagues identified 41 guidelines in the literature, of which 18 focused specifically on sports-related traumatic brain injury. They note that there is a need for high-quality studies to validate the use of these guidelines and reduce the confusion

associated with numerous grading scales. Three of the more commonly used grading scales include the Cantu evidence-based scale (16), the American Academy of Neurology practice parameter (17) and the Colorado Medical Society (18). While all scales are similar for grade I concussion diagnosis, the Cantu scale puts more emphasis on loss of consciousness through grades II and III, while the latter two include loss of consciousness only within grade III. In the 2004 Prague statement (7), the concept of “simple” versus “complex” concussion was introduced in attempts to simplify and standardize the use of grading scales. A “simple” concussion was defined as one that resolves within ten days with appropriate rehabilitation, whereas a “complex” concussion has longer lasting symptoms or reoccurs with exertion (7, 19). In the most recent Zurich consensus statement (6), this simple and complex concept was subsequently abandoned as the panel agreed that the definitions did not fully describe the entities. They reaffirm, however, that most concussions will still resolve in a short period of time (7-10 days). Grading of a concussion therefore remains unstandardized and should be based on a variety of measures both subjective and objective. It is recommended that a clinician choose the scale that they find most clinically appropriate and maintain consistency of use in practice.

When dealing with an acute concussion, several clinical domains should be assessed by a trained healthcare professional including signs, symptoms, behaviour, balance, sleep, and cognition. When a concussion is suspected during play, normal emergency procedures should be employed by the attending therapist to rule out a serious cervical spine injury. A licensed healthcare provider must properly assess the player’s disposition and if unavailable, the player should be removed from play until this can be completed; a trained professional should employ the recently modified Sport Concussion Assessment Tool (SCAT2) (6) to

assist in the decision making process. It should be noted, however, that this tool must not be utilized as the sole basis for recommendations. Serial monitoring over the next several hours is key in determining deterioration of the athlete, as many of the symptoms of a concussion may not manifest for several hours following the injury; oftentimes advanced neuropsychological testing is required to reveal any minimal differences (8, 20, 21, 22). As soon as possible following the injury, the motor domain of neurological functioning should be assessed (within 72 hours) using balance testing as indicated on the SCAT2 (6). At a minimum, the player should not be returned to play on the same day of injury if a concussion is suspected.

### ***Return to Play***

The Concussion in Sport Group (5-7) has offered a graduated return to play protocol for concussed athletes in order to attempt to minimize long term effects of the injury and to stress the importance of treating the injury as what it is – a brain injury – rather than treating it as an orthopaedic-type of injury. It was noted in the most recent Zurich guidelines (6) that the science of concussion is continually advancing and clinical decisions must be made on an individual basis. Cognitive evaluation is recommended as an important component in return to play evaluation (5-7). Cognitive recovery from concussion has been found to generally overlap with clinical symptom recovery, but it has been found to precede it as well (6). The key to concussion management remains physical and cognitive rest until there is resolution of the symptoms, followed by a graded exertion protocol preceding medical clearance for play. This stepwise progression, recommended by McCrory et al. (6), is as follows:

**Rehabilitation Stage**

1. Complete physical and cognitive rest.
2. Light aerobic exercise (<70% MaxHR).
3. Sport Specific Exercise (skating drills).
4. Non Contact Drills (passing drills).
5. Full Contact Practice (normal drills).
6. Return to normal game play.

**Objective of the Stage**

- Asymptomatic for 24 hours.
- Increase heart rate with no aggravation.
- Add specificity of movement with no aggravation.
- Add coordination and cognitive load.
- Restore confidence and assess functional ability.

The above return to play guidelines can be altered for some adult athletes. Return to play on the day of the injury can be achieved in some professional adult athletes because they have access to immediate sideline testing and evaluation by experienced health professionals; although same day return to play is not a recommended practice for all athletes (6). In this methodology, the basic management principles are maintained, but are completed in an expedited manner. Although some studies have found that there are no sequelae in their athletes using the expedited procedure (23), studies looking at high school and collegiate athletes have found that there may be neuropsychological deficits not noted on the sideline that may be present post-injury and may delay recovery (24-30).

***Long-Term Sequelae***

Researchers are now investigating more long-term effects of past concussions and the media is picking up on this as well. It is likely that athletes suffering concussions 20-30 years ago did not receive proper management and return to play advice given the lack of understanding at that time. Guskiewicz et al. (31) suggest that although a single concussion may resolve with little long-term effects, athletes who have suffered multiple concussions show a 5-fold prevalence of cognitive impairment later in life. More specifically, these athletes show a 10-20% annual rate of dementia later in life and an earlier onset of Alzheimer's disease. In fact, authors have noted that a traumatic brain injury is the highest environmental risk factor for developing the neurological disease (32-35).

The explanation for the increased risks of mild cognitive impairment and Alzheimer's appear to be based in the event-related potential P300 subcomponents of EEG wave readings. There are two essential "wavelets" within P300 that researchers are especially interested in when looking at effects of concussion: P3a (frontal lobe, task processing) and P3b (temporal/parietal, attention and memory processing) (36). Following a concussion, the classic P300 amplitude seen in healthy individuals becomes reduced and this manifestation may be long-lasting (37). Specifically, De Beaumont notes that the two subcomponents, P3a and P3b, appear to be strong markers for the detection of mild cognitive impairment, especially within concussion.

De Beaumont et al. (37) tested 56 retired athletes with a mean age between 50 and 65 who had sustained between 1 and 5 past concussions around the age of 20-30 years old. They found that athletes with past concussions scored significantly lower on recognition tests, immediate recall, and delayed recall. This study shows that 30 years after suffering a concussion, athletes may exhibit both cognitive and motor system impairments as well as deficits in episodic memory and other frontal lobe functioning. Thus the authors posit that the P300 latency abnormalities noted following a concussion may be a long-lasting phenomenon and subsequently could be linked to the cognitive impairment experienced. Ponsford (38) lends further support to this notion finding that even a decade following a brain injury, a person's functional status may be affected. The author found that those subjects with lower educational levels experienced a poorer outcome following their brain injuries and that poorer outcome was associated with decreased processing speed and decreased executive functioning. With regard to emotional status, poor outcomes were associated with higher anxiety and depression. The author notes, however, that the research

design does not allow for causal inferences to be made, and in fact the relationship of cognitive and emotional status with functional outcome may be reciprocal.

The above study findings may be linked to a process referred to as chronic traumatic encephalopathy (CTE). CTE is comprised of a variety of symptoms, including memory trouble, behaviour and personality change, disturbed gait and coordination, slurred speech, tremors, and other neurological abnormalities. Neurologically, there is a shrinking of the cerebral hemispheres, temporal lobes, and mammillary bodies, a dilation of the ventricles, and a fenestrated septum pellucidum (39). When assessed microscopically, the brain will stain positively for a tau protein and present with numerous neurofibrillary tangles (common in Alzheimer's disease), and degeneration of the substantia nigra (common Parkinson's disease) (39, 40). To date, many imaging studies have been unsuccessful in consistently finding brain abnormalities in subjects with suspected CTE, and many of the studies are cross-sectional and thus cannot conclude that the changes are related to CTE (40). Given the continually increasing number of retired professional athletes now suffering from symptoms consistent with CTE, further research is warranted.

### ***Cervical Spine Functioning***

Oftentimes, the mechanism of injury for a concussion involves a traumatic force to the body (such as in a body check) being transmitted to the head. In this circumstance, the neck becomes the link between the two regions, and thus is quite vulnerable to injury. Although direct head shots attract the widest attention within sport, indirect forces cannot be overlooked. Within the field of motor vehicle accidents, it has been found that in a collision speed of 6-8 km/h, there is sufficient force to produce a strain of the cervical musculature (41). Given the high levels of speed generated during hockey, (up to 30km/h) (9) especially



at higher levels of competition, one can assume this speed, coupled with a force of 1800N following a collision with another player, to be more than adequate to cause injury to the cervical spine. In fact, neck pain is listed as one of the cardinal symptoms of having suffered a concussion on the SCAT2 (6). Johnston et al. (42) offer four reasons as to why neck pain becomes an integral part of concussion management: 1) there can be a neck injury occurring at the same time as the concussion, 2) given the mechanism of injury for many concussions, a whiplash-type injury can also result, 3) some cervical rehabilitation programs are intense enough to aggravate the concussive symptoms, and 4) headaches stemming from concussion and headaches stemming from neck pain are difficult to differentiate. Thus it is difficult to separate a concussion from neck injury, especially when they may occur during the same traumatic incident. Despite the clear overlap between the two conditions, little-to-no research has been undertaken to further assess the relationship.

Within the past several years, there has been an increased amount of attention in the literature in regards to neck pain and its associated disorders. In 2008 *Spine* published the findings of the Neck Pain Task Force (NPTF) (43), a research group that compiled a synthesis of the literature in regards to neck pain diagnosis and management, and offered advice on the most supported modes of treatment. This research offers a great deal of clarity in regards to the assessment, diagnosis, and management of cervical spine disorders within a variety of populations.

