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Evaluation of the Psychometric and Measurement Properties of the SCAT5 and Child SCAT5

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Abstract

Concussions are one of the most complex conditions to manage in sport medicine due to the individualized clinical presentation caused by the complex neurometabolic cascade that occurs. The identification, assessment and management of concussion requires clinicians to employ a multifaceted approach including the subjective disclosure of symptoms by patients. In order to aid in this, symptom checklists are commonly used as they provide a standardized method for collecting the severity of concussion symptoms. One of the most common symptom checklists is the 5th Sport Concussion Assessment Tool (SCAT5) symptom evaluation which is available in an adult and pediatric version. In order to better understand the psychometric and measurement properties of both versions of the SCAT5 multiple studies were conducted. Using Rasch analysis the reliability and validity of the SCAT5 and Child-SCAT5 symptom evaluations were evaluated, a dichotomous clinical anchor was used to determine the minimal clinically important differences and individual's interpretation of the meaning of the symptoms were investigated using a quasi-qualitative questionnaire. Both the adult and child SCAT5 were found to be reliable but a poor fit to the Rasch model due to the multidimensionality and redundancy within the items and the presence of response dependency between multiple pairs of items. Through an examination of the themes identified from the qualitative survey, 6 items that comprise the SCAT5 were being interpreted in a manor inconsistent with the original wording of the item. Finally, MCID estimates and measures of responsiveness were calculated and all of the MCID estimates for the adult SCAT5 were found to be significant however; the child SCAT5 only had 12 of the items from the child section and 15 items from the adult (parent/guardian) section that were significant. Overall, both tools were found to have serious psychometric issues and require further refinement using a systematic test development methodology in order to guarantee the validity, reliability and clinical utility of the tools.

Keywords

Concussion, mTBI, psychometrics, Rasch, reliability, validity, assessment, symptoms, IRT, test development, MCID, responsiveness, differential item functioning, local dependence

Summary for Lay Audience

The identification, assessment and management of concussions are a complicated task requiring health care professions to use traditional clinical techniques combined with checklists of concussion specific symptoms that help patients disclose the presence and severity of symptoms. The most commonly used symptom checklists is the 5th Sport Concussion Assessment Tool (SCAT5) symptom evaluation which is available in an adult and child version. In order to guarantee that the tool is providing reliable results and is actually measuring concussions symptoms, the measurement properties of the tool needs to be evaluated. In order to evaluate how reliable and accurate the two versions of the SCAT5 symptom evaluation are a technique called Rasch analysis is used which compares various properties of the tool against a statistical model called the Rasch model. Additionally, it is important to understand how patients interpret the meanings of symptoms to ensure consistency and this can be accomplished by asking individuals to describe how they interpret each item using their own words. As clinicians rely on the results of SCAT5 symptom evaluation to track how patients are recovering, it is important to understand how changes in the symptom scores reflect changes in the health status and the minimal clinically important difference is one method that can be used to understand this between. The results of the Rasch analysis revealed that both versions of the SCAT5 are reliable tools but were poor fits to the Rasch model because they were not measuring just concussion symptoms and multiple items were found to be overlapping and measuring the same trait. It was also discovered that 6 of the items on the adult SCAT5 were being interpreted differently than how the items are presented resulting in inconsistent interpretations. These inconsistencies may result communication barriers between the clinician and patient, prolonged symptoms, unnecessary interventions and clinical errors. Finally, estimates of what is considered a clinically important change in responses for all of the items from both versions of the SCAT5 were calculated providing valuable information for health care providers to use when interpreting the results of the symptom checklists. Overall, both versions of the SCAT5 had serious measurement issues which require them to be redeveloped in order to guarantee accuracy and reliability.

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Chapter 1

1.1 Introduction

Concussions are a traumatic brain injury due to a biomechanical force resulting in a transient disturbance to brain function without detectable structural damage.[1–3] This disturbance is a result of a complex neurometabolic cascade involving ionic, metabolic and pathophysiological events.[1–3] There are several common characteristics that can be used to identify a concussion clinically including a traumatic blow to the head, face, neck or other part of the body that attenuates force to the head, the presence of short term symptoms and impaired neurological function.[3] Due to the nature of the clinical manifestation of concussion, the identification, assessment and management of concussions requires clinicians to apply a multifaceted approach in order to make informed clinical decisions.[1–3] While concussions are extremely prevalent in sport, the tools used by clinicians are not widely studied and the most commonly referenced clinical tool, the Sport Concussion Assessment Tool (SCAT), was not developed using a systematic test construction methodology rather it was developed and revised using a combination of existing tools and expert opinion.[2–9] As there are currently no objective diagnostic modalities available and the reliance on subjective reporting of symptoms by patients forms the foundations for the assessment and management of concussion, there is a need to ensure that these tools are clinically useful for the diagnosis and management of concussion.[2] Therefore, as there is a lack of evidence regarding the validity and reliability of the SCAT an evaluation of the psychometric and measurement properties of the adult and child version of the most current version of the SCAT (the SCAT5 and Child SCAT5) is required in order to better understand how the tool currently functions in order to identify areas that would benefit from redevelop using an appropriate, systematic methodology.[9]