Body contact sports have an inherent risk of neck injury, and this has been documented in the literature. In a study by Delaney and Al-Kashmiri (44), they looked at neck injury in ice hockey, football, and soccer from 1990-1999. They concluded that football has more neck injuries than both hockey and soccer, but hockey had the smallest

number of participants sampled. In their sample for the time period chosen, the authors found over 5000 cases of neck injury, most of which were contusions, sprains, or strains. In another recent study (45) they report the risk of head or neck injury in ice hockey to be 96 per 1000 player hours in junior hockey, with 2-20% of these injuries being concussions alone. Hogg-Johnson et al. (46) synthesized the evidence of incidence of neck injury per exposure in a variety of sports, including ice hockey. It was found that before the institution of the stiffer no checking from behind penalty in Canadian University hockey around 1990, there were approximately 2.37 incidences per 1000 exposures. Following the implementation of the checking from behind rule, this dropped substantially to 0.56 incidences per 1000 exposures in 1990/92 and has since dropped even lower to 0.29 in 1997/98. Thus although there is ample research available on neck injuries within sport, little to no quality research exists in regards to its association with a concussive injury.

### ***Research Goals***

The goals of this study are three-fold. Firstly, attempts will be made to show the simplicity and importance of utilizing basic concussion assessment tests, such as the SCAT2, as a baseline and follow-up measurement tool for hockey teams, and to offer descriptive statistics on the scoring trends of the SCAT2. Also, this study aims to tease out the number of players whom either have not been acknowledged or have not reported the occurrence of a concussion, and whether or not they may be suffering from a greater number of long-term sequelae as a result. Finally, cervical spine scores (range of motion values, Neck Disability Index scores) will be compared to concussion factors (positive indication of past concussion, missed concussion, or no concussion) to assess the degree of interplay between the two topics.

Specifically, it is hypothesized that there are a large proportion of players who have sustained a concussion during play/practice and have either not reported it, or have not been acknowledged, in order to avoid lost playing time. Subsequently, these players will report an elevated number of long-term sequelae, such as decreased cervical range of motion, decreased deep neck flexor endurance, lower balance scores, and poorer performance on concentration tasks than their non-concussed counterparts.

## **Methods**

### ***Participants***

Participants were contacted through the coaching/training staff of local hockey teams to gauge interest for participation in this study. Two female varsity hockey teams and two male Junior B hockey teams from Southwestern Ontario agreed to allow the study investigator to collect information from their athletes. In total, 80 athletes (N female=41, N male=39) were included in the study. The average age of the males was 18.23 (SE=.27) years old, and for the females was 19.89 years old (SE=.24). Participants, on average, had been involved in hockey for 13.14 years and began playing organized sport at the age of 5.26 years. There are no significant differences between genders for the age at which they began playing organized sport ( $F(1,78)=1.04, p>.05$ ) or the number of years participating in hockey ( $F(1,76)=.26, p>.05$ ). No participants were recovering from a concussion at the time of assessment.

### ***Materials***

Prior to beginning the assessments, voluntary informed consent was obtained (Appendix 1). The assessment began with two brief, self-report questionnaires: The Neck

Disability Index (NDI) (47) with a visual analogue neck pain scale (48) appended to the bottom of the tool (Appendix 2), and a Health History Questionnaire (Appendix 3). The NDI is one of the most widely utilized measures for neck disability and has been well-validated (49). Test-retest correlations have been reported between 0.90 and 0.93, and internal consistency has shown Cronbach  $\alpha$  values ranging between 0.74 and 0.93. The tool's developers consider a score of 5-14 points to be indicative of a mild level of disability, 15-24 points to be moderate disability, 25-34 points to be severe disability, and anything above 35 points as complete disability. The Health History Questionnaire was adapted using forms from the Thinkfirst Concussion Questionnaire (50) combined with portions of the SCAT2 (6) (Appendix 4). This questionnaire was employed to obtain a basic health history of the participant, information on any properly diagnosed and managed concussions and conversely, and any indication of a missed or unreported concussion (through assessment of the athlete's answer to question 7 and question 11).

### ***Procedures***

Following completion of the questionnaires, the investigator performed a confidential cervical spine examination, as well as cognitive and balance assessments as dictated by the SCAT2. Active cervical spine range of motion was measured by use of a Baseline® 12" 360° goniometer, assessing the cardinal ranges of motion to within 5 degrees. Cervical muscle testing involved a modified assessment of the endurance of the deep neck flexors (51) in which the athlete was placed supine and their neck positioned with the chin 'tucked' and instructed to hold the position against gravity when the investigator removes his hands. A statistically significant reduction in endurance has been shown within subjects suffering from neck pain and can be theorized to precede or coincide with a cervical injury (52-56).

Manually applied resistance to the cardinal ranges of motion was employed according to Kendall and McCreary (57) and was graded on a scale of 1-5. A score of 5 was given to full activation of the muscles against a resistance of 5-10 pounds, a score of 4 was given for activation against a slightly reduced resistance, a score of 3 was given for only slight resistance countered, a score of 2 was given for movement only against gravity, and a score of 1 was given if there was no ability to contract the muscle being tested. A cervical orthopaedic examination was performed to investigate any underlying conditions that may confound results using assessment methods including: Kemp's test, Neutral Foraminal Compression, Radiculopathy testing (58), Spurling's test, Jackson's test, and a Valsalva maneuver (Appendix 5 - first section).

A Standardized Assessment of Concussion (SAC) was employed as per the SCAT2 (6), followed by a balance examination using three twenty-second testing scenarios (double leg stance, single leg stance, and tandem stance, all on a stable surface). Finally, the Cognitive Assessment was followed-up by utilizing the delayed recall test as described in the SCAT2 (Appendix 5 – second section).

Statistical analysis was completed using SPSS 17.0.

## **Results**

### ***Concussion Descriptives***

Table 1 and Chart 1 summarize the percentage of athletes who reported symptoms following a hit in hockey:

**Table 1: Percent Athletes Reporting Symptoms**

<b>Symptom Experienced</b>	<b>Concussion (N=40)</b>	<b>No Concussion (N=26)</b>	<b>Unsure N=(14)</b>
Confusion	30% (N=12)	3.8% (N=1)	21.4% (N=3)
Getting “dinged”	10% (N=4)	7.7% (N=2)	21.4% (N=3)
Headaches	67.5% (N=27)	30.8% (N=8)	71.4% (N=10)
Dizziness	52.5% (N=21)	7.7% (N=2)	57.1% (N=8)
Getting “bell rung”	35% (N=14)	11.5% (N=3)	35.7% (N=5)
Balance problem	17.5% (N=7)	3.8% (N=1)	21.4% (N=3)
Poor memory	12.5% (N=5)	3.8% (N=1)	7.1% (N=1)
Blurry vision	30% (N=12)	3.8% (N=1)	35.7% (N=5)
Nausea	20% (N=8)	0	7.1% (N=1)
Tinnitus	12.5% (N=5)	34.6% (N=9)	28.6% (N=4)
“Seeing stars”	5% (N=2)	3.8% (N=1)	0

Generally, in those athletes who described having sustained a concussion (N=40), the three most commonly reported symptoms are headache (N=27), dizziness (N=21), and getting their “bell rung” (N=14). The most common number of symptoms reported following a hit are one symptom (N=8) and two or three symptoms (N=8). Interestingly, 10% of the athletes who apparently had sustained a concussion reported experiencing no symptoms. This may be explained by several factors, including the use of a non-exhaustive list of concussion symptoms, not understanding the question, or simply declining to answer the question.

Table 2 summarizes the number of symptoms reported by the participants according to indication of concussion. It is interesting to note that in participants who reported having

never sustained a concussion (N=26), 15 expressed having anywhere from 1-4 symptoms following a hit in hockey.

**Table 2: Quantity of Symptoms Experienced Following a Hit**

Number of Symptoms Reported	Concussion (N=40)	No Concussion (N=26)	Unsure (N=14)
0	10% (N=4)	42.3% (N=11)	0
1	20% (N=8)	26.9% (N=7)	21.4% (N=3)
2	20% (N=8)	15.4% (N=4)	42.9% (N=6)
3	20% (N=8)	7.7% (N=2)	7.1% (N=1)
4	7.5% (N=3)	7.7% (N=2)	0
5	5% (N=2)	0	14.3% (N=2)
6	12.5% (N=5)	0	7.1% (N=1)
7	0	0	0
8	2.5% (N=1)	0	0
9	2.5% (N=1)	0	7.1% (N=1)

Also interesting to note, all participants who were unsure reported one or more symptoms, which leads the investigator to assume that this group, for all intents and purposes, could be combined with the positive indication of concussion group. In combining these two groups into one single group, it is found that there is a significantly greater number of symptoms reported for this combined concussion group ( $\chi^2=9.37$ ,  $p=0.0022$ , Fisher's exact  $p=0.002631$ ) than those who stated they had not had a concussion. In general, those who indicated having suffered a concussion at some point in the past experienced an average of 2.9 symptoms ( $s=2.22$ ), those who indicated they had not suffered a concussion experienced 1.1 symptoms ( $s=1.3$ ), and those who were unsure experienced 3.1 symptoms ( $s=2.3$ ). Upon further analysis, it was discovered that there was a significant difference between those who answered 'yes' to the question of a past concussion and the 'no' group in

that the 'yes' group experienced more symptoms; also, the 'unsure' group indicated significantly more symptoms compared to the 'no' group ( $F(2,79)=7.61, p<.05$ ).

In combining the unsure group to the concussion group, there are a total of 31 of the 39 total males that had indeed suffered a concussion (79.49%) and a total of 23 of the 41 female athletes who had suffered a concussion (56.10%). The proportion of individuals suffering a concussion is significantly greater than the proportion of those who reported no concussion ( $\chi^2=4.98, p=0.026$ , Fisher's exact  $p=0.016175$ ) in both males and females. This total may again be an underestimation, as it does not take into account those athletes who indicated not having suffered a concussion, yet indicated concussive symptoms.

In total, 23 athletes reported sustaining one concussion in the past five years, 9 reported sustaining two concussions, and 1 athlete had reported experiencing six concussions in the past five years with a total of six different symptoms noted. This shows that 33 of the 40 athletes who had reported sustaining a concussion suffered it in the last five years, leaving 7 athletes who must have sustained the concussion prior to this time. Given the average age of the sample ( $M(\text{men})=18.23$  years,  $SE=.27$ ),  $M(\text{women})=19.89$  years,  $SE=.24$ ), this leads to the possibility of a number of athletes suffering concussive symptoms around the age of 13-14 years old.

In regards to the athletes who indicated suffering a concussion, 22.5% ( $N=9$ ) were self-diagnosed, 7.5% ( $N=3$ ) were told by their coach they had suffered a concussion, 32.5% ( $N=13$ ) were told by their team's athletic therapist, 45% ( $N=18$ ) were diagnosed by their medical doctor, and 7.5% ( $N=3$ ) were diagnosed by their chiropractor. In those subjects indicating having suffered a concussion in the past, the average time sat out of competition was 4-7 days ( $s=1.39$ ) and the average duration of symptoms was between 1 and 3 days



( $s=1.06$ ). Naturally, these scores were significantly greater than time out of competition ( $F(2,76)=50.32, p=.000$ ) and duration of symptoms ( $F(2,76)=50.78, p=.000$ ) for those athletes who did not experience a concussion.

Respondents who indicated having sustained a concussion in the past ( $N=40$ ) scored similarly on the SAC ( $M=55.13, SE=.37$ ) compared to those indicating having never suffered a concussion ( $N=26, M=55.54, SE=.39$ ). This difference is not significant ( $t(64)=-.74, p>.05$ ). In looking at the individual sections of the SAC, there are no significant differences between the concussion group and no concussion group (Orientation:  $t(39)=-1.43, p>.05$ ; Immediate Memory:  $t(64)=-1.35, p<.05$ ; Concentration:  $t(64)=-0.03, p>.05$ ; Balance:  $t(64)=-0.64, p>.05$ ; and Delayed Recall:  $t(64)=-.43, p>.05$ ). If one takes into consideration the “unsure” group, no significant differences remain between the groups on their SAC scores ( $F(2,77)=.34, p>.05$ ). The mean SAC scores were calculated according to team as well, and are reported in Table 3.

**Table 3: Mean Standardized Assessment of Concussion Scores According to Team**

	<b>Team A (male)</b>	<b>Team B (male)</b>	<b>Team C (female)</b>	<b>Team D (female)</b>
<b>Orientation (5)</b>	4.95	5	5	4.95
<b>Immediate Memory (15)</b>	14.14	14.44	14.86	14.75
<b>Concentration (5)</b>	2.38	2.28	3.05	3.20
<b>Balance (30)</b>	28.05	27.89	28.10	28.05
<b>Coordination (1)</b>	1	1	1	1
<b>Delayed Recall (5)</b>	3.81	4.06	4.10	3.90
<b>SAC Total (61)</b>	54.33	54.66	56.10	55.85

A t-test was performed for gender and SAC scores indicating that the females (M=55.98, SE=.28) scored significantly higher than males (M=54.49, SE=.37) overall on the SAC ( $t(78)=-3.27, p<.05$ ). In the subsections of the SAC, the females (M=14.8, SE=.08) scored significantly higher than their counterparts (M=14.28, SE=.16) on the Immediate Memory section ( $t(55.98)=-2.93, p<.01$ ). Additionally, a similar finding appeared with the scores for Concentration between men (M=2.33, SE=.17) and women (M=3.12, SE=.13) ( $t(78)-3.64, p<.01$ ). It must be noted, however, that these scores will be inherently confounded by higher educational level and significantly higher age in the female participants (M(men)=18.23 years, SE=.27), M(women)=19.89 years, SE=.24;  $t(66)=-4.69, p<.01$ ).

### ***Cervical Spine Descriptives***

For the purposes of this study, *cervical functioning* refers to the range of motion of the cervical spine, cervical musculature activation levels, neck pain, and their effect on activities of daily living. Table 4 reveals the mean degrees of range of motion assessed for males with a past concussion:

**Table 4: Cervical Range of Motion in Males**

<b>Range of Motion</b>	<b>Concussion</b>	<b>N</b>	<b>Mean (degrees)</b>	<b>Normal ROM</b>	<b>Std. Dev.</b>	<b>Std. Err.</b>
<b>Flexion</b>	Yes	21	54.76	40-60 degrees	12.99	2.83
	No	8	53.75		14.33	5.07
	Unsure	10	54.00		15.95	5.04
<b>Extension</b>	Yes	21	35.71	40-75 degrees	8.56	1.87
	No	8	35.63		9.04	3.20
	Unsure	10	36.00		9.94	3.15
<b>Left Lateral Flexion</b>	Yes	21	47.14	40-45 degrees	9.69	2.12
	No	8	46.25		11.88	4.20
	Unsure	10	45.50		5.50	1.74
<b>Right Lateral Flexion</b>	Yes	21	47.14	40-45 degrees	9.69	2.12
	No	8	45.00		10.00	3.54
	Unsure	10	43.50		8.52	2.69
<b>Left Rotation</b>	Yes	21	83.57	50-80 degrees	11.95	2.60
	No	8	80.63		17.00	6.01
	Unsure	10	81.00		7.38	2.33
<b>Right Rotation</b>	Yes	21	79.52	50-80 degrees	11.28	2.46
	No	8	76.88		15.10	5.34
	Unsure	10	76.00		10.49	3.32

Table 5 reveals the mean degrees of range of motion assessed for females with the indication of a past concussion factored in:

**Table 5: Cervical Range of Motion in Females**

<b>Range of Motion</b>	<b>Concussion</b>	<b>N</b>	<b>Mean (degrees)</b>	<b>Normal ROM</b>	<b>Std. Dev.</b>	<b>Std. Err.</b>
<b>Flexion</b>	Yes	19	51.58	40-60 degrees	10.81	2.48
	No	18	55.00		18.94	4.47
	Unsure	4	66.25		17.97	8.99
<b>Extension</b>	Yes	19	38.95	40-75 degrees	14.68	3.37
	No	18	45.56		14.64	3.45
	Unsure	4	35.00		14.14	7.07
<b>Left Lateral Flexion</b>	Yes	19	45.53	40-45 degrees	6.43	1.48
	No	18	47.22		10.17	2.40
	Unsure	4	48.75		11.09	5.54
<b>Right Lateral Flexion</b>	Yes	19	45.79	40-45 degrees	7.12	1.63
	No	18	46.39		10.26	2.42
	Unsure	4	43.75		6.29	3.15
<b>Left Rotation</b>	Yes	19	73.42	50-80 degrees	12.92	2.96
	No	18	70.28		11.57	2.73
	Unsure	4	73.75		6.29	3.15
<b>Right Rotation</b>	Yes	19	76.58	50-80 degrees	9.87	2.26
	No	18	78.06		12.96	3.06
	Unsure	4	75.00		4.08	2.04

One-way ANOVAs were performed and no significant differences were found in range of motion scores and concussion reporting for males or females ( $p > .05$ ). Similar non-significant results are found when ignoring the gender factor ( $p > .05$ ).

Deep neck flexor endurance was measured in seconds, held to a maximum of one minute, and analyzed for a difference between genders. It was discovered that the males ( $M=52.85$  sec.,  $SE=2.00$ ) held the position significantly longer than the females ( $M=43.95$  sec.,  $SE=2.92$ ) ( $t(70.13)=2.51$ ,  $p < .05$ ). According to whether or not the individual had experienced neck pain in the past, deep neck flexor endurance was analyzed for any significant differences. There were no significant differences between individuals who had experienced neck pain in the past ( $M=47.08$  sec.,  $SE=2.78$ ) and individuals who had not experienced neck pain ( $M=49.07$  sec.,  $SE=2.53$ ), ( $t(77)=-.531$ ,  $p > .05$ ). For individuals

currently experiencing neck pain ( $M=36.83$  sec.,  $SE=9.18$ ), there is a small, but non-significant decrease in deep neck flexor endurance compared to individuals with no neck pain ( $M=49.22$  sec.,  $SE=1.83$ ), ( $t(78)=-1.79$ ,  $p=.08$ ). Finally, there were no significant differences found in any of the concussion groups for duration held ( $F(2,77)=.92$ ,  $p>.05$ ). Those who indicated having suffered a concussion held the position for an average of 47.83 seconds, no indication of concussion held the position for 46.19 seconds, and the unsure group held for 53.50 seconds.