1.2 Concussion

1.2.1 Definition

A concussion a type of traumatic brain injury caused by an external biomechanical force directly to the head, face, neck or other part of the body that causes a force to be transmitted to the head.[3,10] This results in a disruption of brain function and manifests as a variety of clinical signs and symptoms over a period of minutes to hours and typically resolve spontaneously following a sequential course over a period of days to weeks however, some patients experience persistent symptoms.[3,10] Concussions result in functional disturbances to the brain rather than structural abnormalities and are not detected by standard neuroimaging modalities however in rare cases an intracranial hematoma can form which is detectible using neuroimaging and can be a life-threatening condition without medical intervention.[3,10]

1.2.2 Pathophysiology

The pathophysiology of concussion is a complex neurometabolic chain reaction specific to each injury and is not defined by a specific set of clinical characteristics.[1,11] This neurometabolic chain reaction is responsible for the unique symptomology experienced by each individual and is caused unique combination of biomechanical injury, cellular energy crisis, cytoskeletal damage, axonal dysfunction, impaired neurotransmission and cellular death.[1,11]

During the acute stages of this chain reaction there is an ionic flux and indiscriminate glutamate release and due to the mechanoporation of the lipid membranes, an efflux of potassium and influx of sodium and calcium can occur. The ionic flux and depolarization of voltage or ligand gated ion channels manifests and a depression-like state and is thought to be responsible for the acute impairment of brain function.[1,11] In order to correct for the ionic flux and to restore homeostatus, adenosine triphosphate ionic pumps are activated which can deplete intracellular energy reserves, increasing the amount of adenosine diphosphate resulting in hyperglycolysis.[1,3,11,12] As a result of

hyperglycolysis, an impairment of glucose metabolism can occur for as long as 7 to 10 days resulting in behavioral changes and cognitive impairments.[1,3,11,12]

As a result of the biomechanical forces, damage to the neurons, glia and dendrites can occur and the influx of excess calcium ions can result in axonal damage. This can result in a loss of structural integrity and may result in damage to the cytoskeletal components.[1,3,11–15] Any damage to the axon can result in atrophy of the neuron resulting in cognitive impairments and a reduction in reaction time.[1,3,11,12,16–19] While very little cell death occurs after a concussion, repeated concussions can result in damage to the white matter and to the axon itself, resulting in more severe cognitive and functional impairments.[1,3,11,12,17] Additionally, the functioning of the brain's neurotransmitters can impaired, interfering with the normal electrophysiology of the brain and can result in impairments to the individual's memory.[1,3,11,12,19–21]

1.2.3 Mechanism

There is no one single mechanism that causes concussions, which further complicates the identification, assessment and management of them. A concussion can be caused by a direct force to the head, face or neck or indirectly by a force to another part of the body that results in an impulsive force that is transmitted to the head.[3]

1.2.4 Epidemiology

The exact number of concussions that occur per year is unknown as there is no single injury surveillance system in place nor do all concussions present to clinicians who bill the public health system. It is estimated that between 2% and 15% of all athletes who participate in organized sports will suffer a concussion during a season.[2] In the United States there are anywhere from 1.6 to 3.8 sport related concussions annually with most occurring dur games (13.8/1000 hours). In Ontario, there were 1,330,336 concussions diagnosed by a clinician who bills the public health system between 2008 and 2016 resulting in an annual average of 147,815 per year.[22] In Ontario, 1152 concussions occur for every 100,000 residents and children under the age of 5 had a higher rate of concussion with 3600 concussions for every 100,000 residents.[22]

1.2.5 Diagnosis

Concussions are considered to be one of the most complex injuries in sports medicine to identify, diagnose and manage. This complexity is due to the rapid progression of signs and symptoms that overlap other acute and chronic conditions combined with the absence of objective tests.[3] To further complicate the issue, concussions can occur without any loss of consciousness or presence of symptoms at the time of injury and may not manifest for hours to days post-injury.[2,3]