As expected, those subjects currently experiencing neck pain ( $M=8.67$ ,  $SE=1.17$ ) scored significantly higher on the neck disability index compared to those who did not have neck pain ( $M=2.00$ ,  $SE=.27$ ) ( $t(77)=6.65$ ,  $p=0.000$ ). Subjects who indicated that they had suffered a concussion at some point in the past ( $M=2.90$ ,  $SE=.49$ ) scored slightly higher on the neck disability index than the subjects who indicated they did not suffer a concussion ( $M=1.96$ ,  $SE=.48$ ). This difference was not significant ( $t(64)=1.30$ ,  $p>.05$ ).

Tables 6 to 8 provide an overall summary of all pertinent descriptive statistics according to whether or not a concussion was suffered. For these tables, the unsure group was combined with the group who indicated positively suffering a concussion.

**Table 6: Summary of Symptoms Experienced**

MALES	Concussion	Confusion	Dizziness	Poor Memory	Tinnitus	Dinged	Bell Rung	Blurry Vision	Headache	Balance	Nausea
	Yes (N=31)	22.58%	51.61%	9.67%	16.13%	19.35%	41.94%	35.48%	70.97%	19.35%	16.13%
	No (N=8)	77.42%	48.39%	90.33%	83.87%	80.65%	58.06%	65.42%	29.03%	80.65%	83.87%

  

FEMALES	Concussion	Confusion	Dizziness	Poor Memory	Tinnitus	Dinged	Bell Rung	Blurry Vision	Headache	Balance	Nausea
	Yes (N=23)	34.78%	56.52%	13.04%	17.39%	4.35%	26.09%	26.09%	65.22%	13.04%	17.39%
	No (N=18)	65.22%	43.48%	86.96%	82.61%	95.65%	73.91%	73.91%	34.78%	86.96%	82.61%

**Table 8: Summary of SCAT2 Scoring**

MALES	Concussion	SAC Total	Orientation	Immediate Memory	Concentration	Balance	Coordination	Delayed Recall
	Yes (N=31)	54.48	4.97	14.23	2.39	28	1	3.9
	No (N=8)	54.5	5	14.5	2.13	27.88	1	4

  

FEMALES	Concussion	SAC Total	Orientation	Immediate Memory	Concentration	Balance	Coordination	Delayed Recall
	Yes (N=23)	55.96	4.95	14.78	3.13	27.91	1	4.17
	No (N=18)	56	5	14.93	3.11	28.28	1	3.78

**Table 9: Summary of Cervical Functioning**

MALES	Concussion	Flexion	Extension	Left Lateral	Right Lateral	Left Rotation	Right Rotation	Neck Pain Yes	Deep Neck Flexor Endurance	NDI Score
	Yes (N=31)	54.76	35.71	47.14	47.14	83.57	79.52	3.23%	52.90 sec	1.93
	No (N=8)	53.75	35.63	46.25	45	80.63	76.88	96.77%	52.63 sec	1.25

  

FEMALES	Concussion	Flexion	Extension	Left Lateral	Right Lateral	Left Rotation	Right Rotation	Neck Pain Yes	Deep Neck Flexor Endurance	NDI Score
	Yes (N=23)	51.58	38.95	45.53	45.79	73.42	76.58	17.39%	44.43 sec	3.87
	No (N=18)	55	45.56	47.22	46.39	70.28	78.06	82.61%	43.33 sec	2.28

## Discussion

### *Concussion Reporting*

The results of this study show an astounding number of young athletes who have suffered a concussive-type injury within hockey, yet have failed to report it or have not been acknowledged. The data indicates that 50% of participants indicated having suffered a concussion. Yet if one combines the unsure group to the concussion group due to the indication of positive signs/symptoms, there were 54 athletes who appear to have suffered concussions. Additionally, taking into consideration the 15 athletes who unknowingly expressed experiencing concussive symptoms following a hit in hockey, there were a total of 69 athletes who had experienced a concussion in their playing careers to date (86.25%). The author notes that this number may in fact be an underestimation, as the list of commonly experienced symptoms following a hit was not exhaustive.

Upon comparing SAC scores between non-concussed and previously concussed athletes, there were no significant findings. This should be viewed cautiously. Research has been continually evolving and an astute clinician does not rely on one single measure in assessing concussions. Furthermore, these data did not indicate the length of time since the last concussion was suffered. As outlined previously, the athlete may present as asymptomatic following the incident and basic neurological testing may yield negative results. Yet when advanced neuropsychological testing is applied, subtle abnormalities may appear. This will be an individualistic response to the injury, making the formation of steadfast rules for post-concussion management difficult. Regardless of positive or negative cognitive test results, one should be cognizant of the neurometabolic events that are occurring immediately following a disturbance to the brain. Those involved in management

must be aware that the athlete could develop functional abnormalities at any time, and for hours to days following the injury the brain will be more susceptible to further damage (8, 38, 59-66).

The majority of athletes in this study sustained their concussions, on average, less than five years previous. This would make most clinicians assume that the concussion, if symptom free at that point, is no longer of concern. Yet given the growing body of evidence showing long-term sequelae decades following a concussive injury (31, 37, 38, 67), the results of this study cannot concretely show a lack of correlation between previously concussed athletes and long term decrements on basic cognitive testing. Numerous studies (31, 38-40, 67) have illustrated frightening long-term consequences of concussions, which lend support to the recommendation to perform serial monitoring, at a minimum, for hours following the incident (6).

It becomes essential in educating both the athletes and the coaching staff/parents of athletes regarding the true nature of the injury given the plethora of information that has surfaced over the last several years. There may be cases of concussion where the athlete is symptom-free, yet continually shows neurological decrements on advanced neuropsychological testing, or conversely tests may be normal yet the athlete experiences continued symptomatology. Caution must be used in assuming the player is ready to return to play if experienced health professionals have not been consulted, especially in the case of multiple concussions. A player may appear to be functioning normal on everyday tasks, but novel learning and new memory tasks may reveal cognitive abnormalities.



### *Cervical Spine Functioning*

Due to the inherent concomitance between concussion and neck pain (42), several cervical spine measures were assessed. Tables 4 and 5 present the passive ranges of cervical spine motion found in the participants and compares this to any indication of concussion. In this particular data set, there appears to be no significant differences in motion of the cervical spine between genders or indication of past concussion ( $p>.05$ ). Despite this finding, it would be prudent to note that given a population of recently concussed athletes, one is likely to find a decreased cervical range of motion in the acute stage. Traumatic forces applied to the neck may create damage to the cervical spine musculature and joint capsule of the facets (41). These factors would create a decreased range of motion, as well as positive orthopaedic tests. The findings of this study should not be used to rule out correlation between cervical dysfunction and acute concussion occurrence.

Two of the most commonly reported symptoms in this study are headache ( $N=27$ ) and dizziness ( $N=21$ ). One may theorize that the headaches suffered by many athletes following a concussion may not only be neurologically linked, but physically linked as well. Cervicogenic headaches are common afflictions in the general population, and by definition are associated with injury or lesion to the neck and/or head and refer pain to the head and/or face (68). This poses the question, “is the headache/dizziness caused by the concussion, or is the headache/dizziness caused by the neck injury sustained concurrently with the concussion?” Contemplation of these questions becomes very important when looking at therapeutic interventions during the return to play process. Although supporting literature is sparse, one may theorize that direct treatment of associated cervical pain may help to alleviate some of the correlated sequelae of the concussion; although if not undertaken

cautiously, it could also potentially prolong recovery. Further research is warranted in assessing this relationship.

As previously stated, a statistically significant reduction in endurance has been shown within participants suffering from neck pain and can be theorized to precede or coincide with a cervical injury (52-56). This study supported these findings by showing athletes currently experiencing neck pain showed a reduction in deep neck flexor endurance, although significance was not quite obtained possibly due to a small sample size.

Regardless, it lends support to the inclusion of tests of cervical functioning to the normal preseason baseline testing protocols for concussions. Interesting results might be obtained by way of a large sample of preseason-tested athletes and their risk for sustaining a concussion as related to the level of stability/support offered by the cervical musculature.

### ***Summary***

It is well established that concussions continue to be underreported, despite a continuing increase in the dissemination of information (1-3). This study was able to show a shocking level of underreporting of concussions – over 85% of subjects reported concussive symptoms following a hit, while only 50% knowingly reported having been diagnosed. With the wealth of information that is surfacing regarding long-term ill effects of concussions, it is worrisome that many athletes may have numerous concussions throughout their careers and receive no formal treatment or acknowledgment of the injury. As concussion is not a visible injury, many athletes are likely to avoid reporting their symptoms out of fear of chastisement and the bravado of participating in contact sport.

This study was unable to find significant differences in SAC scores using the SCAT2, but it should be noted that there are limitations to the study that may have prevented this.

There was no indication as to the date of the last concussion, aside from within 5 years. It may be ascertained that if a concussion was experienced only weeks prior, a large sample of this timeframe may yield subtle differences despite having recovered and returned to competition. Also, the use of the SCAT2 will not be as sensitive in assessing the attenuated cognitive decrements, as compared to advanced neuropsychological workups. Despite this, the SCAT2 should remain as an essential tool for all age levels and sports. The SCAT2 is cost-effective and simple to use and takes little training to administer. Cognitive inconsistency can easily be identified using this tool, which can then be used as a springboard for referral to health care professionals for the administration of advanced testing. As a baseline measure, the SCAT2 takes little time to administer to a team, and is widely available for use at no cost. For the majority of minor league teams with a limited budget, this offers a great alternative to the more expensive and less convenient computer-based testing.