1.2.5.1 Identification

While the formal diagnosis of concussion should occur in a clinical office setting, the identification of a potential concussion in athletes typically takes place on the sideline in the field. The goal of sideline identification is not to replace a comprehensive clinical evaluation, rather it is to identify individuals who may have suffered a concussion, remove them from play for evaluation and refer them for a more comprehensive assessment in a controlled office environment. The sideline evaluation should briefly screen for serious physical injuries to the head and neck, assess the individual's physical and mental state, attention and memory function and evaluate any immediate concussion symptoms.[3]

1.2.5.2 Clinical Assessment/Diagnosis

The diagnosis of concussion requires a multifaceted approach involving a combination of a comprehensive clinical history, a physical examination and subjective symptom reporting and tracking.[3] The physical examination should include an assessment of cranial nerves function, manual testing of muscle strength and range of motion, deep tendon reflex testing, an inspection of the head and neck for trauma, a balance assessment, ocular examination, vestibular examination, an evaluation of the mental status and evaluation of any existing or coexisting injuries.[2,3,23]

The confirmation of the diagnosis of concussion requires an evaluation of the signs and symptoms that cannot be explained by drug, alcohol or medical use or other

injuries combined with the identification of a clear mechanism consistent with a concussion.[2,3] The use of sideline neurocognitive and balance assessments has decreased clinical value after 3 days post-injury however concussion symptom evaluation and tracking does maintain clinical utility.[2,3]

1.2.5.3 Physical Examination

The physical examination of concussion should cover multiple clinical domains and consider any differential, comorbid, concurrent and confounding diagnosis. The physical examination may include an evaluation of the patient's vital signs, mental and cognitive status, a physical assessment of the head and neck, assessment of vestibular and ocular function, balance and coordination, and a comprehensive neurological assessment.[23] Measurement of the patient's blood pressure, heart rate, temperature may be required and is recommended when there is a complain of dizziness and may require an evaluation of orthostatic vital signs, exercise tolerance testing or tilt table testing.[23] The evaluation of a patient's mental and cognitive status may require the use of additional clinical tools to screen for psychogenic conditions especially in patients with pre-existing conditions.[23]

The physical assessment of the head and neck for trauma or other conditions should include a thorough palpation of the areas, an evaluation of active and passive range of motion and targeted manual muscle testing.[23] An evaluation of the patient's cranial nerve function and deep tendon reflexes should also be completed as there can be injury to single or multiple cranial nerves regardless of the magnitude of the injury.[23] In order to assess the vestibular and ocular systems clinicians can employ a standardized tool, like the Vestibular Ocular Motor Screening (VOMS) tool and balance and coordination can be accomplished with simple in-office testing.[23]

1.2.5.4 Tools

There is an identified lack of objective and clinically useful tools for the diagnosis of concussion which has resulted in the focus on commercial and non-commercial development rather than refinement and validation.[2] There are numerous paper and

computer based products available covering multiple clinical domains but there remains a lack of rigorous psychometric testing to ensure reliable and valid results.[9,24] Of all the tools currently available, the Sport Concussion Assessment Tool is one of the most widely referenced and as it is freely available to anyone, and was developed and published alongside the Consensus Statement on Concussion in Sport.[3]

1.2.5.4.1 Sport Concussion Assessment Tool 5th

1.2.5.4.1.1 Overview

The SCAT was originally developed during the Second Consensus Conference on Concussion in Sport in 2004, has undergone three revisions since and the second revision saw the development of a child specific version.[3,25,26] A child specific version was required as there is evidence that children under the age of 13 report concussion symptoms differently and may require input from the parents. The most recent version, the SCAT5, was revised during the Fifth Consensus Conference without any material changes to the symptom evaluation section. This section has not seen any revisions, aside from the development of a child specific version, since the original version was published.[3,27]

The SCAT was intended to be a standardized tool used during the assessment of a sports concussion as well as an educational tool.[26] The SCAT was not developed using accepted psychometric techniques, but rather it was developed by a group of experts by combining 8 existing tools: Sideline evaluation of concussion, Management of concussion sports palm card, Standardized assessment of concussion, Sideline concussion check, McGill abbreviated concussion evaluation, National Hockey League physician evaluation form, UK Jockey Club assessment of concussion and the Maddocks questions.[3,25]