The final goal of this study was to show a link of cervical disorders to concussion. This proved to be elusive, largely due to the limited follow-up available with the participants. Nonetheless, support is given to the suggestion to include cervical testing as part of a complete preseason baseline testing protocol. Differences were found between males and females, especially in regards to deep neck flexor endurance. This could show potential for the need to train the neck strength and endurance of athletes in contact sport, especially females. Theoretically speaking, possessing a more stable link between the body and the head may limit the level of force transmitted to the head following a hit in contact sport. Although this would by no means dramatically reduce the incidence of concussion, it may limit the associated cervical pain syndromes that often develop concomitantly.

This study has shown some important implications in concussion management. Namely there is a need for further dissemination of the long-term effects associated with concussions. Through educating those parties involved, including the players, the reporting of concussion may improve. Once players realize the true complexity and severity of a concussion, they may be less likely to avoid reporting the concussion by just “shaking it off”. This education needs to start well before athletes enter body contact leagues, as the age at which athletes are experiencing their first concussion can be quite young. With a rudimentary understanding of the neurological changes that occur following a hit to the head, there may be less player frustration when they are not allowed to return to the game. Steps are being taken by leagues, officials, and coaches/parents to attempt to protect our athletes, but ultimately it will come down to the players themselves – their understanding and respect of the severity of a concussive injury and its potential long-term effects.

### **Limitations**

The main limitation within this study was the lack of follow-up available with any concussed players. This may have allowed for a more clear description of the relationship between neck dysfunction and concussive injury. With the lack of participating teams available, and the busy schedules of all involved, original protocols could not be followed, thus sacrificing some important potential data.

Furthermore, the use of the SCAT2, although an easily-administered and cost-effective tool, will not be as sensitive to minor cognitive discrepancies that may be uncovered through the use of more advanced computer-based neuropsychological tests.

Some minute changes may have been present in participants who were previously concussed that the SCAT2 was unable to tease out.

The questionnaires used were abbreviated to reduce the time commitment by the participating teams. Specifically, a non-exhaustive list of commonly experienced concussive symptoms was used in place of the symptom checklist found on many concussion assessment tools. Although the more commonly reported symptoms were utilized, this may have lead to an overestimation of their occurrence due to lack of choice for the participants. Conversely, it also may have lead to an underestimation of the true number of unacknowledged or unreported concussions. There may be instances where an athlete may have experienced symptoms such as anxiety or photophobia following a hit in hockey, but because the options were not given, could not report it.

There was no indication of the date of the participant's last concussion, aside from noting that it occurred within the last 5 years. This could confound a temporal relationship between a concussion and cognitive dysfunction. A more accurate description of the last concussion would have aided the data, as there may have been participants who suffered a concussion only days/weeks prior to testing and thus would skew the results to stronger correlations.

There is the possibility of false positives in regards to concussion recognition. Many of the symptoms presented could be associated with an unrelated issue. For example, an athlete may suffer from a headache during play from dehydration, fatigue, or lack of food intake and may mistakenly associate this symptom with a body check. To decrease the false positives associated with symptom recognition, it may be useful to use additional objective measures, such as the Headache Disability Inventory (69). Also there could be an issue with

somatization, where an athlete who is under stress may express certain symptoms. A measure of personality traits may also prove useful in future studies to assess the number of participants who may exaggerate symptomatology.

A larger sample size would have increased the likelihood of uncovering subtle relationships in the data. For example, with a higher number of participants suffering from neck pain associated with a hit in hockey, a significant correlation with decreased deep neck flexor endurance may have been obtained. Similarly, if a greater number of recently concussed athletes were assessed, range of motion differences would have been more likely to be noted.

There was a significant effect of age, and inherent education, within the females. This made comparing test scores between the genders biased. If there was an opportunity for choice of participants within a larger sample, it may have been simpler to match for age and education level, thus making it more appropriate to comment on differences in cognitive functioning scores.

### **Future Directions**

In one of the few studies looking at concurrent head and neck injury in hockey, Hynes et al. (70), sought to determine if there was overlap between concussion and whiplash-associated disorders (WAD) in hockey, and to determine if complete resolution of both disorders could occur in 7-10 days. Regardless of WAD classification, all subjects reported concussive symptoms. No clear relationship was found between severity of WAD and number of concussive symptoms. Five subjects reported resolution of their concussive symptoms at 7-10 days, and two of these five were still reporting WAD symptoms.

Complete resolution of WAD symptoms was noted by six subjects at the follow up, and of these six, three were still experiencing concussive symptoms.

Despite a small sample size, the study was able to indicate that there was a relationship between concussion and WAD in hockey. Similar to the Johnston et al. study (42), the researchers noted a strong overlap in the symptomatology of the two conditions, making separate definitive diagnoses difficult. Statistical analysis of these findings was not done due to low sample size and subsequently low power.

It may be prudent to note that current research is indicating the obscurity of WAD as a diagnosis, mostly due to the subjective symptoms and limited objective findings used in its diagnosis (71). Recently the NPTF published several studies on the diagnosis and management of neck pain (43). In these publications, the authors have offered a new grading system for neck pain to aid researchers and clinicians alike in their respective frameworks (72). Thus, adoption of the recent NPTF guidelines may prove more useful in a research setting (Appendix 6) as the guidelines are simple and clear, and provide helpful interventions for each grade of neck pain.

Originally in this study, it was hoped to have a more complete approach to the assessment of cervical dysfunction, including follow-up assessments in the event of a concussive injury in one of the participants. Although initial cooperation from team management was exceptional, follow-up protocols could not be undertaken. Subsequently, no data was able to be collected immediately following a concussion.

Given the propensity of data available on cervical pain syndromes, headaches, and other head/neck dysfunctions, the research potential this information could offer to the field of concussions is endless. Anecdotally, health care professionals have expressed the

difficulty in managing the cervical symptoms associated with concussions, and little to no research has been completed assessing the relationship. For example, headaches consistently appear as one of the most common symptoms aggravated during the return to play process. Certain classifications of headache are aggravated by physical activity (68), and during an increase in activity level is a common point during the return to play process in which concussive symptoms are aggravated.

With further research assessing the link to cervical injury and the treatment to alleviate this, there is great potential to limit the frustrations experienced by players and coaching staff alike caused by setbacks that may be more related to cervical pain than concussive injury.

### **Recommendations**

In working with sports teams, health care professionals and the like need to continue to update themselves with the most current and relevant research advancements in regards to concussions. If one is in a position to be sought after for management and diagnostic advice in regards to concussion, it stands to be of the utmost importance to educate not only oneself, but also all the individuals on the team, including the coach, training staff, and players. It does not take a great deal of time out of a preseason practice to meet as a group, with the parents (if applicable), coaches, equipment and training staff, and other personnel, to discuss the signs and symptoms of a concussion and the importance of bringing these to the attention of a team member. A single staff member may not be able to monitor the post-hit symptoms of every player on the team, but if a teammate or other individual is aware of the signs and symptoms of a concussion and notes one of these in a player, it can be more efficiently brought to the attention of the appropriate individual.



The majority of signs and symptoms of a concussion are recognized, notably by parents of hockey players (73), yet little is known by those involved in regards to management from the point of recognition. Anecdotally, many primary questions are still being posed by training staff, such as “When will the player be able to return?” and “He has been feeling fine for a day or two now. Can he play in the game tonight?”. If educated more thoroughly in regards to concussion pathophysiology and management, the risks associated with returning and athlete to play too soon may be minimized.

In some cases it may be prudent to employ gentle fear tactics to arouse attention, particularly in the players themselves. If players are shown the seriousness of the consequences of multiple concussions by using examples of players whose careers have been ended, more players may come forward when they are concussed. Many athletes have been taught to ‘shake it off’ following a vicious hit, and reports of getting a ‘bell-ringer’ two or three times per game are not uncommon. By simplifying the research in layman’s terms to explain the neurometabolic processes involved in concussion, players will realize that although a concussion may not be a visible injury, its pathophysiology can be immediately serious and long lasting.

Those involved in the education of team members will undoubtedly encounter resistance, especially when discussing return to play protocols. The best one can do is simply present the current state of knowledge in an unbiased manner, and hope that the information will not fall on deaf ears. It is unfortunate that, in all likelihood, the true acknowledgment of the potential seriousness of repeatedly ‘getting dinged’ will not be recognized until there is continued emergence of retired athletes suffering from long-term, and avoidable, consequences to concussion.

**Appendix One**  
**Informed Consent**

### WILFRID LAURIER UNIVERSITY INFORMED CONSENT STATEMENT

Co-Management of Concussion and Neck Pain and its Effect on Return to Play

Dr. Craig Coghlin, Investigator

Dr. Pamela Bryden, Advisor

You are invited to participate in a research study. The purpose of this study is to assess the correlation between neck pain and concussion in ice hockey and to observe the effectiveness of management protocols on return to play.

The primary investigator, Dr. Craig Coghlin, is a Masters student at Wilfrid Laurier University. Dr. Coghlin is a licensed Doctor of Chiropractic in the province of Ontario, but will be in no way involved in the team's customary injury management protocols, nor will be providing advice on treatment referrals or return to play. Dr. Coghlin has passed all licensing board exams and ethical examinations, is in good standing with all governing colleges, and has three years of clinical experience. It is these credentials that permit Dr. Coghlin to perform a physical examination and offer a diagnosis.

#### **INFORMATION**

Participation in this study involves a pre-season baseline testing procedure in which the athlete will answer a variety of questions pertaining to past and/or present neck pain and/or concussive symptoms. Baseline cognitive and physical measures will be attained through simple questionnaires, short verbal questions, and brief physical examinations.

In the event of a concussion, your team therapist will manage your injury as per the team's normal protocols. The study investigator will then return and attain further information on your concussive state and examine any physical injury to the cervical spine. You will be asked to briefly check off your daily symptoms on a form and describe what management you are receiving and its effectiveness. Once returned to play by your team therapist, the study investigator will once again perform a brief cognitive and physical examination.

You will only become a full participant in the study in the event of a traumatic concussive injury. Baseline testing will last approximately 20 minutes per player, and subsequent testing sessions will last 10-15 minutes per subject. Daily progress forms will take subjects approximately 1 minute to complete. Amount of time as a subject in the study will vary according to your physical and cognitive recovery from injury.

During the physical examination, rest breaks will be offered and you have the option of stopping the procedures at any time you wish. As a participant you have the right to withdraw at any point and your data will be removed from the study.

There is expected to be a total of approximately 100 athletes taking part in the study, with only 10-20 of these athletes expected to incur a concussion.

#### **RISKS**

As with any medical examination, some discomfort may arise during physical examination of the cervical spine following injury. The purpose of such orthopaedic examinations is to stress individual tissues or structures to evaluate their integrity. If a tissue's integrity is compromised, pain will indicate the level of injury. Although rare, a tissue that has been compromised may be further aggravated through range of motion testing. In the case of further injury, palliative care will be offered by the attendant healthcare provider. Concussive symptoms may be aggravated during some testing protocols. A concussion is a form of traumatic brain injury, and is susceptible to aggravation through any physical or mental exertion. Such symptoms as dizziness or headache may be aggravated temporarily during testing procedures. Again, in the case of aggravation of symptoms, testing will be halted and palliative care will be offered by the attending healthcare provider. All procedures will be performed by a trained and licensed healthcare provider and all attempts to limit this discomfort will be

made. Verbal indication of pain levels and/or subjective symptoms by the participant will be essential information to the examiner, and the participant may request to stop the assessment at any time.

**BENEFITS**

This research will assist the scientific community in assessing the correlation between neck pain and concussion in contact sport. Results from the varied management of symptoms will give insight into what protocols are successful in the treatment of each condition and will indicate whether or not current scientific advances have been well distributed to teams for employment into their normal protocols.

**CONFIDENTIALITY**

All information collected by the investigator during the baseline and testing procedures will be held in strict confidence. Any testing results and/or informal clinical information divulged will not be released to team coaches, therapists, or training staff without permission from the athlete. No identifiable factors of the team or individual player will be published in any manner. All participants will receive a code that will accompany their file to maintain complete anonymity in the data. Only the primary investigator and the project's advisor will have access to the data collected, and when not in transit will be kept secure in a locking file cabinet on campus at Wilfrid Laurier University (SR216). Data will be kept for a period of 5 years in this state by the primary investigator, after which it will be shredded and disposed of.

**CONTACT**

If you have questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study) you may contact the researcher, Dr. Craig Coghlin, at 519-884-0710 ext. 3316. This project has been reviewed and approved by the University Research Ethics Board. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Robert Basso, Chair, University Research Ethics Board, Wilfrid Laurier University, (519) 884-1970, extension 5225 or rbasso@wlu.ca

**PARTICIPATION**

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed. You have the right to omit any question(s)/procedure(s) you choose.

**FEEDBACK AND PUBLICATION**

Research results will be distributed to teams and players following completion of the study in the form of an informational pamphlet. Results will be published in a scientific journal and may be presented in academic conferences or seminars. Date of completion of this research is estimated to be June 2010.

**CONSENT**

I have read and understand the above information. I have received a copy of this form. I agree to participate in this study.

Participant's signature \_\_\_\_\_

Date \_\_\_\_\_

Investigator's signature \_\_\_\_\_

Date \_\_\_\_\_

**Appendix Two**

**Neck Disability Index with Visual Analogue Scale**

The Neck Disability Index

Patient name: \_\_\_\_\_ File# \_\_\_\_\_ Date: \_\_\_\_\_

Please read instructions:

This questionnaire has been designed to give the doctor information as to how your neck pain has affected your ability to manage everyday life. Please answer every section and mark in each section only the ONE box that applies to you. We realize that you may consider that two of the statements in any one section relate to you, but please just mark the box that most closely describes your problem.

SECTION 1-PAIN INTENSITY

- I have no pain at the moment.
The pain is very mild at the moment.
The pain is moderate at the moment.
The pain is fairly severe at the moment.
The pain is very severe at the moment.
The pain is the worst imaginable at the moment.

SECTION 6-CONCENTRATION

- I can concentrate fully when I want to, with no difficulty.
I can concentrate fully when I want to, with slight difficulty.
I have a fair degree of difficulty in concentrating when I want to.
I have a lot of difficulty in concentrating when I want to.
I have a great deal of difficulty in concentrating when I want to.
I cannot concentrate at all.

SECTION 2-PERSONAL CARE (Washing, Dressing, etc.)

- I can look after myself normally, without causing extra pain.
I can look after myself normally, but it causes extra pain.
It is painful to look after myself and I am slow and careful.
I need some help, but manage most of my personal care.
I need help every day in most aspects of self care.
I do not get dressed; I wash with difficulty and stay in bed.

SECTION 7-WORK

- I can do as much work as I want to.
I can do my usual work, but no more.
I can do most of my usual work, but no more.
I cannot do my usual work.
I can hardly do any work at all.
I can't do any work at all.

SECTION 3-LIFTING

- I can lift heavy weights without extra pain.
I can lift heavy weights, but it gives extra pain.
Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, for example, on a table.
Pain prevents me from lifting heavy weights off the floor, but I can manage light to medium weights if they are conveniently positioned.
I can lift very light weights.
I cannot lift or carry anything at all.

SECTION 8-DRIVING

- I can drive my car without any neck pain.
I can drive my car as long as I want, with slight pain in my neck.
I can drive my car as long as I want, with moderate pain in my neck.
I can't drive my car as long as I want, because of moderate pain in my neck.
I can hardly drive at all, because of severe pain in my neck.
I can't drive my car at all.

SECTION 4-READING

- I can read as much as I want to, with no pain in my neck.
I can read as much as I want to, with slight pain in my neck.
I can read as much as I want to, with moderate pain in my neck.
I can't read as much as I want, because of moderate pain in my neck.
I can hardly read at all, because of severe pain in my neck.
I cannot read at all.

SECTION 9-SLEEPING

- I have no trouble sleeping.
My sleep is slightly disturbed (less than 1 hr sleepless).
My sleep is mildly disturbed (1-2 hrs sleepless).
My sleep is moderately disturbed (2-3 hrs sleepless).
My sleep is greatly disturbed (3-5 hrs sleepless).
My sleep is completely disturbed (5-7 hrs sleepless).

SECTION 5-HEADACHES

- I have no headaches at all.
I have slight headaches that come infrequently.
I have moderate headaches that come infrequently.
I have moderate headaches that come frequently.
I have severe headaches that come frequently.
I have headaches almost all the time.

SECTION 10-RECREATION

- I am able to engage in all my recreation activities, with no neck pain at all.
I am able to engage in all my recreation activities, with some neck pain at all.
I am able to engage in most, but not all, of my usual recreation activities, because of pain in my neck.
I am able to engage in few of my recreation activities, because of pain in my neck.
I can hardly do any recreation activities, because of pain in my neck.
I can't do any recreation activities at all.

Please indicate your current neck pain level by placing a "dash" along the line below:
No Pain ----- Agonizing Pain

**Appendix 3**

**Health History Questionnaire**

Participant: \_\_\_\_\_ M / F  
D.O.B.: \_\_\_\_\_

Date: \_\_\_\_\_  
Team / Position: \_\_\_\_\_

Health History Questionnaire

- 1. At what age did you begin playing organized sport? \_\_\_\_\_
- 2. How many years have you played hockey? \_\_\_\_\_
- 3. How would you describe your style of play? -- Check one:  
 aggressive    offensive    defensive  
 finesse    checker    \_\_\_\_\_
- 4. Do you wear a mouth guard while playing?  YES /  NO  
-if YES, what kind?  
 stock                                 boil and bite  
 custom front teeth                 custom all teeth
- 5. Have you ever suffered from neck pain in the past?  
 YES                 NO
- 6. Are you currently experiencing neck pain?  
 YES                 NO
- 7. Have you ever suffered a concussion?  
 YES                 NO                 Not Sure
- 8. If yes to #7.  
a) how many times while playing sport in the last 5 years? \_\_\_\_\_  
b) how long did the symptoms last?  
 1-3 days     4-7 days     8-10 days  
 11-14 days     more than two weeks
- c) what is the longest you've had to sit out because of a concussion?  
 1-3 days     4-7 days     8-10 days  
 11-14 days     more than two weeks
- d) who told you that you could not play because of the concussion?  
 myself     coach     team therapist  
 family doctor    chiropractor    \_\_\_\_\_
- 9. Have you ever been knocked unconscious?  
 YES                 NO
- 10. If yes to #9.  
a) how many times? \_\_\_\_\_  
b) what is the longest duration you've been knocked unconscious? \_\_\_\_\_

- 11. After being hit in the head in sports, have you ever experienced any of the following symptoms:  
 confusion     getting 'dinged'     headaches  
 dizziness     getting 'bell rung'     balance problem  
 poor memory    blurry vision     nausea  
 ringing in the ears     \_\_\_\_\_

12. In regards to how you feel NOW, please rate the following:

	none	mild	moderate	severe			
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

- 13. Do the above symptoms get worse with physical activity?  
 YES                 NO
- 14. Do the above symptoms get worse with mental activity?  
 YES                 NO



**Appendix Four**

**SCAT2**

# SCAT2



FIFA®



## Sport Concussion Assessment Tool 2

Name

Sport/team

Date/time of injury

Date/time of assessment

Age Gender M F

Years of education completed

Examiner

### What is the SCAT2?

This tool represents a standardized method of evaluating injured athletes for concussion and can be used in athletes aged from 10 years and older. It supersedes the original SCAT published in 2005<sup>2</sup>. This tool also enables the calculation of the Standardized Assessment of Concussion (SAC)<sup>3,4</sup> score and the Maddocks questions<sup>5</sup> for sideline concussion assessment.

### Instructions for using the SCAT2

The SCAT2 is designed for the use of medical and health professionals. Preseason baseline testing with the SCAT2 can be helpful for interpreting post-injury test scores. Words in *italics* throughout the SCAT2 are the instructions given to the athlete by the tester.

This tool may be freely copied for distribution to individuals, teams, groups and organizations.

### What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms (like those listed below) and often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (such as headache), or
- Physical signs (such as unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour

**Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.**

## Symptom Evaluation

### How do you feel?

You should score yourself on the following symptoms, based on how you feel now:

	none	mid	moderate	severe			
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

**Total number of symptoms** (Maximum possible: 22)

### Symptom severity score

(Add all scores in table, maximum possible: 22 x 6 = 132)

Do the symptoms get worse with physical activity?	Y	N
Do the symptoms get worse with mental activity?	Y	N

### Overall rating

If you know the athlete well prior to the injury, how different is the athlete acting compared to his / her usual self? Please circle one response:

no different                      very different                      unsure

## Cognitive & Physical Evaluation

**1 Symptom score** (from page 1)  
22 minus number of symptoms \_\_\_\_\_ of 22

**2 Physical signs score**  
Was there loss of consciousness or unresponsiveness?  Y  N  
If yes, how long? \_\_\_\_\_ minutes  
Was there a balance problem/unsteadiness?  Y  N  
**Physical signs score** (1 point for each negative response) \_\_\_\_\_ of 2

**3 Glasgow coma scale (GCS)**  
**Best eye response (E)**  
No eye opening 1  
Eye opening in response to pain 2  
Eye opening to speech 3  
Eyes opening spontaneously 4  
**Best verbal response (V)**  
No verbal response 1  
Incomprehensible sounds 2  
Inappropriate words 3  
Confused 4  
Oriented 5  
**Best motor response (M)**  
No motor response 1  
Extension to pain 2  
Abnormal flexion to pain 3  
Flexion/Withdrawal to pain 4  
Localizes to pain 5  
Obey commands 6  
**Glasgow Coma score (E + V + M)** \_\_\_\_\_ of 15  
*(If a patient is comatose for all three items, repeat subsequent determination)*

**4 Sideline Assessment – Maddocks Score**  
*"I am going to ask you a few questions, please listen carefully and give your best effort."*  
**Modified Maddocks questions** (1 point for each correct answer)  
At what venue are we at today? 0 1  
Which half is it now? 0 1  
Who scored last in this match? 0 1  
What team did you play last week/game? 0 1  
Did your team win the last game? 0 1  
**Maddocks score** \_\_\_\_\_ of 5  
*Maddocks score is validated for sideline diagnosis of concussion early and is not included in SCAT2 Summary Score for final testing.*

This tool has been developed by a group of international experts at the 3<sup>rd</sup> International Consensus Meeting on Concussion in Sport held in Zurich, Switzerland in November 2008. The full details of the conference outcomes and the authors of the tool are published in British Journal of Sports Medicine, 2009, volume 43, supplement.  
The outcome paper will also be simultaneously co-published in the May 2009 issues of Clinical Journal of Sports Medicine, Physical Medicine & Rehabilitation, Journal of Athletic Training, Journal of Clinical Neuroscience, Journal of Science & Medicine in Sport, Neurosurgery, Scandinavian Journal of Science & Medicine in Sport and the Journal of Clinical Sports Medicine.  
McCrory P, et al. Consensus and agreement statement of the 3<sup>rd</sup> International Consensus on Concussion in Sport. Prague 2008. British Journal of Sports Medicine, 2009, 43, 198-204.

**Cognitive assessment**  
**Standardized Assessment of Concussion (SAC)**  
**Orientation** (1 point for each correct answer)  
What month is it? 0 1  
What is the date today? 0 1  
What is the day of the week? 0 1  
What year is it? 0 1  
What time is it right now? (within 1 hour) 0 1  
**Orientation score** \_\_\_\_\_ of 5

**Immediate memory**  
*"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."*

**Trials 2 & 3:**  
*"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."*  
Complete all 3 trials regardless of score on trial 1. Read the words at a rate of one per second. Score 1 pt for each correct response. Total score equals sum of all 3 trials. If a participant misses the 3 trials, that delayed recall will be tested.

List	Trial 1	Trial 2	Trial 3	Alternative word list
elbow	0 1	0 1	0 1	candle baby finger
apple	0 1	0 1	0 1	paper monkey penny
carpet	0 1	0 1	0 1	sugar perfume blanket
saddle	0 1	0 1	0 1	sandwich sunset lemon
bubble	0 1	0 1	0 1	wagon iron insect

**Total** \_\_\_\_\_  
**Immediate memory score** \_\_\_\_\_ of 15

**Concentration**  
**Digits Backward:**  
*"I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."*  
If correct, go to next string length; if incorrect, read trial 2. One point possible for each string length. Stop after incorrect on both trials. The digits should be read at the rate of one per second.

		Alternative digit list
4-9-3	0 1	6-2-9 5-2-5 4-1-5
3-8-1-4	0 1	3-2-7-9 1-7-9-5 1-9-6-8
6-2-9-7-1	0 1	1-5-2-8-6 3-8-5-2-7 6-1-8-4-2
7-1-8-4-6-2	0 1	5-3-9-1-4-5 8-3-1-9-6-4 7-2-4-8-5-6

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

1 pt for entire sequence correct  
Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan 0 1  
**Concentration score** \_\_\_\_\_ of 5

McCrory M. Standardized mental status testing of acute concussion. Clinics Journal of Sports Medicine, 2001, 11, 176-181.  
McCrory M, Randolph G, Kelly J. Standardized Assessment of Concussion Manual for administration, scoring and interpretation. Walpole, Wisconsin, USA.  
Maddocks D, Dickel G, Saling MM. The assessment of orientation following concussion in athletes. Clin J Sport Med, 1995, 9(1):32-7.  
Turkiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports, 2013, 2, 24-31.

## 6 Balance examination

The balance testing is based on a modified version of the Balance Error Scoring System (BESS). A stopwatch or watch with a second hand is required for this test.

### Balance testing

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

#### (a) Double leg stance:

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

#### (b) Single leg stance:

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

#### (c) Tandem stance:

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

### Balance testing – types of errors

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

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

Which foot was tested:      Left      Right

(i.e. which is the **non-dominant** foot)

Condition	Total errors
Double Leg Stance (feet together)	of 10
Single leg stance (non-dominant foot)	of 10
Tandem stance (non-dominant foot at back)	of 10
<b>Balance examination score (30 minus total errors)</b>	<b>of 30</b>

## 7 Coordination examination

### Upper limb coordination

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

Which arm was tested:      Left      Right

Starting:      5 correct repetitions in < 4 seconds = 1

Note the testers: Athletes fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions. Failure should be scored as 0.

**Coordination score**      **of 1**

## Cognitive assessment

### Standardized Assessment of Concussion (SAC)

#### Delayed recall

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

Circle each word correctly recalled. Total score equals number of words recalled.

List	Alternative word list
elbow	candle      baby      finger
apple	paper      monkey      penny
carpet	sugar      perfume      blanket
saddle	sandwich      sunset      lemon
bubble	wagon      iron      insect

**Delayed recall score**      **of 5**

### Overall score

Test domain	Score
Symptom score	of 22
Physical signs score	of 2
Glasgow Coma score (E + V + M)	of 15
Balance examination score	of 30
Coordination score	of 1
<b>Subtotal</b>	<b>of 70</b>
Orientation score	of 5
Immediate memory score	of 5
Concentration score	of 15
Delayed recall score	of 5
<b>SAC subtotal</b>	<b>of 30</b>
<b>SCAT2 total</b>	<b>of 300</b>
<b>Headache score</b>	<b>of 3</b>

Definitive normative data for a SCAT2 "cut-off" score is not available at this time and will be developed in prospective studies. Embedded within the SCAT2 is the SAC score that can be utilized separately in concussion management. The scoring system also takes on particular clinical significance during serial assessment where it can be used to document either a decline or an improvement in neurological functioning.

**Scoring data from the SCAT2 or SAC should not be used as a stand alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion.**

## Athlete Information

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

### Signs to watch for

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

- Have a headache that gets worse
- Are very drowsy or can't be awakened (woken up)
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused, are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on your feet, have slurred speech.

**Remember, it is better to be safe.**

Consult your doctor after a suspected concussion.

### Return to play

Athletes should not be returned to play the same day of injury. When returning athletes to play, they should follow a stepwise, symptom-limited program, with stages of progression. For example:

1. rest until asymptomatic (physical and mental rest)
2. light aerobic exercise (e.g. stationary cycle)
3. sport-specific exercise
4. non-contact training drills (start light resistance training)
5. full contact training after medical clearance
6. return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should return to stage 1 if symptoms recur. Resistance training should only be added in the later stages.

**Medical clearance should be given before return to play.**

Tool	Test domain	Time	Score
		Date tested	
		Days post injury	
SCAT2	Symptom score		
	Physical signs score		
	Glasgow Coma score (E + V + M)		
	Balance examination score		
	Coordination score		
SAC	Orientation score		
	Immediate memory score		
	Concentration score		
	Delayed recall score		
	<b>SAC Score</b>		
<b>Total</b>	<b>SCAT2</b>		
<b>Symptom severity score (max possible 132)</b>			
<b>Return to play</b>		Y	N
		Y	N
		Y	N
		Y	N

Additional comments

## Concussion injury advice (To be given to concussed athlete)

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. It is expected that recovery will be rapid, but the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

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

### Other important points:

- Rest and avoid strenuous activity for at least 24 hours
- No alcohol
- No sleeping tablets
- Use paracetamol or codeine for headache. Do not use aspirin or anti-inflammatory medication
- Do not drive until medically cleared
- Do not train or play sport until medically cleared

Clinic phone number

Patient's name

Date/time of injury

Date/time of medical review

Treating physician

Contact details or stamp

**Appendix Five**

**Cervical Orthopaedic Examination**

**Portions of SCAT2 Employed During Testing**

Participant: \_\_\_\_\_ M / F  
 D.O.B.: \_\_\_\_\_

Date: \_\_\_\_\_  
 Team / Position: \_\_\_\_\_

## Baseline Physical Examination

### 1. Cervical Range of Motion

- a) Flexion = \_\_\_\_\_
- b) Extension = \_\_\_\_\_
- c) Left Lateral = \_\_\_\_\_
- d) Right Lateral = \_\_\_\_\_
- e) Left Rotation = \_\_\_\_\_
- f) Right Rotation = \_\_\_\_\_

### 2. Resisted Cervical Manual Muscle Testing

- i) Deep Neck Flexor Endurance (to shake or voluntary withdraw) = \_\_\_\_\_
- ii) Resisted Flexion = \_\_\_\_\_ / 5
- iii) Resisted Extension = \_\_\_\_\_ / 5
- iv) Resisted Left Lateral = \_\_\_\_\_ / 5
- v) Resisted Right Lateral = \_\_\_\_\_ / 5
- vi) Resisted Left Rotation = \_\_\_\_\_ / 5
- vii) Resisted Right Rotation = \_\_\_\_\_ / 5

### 3. Notes on General Posture / Concerns / Extra Testing Performed:

	RIGHT	LEFT
<u>Kemps</u>		
<u>Neutral Compression:</u>		
<u>Radiculopathy:</u>		
<u>Spurlings Lateral:</u>		
<u>Jackson's Rotation:</u>		
<u>Valsalva:</u>		
_____		
_____		
_____		
_____		
_____		

### Cognitive assessment

#### Standardized Assessment of Concussion (SAC)

**Orientation** (1 point for each correct answer)

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

**Orientation score** \_\_\_\_\_ of 5

**Immediate memory**  
*"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."*

**Trials 2 & 3**  
*"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."*

Complete all 3 trials regardless of score on trial 1 & 2. Read the words at a rate of one per second. Score 1 pt for each correct response. Total score equals sum across all 3 trials. Do not return the alternate word list until the end of the trial.

List	Trial 1	Trial 2	Trial 3	Alternative word list		
elbow	0 / 1	0 / 1	0 / 1	handle	baby	finger
apple	0 / 1	0 / 1	0 / 1	paper	monkey	penny
carrot	0 / 1	0 / 1	0 / 1	sugar	perfume	blanket
saddle	0 / 1	0 / 1	0 / 1	sandwich	curtains	lemon
quibble	0 / 1	0 / 1	0 / 1	wallet	tree	project

**Total**

**Immediate memory score** \_\_\_\_\_ of 15

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

1. Place finger to point stroke length. If incorrect, read trial 2. One point possible for each stroke length. Stop after incorrect on both trials. The digits should be read at the rate of one per second.

	0	1	2	3	4	5
4-9-2	0	1	6-2-0	5-2-6	1-1-5	
3-8-1-4	0	1	3-7-7-9	1-7-9-1	4-9-5-8	
6-2-4-7-1	0	1	1-5-2-8-4	4-8-4-7-7	5-1-8-4-4	
7-1-8-4-6-2	0	1	5-3-9-1-4-8	8-3-1-5-8-4	7-2-4-8-5-6	

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

1 pt for entire sequence correct

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-April-Mar-Feb-Jan 0 / 1

**Concentration score** \_\_\_\_\_ of 5

Participant: \_\_\_\_\_ M / F  
 D.O.B.: \_\_\_\_\_

Date: \_\_\_\_\_  
 Team / Position: \_\_\_\_\_



**Balance examination**

This Balance testing is based on a modified version of the Balance Error Scoring System (BESS).<sup>22</sup> The goal is to watch with a trained hand, for cues for the BESS test.

**Balance testing**

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

**(a) Double leg stance.**

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

**(b) Single leg stance:**

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

**(c) Tandem stance:**

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

**Balance testing types of errors**

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

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

Which foot was tested: \_\_\_\_\_ Left \_\_\_\_\_ Right  
(Use initials for the non-dominant foot)

Condition	Total errors
Double Leg Stance (heel to heel)	_____ of 10
Single leg stance (dominant leg)	_____ of 10
Tandem stance (heel to heel heel to back)	_____ of 10
<b>Balance examination score</b> (10 minus total errors)	_____ of 30



**Coordination examination**

**Upper limb coordination**

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

Which arm was tested: \_\_\_\_\_ Left \_\_\_\_\_ Right

Repetitions: \_\_\_\_\_ (count repetitions in 4 seconds)

Note for testers: Athletes fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions. A score should be given for 4/5.

Coordination score \_\_\_\_\_ of 1



**Cognitive assessment**

**Standardized Assessment of Concussion (SAC)**

**Delayed recall**

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

Circle each word from memory on list. Total score is the number of words recalled.

List	Alternative word list		
allow	handle	fan	finger
apple	paper	monkey	panny
carrot	sugar	perfume	banquet
saddle	sandwich	sunset	temper
bubble	napkin	iron	insect

Delayed recall score \_\_\_\_\_ of 5



**Appendix Six**

**Neck Pain Task Force Grading and Interventions**

## Neck Pain Grades and Interventions Neck Pain Task Force

### ***Grade I Neck Pain***

Neck pain with no signs or symptoms of major structural pathology (such as a fracture, dislocation, spinal cord injury). No or minor interference with activities of daily living.

### ***Grade II Neck Pain***

Neck pain with no signs of major structural pathology, but existence of interference of activities of daily living.

#### **Interventions for Grade I or II Neck Pain:**

*Likely Helpful:* educational video, mobilization, exercise, combination of mobilization and exercise, manipulation, other manual therapy (soft tissue therapy), acupuncture, low-level laser, analgesics.

*Possibly Helpful:* pulsed electromagnetic therapy, exercise, cognitive behavioural therapy.

*Likely Not Helpful:* collars, passive modalities, referral to fitness program, frequent health care use, methylprednisone, Botulinum toxin A, corticosteroid injections, neurotomy, cervical decompression, cervical fusion or disc replacement.

### ***Grade III Neck Pain***

Neck pain with no signs of major structural pathology, but presence of neurological signs (such as decreased reflexes, weakness, or sensory deficit).

*\*Currently there are no non-invasive interventions that have sufficient evidence to support their use.*

#### **Interventions for Grade III Neck Pain**

*Likely Helpful:* anterior cervical discectomy (in cervical radiculopathy – short term), anterior cervical discectomy with fusion (in cervical radiculopathy –short term)

*Possibly Helpful:* <4 injections of corticosteroids

*Likely Not Helpful:* thermal heating of dorsal root ganglion

### ***Grade IV Neck Pain***

Neck pain with signs of a major structural pathology.

**\*\* Beyond the scope of this research study.**

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