1.2.5.4.1.2 Components

The adult and child versions of the SCAT5 are extremely similar and are comprised of 5 sections: immediate on field assessment, symptom evaluation, cognitive screening,

neurological screening and delayed recall. The only major differences between the adult and child versions of the SCAT5 are the inclusion of a two-digit string to provide a simpler starting point for the digits backward section, inclusion of the days of the week backwards in the child version rather than the months backwards as in the adult and the removal of the modified Maddocks section. [3,5,26] The adult SCAT5 symptom evaluation is comprised of 22 symptoms on a 7-point Likert-scale, from 0 to 6 where the Child SCAT5 has two separate sections, one for the child and one of the parents, that consist of 21 symptoms in each section on a 4-point Likert-scale, from 0 to 3.[3,5,26]

1.2.5.4.1.3 Development

1.2.5.4.2 Neurocognitive/Neuropsychological Testing

The use of computerized neurocognitive and neuropsychological testing has become more accessible to all types of athletes and may play an important role in a multifaceted, multimodal and multidisciplinary approach to concussion assessment and management. These tests do have clinical value and can contribute valuable information however, the test should be administered by a neuropsychologist and are not required in all cases post-injury.[3] Additionally, pre-season baseline neuropsychological testing is not recommended as it may not produce valid and reliable results and has limited clinical utility.[3,7,28]

1.2.5.4.3 Symptom Checklists

A symptom checklist is an evaluation tool designed for the self-reporting of the presence and severity of various symptoms potentially resulting from a concussion. Symptom checklists have been shown to have clinical utility in the identification, diagnosis and for tracking recovery in patients.[24,29] There are numerous symptom checklists available; however, no single tool has been shown to be superior to another.[29] Many of the symptom checklists that are commonly used, including the SCAT5 and Child SCAT5 symptom evaluation, were not developed using a systematic methodology and relied on expert opinion instead.[24,29]

Of the available symptom checklists, only 5 have been subject to psychometric evaluation and have published some evidence of their reliability and/or validity: the Graded Symptom Checklist, Sport Concussion Assessment Tool (SCAT) Symptom Evaluation, ImPACT-22 Post-concussion Scale and the 9 and 16 item Head Injury Scales.[9,24,30] The Graded Symptom Checklists is a 17-item symptom checklist with a sensitivity of 0.89 and specificity of 1.0 at the time of injury and a reduced sensitivity of 0.04 7 days post-injury (sensitivity is the probability of correctly identifying a concussion and specificity is the probability of identifying of correctly ruling out a concussion).[24] The ImPACT-22 Post Concussion Scale has demonstrated construct validity and internal consistency with a Cronbach's alpha of 0.88-0.94.[9,24] The Head Injury Scale 9-item version has demonstrated construct and factorial validity and internal consistency with a Cronbach's alpha of 0.84 however the 16-item version only has demonstrated factorial validity and internal consistency with a Cronbach's alpha of 0.78.[9,24] The SCAT3 symptom evaluation has demonstrated face and content validity and has a sensitivity of 0.47-0.72 and a specificity of 0.79-0.92.[9,24,30]

1.2.5.4.4 Imaging Modalities

The use of standard neuroimaging modalities is not recommended for the assessment of concussion in the majority of cases due to the functional nature of the injury.[3] In cases where there is a concern over the presence of a intracranial hematoma or macrostructural injury a head CT is the standard technique that should be used.[2,3] The use of conventional brain MRI is not clinically useful except in atypical cases and emerging advanced neuroimaging may be useful to detect changes in brain structure and function but are limited to research studies at this time.[2,3]

1.2.6 Treatment

Previously treatment focused on complete rest: removal from cognitive, visual and auditory stimulus and avoidance of physical activity however, these recommendations were not supported by evidence. Currently, the best available evidence supports the opposite of previous recommendations and focuses on encouraging individuals to become

gradually and progressively more physically and cognitively active so long as they are not exacerbating their symptoms.[2,3,31] Clinicians are now encouraged to identify and treat concussions symptomatically using a multidisciplinary approach and there is evidence suggesting that active recovery may facilitate recovery rather than prolong it since exercise has been shown to improve autonomic nervous system balance, CO2 sensitivity, cerebral blood flow, mood and sleep.[2,3,31] As concussions will manifest with an unique symptomology for each individual, the identification of symptoms common to overlapping clinical profiles may help provide better targeted care and may include cognitive, affective, fatigue, migraine -headache vestibular and ocular.[2]

1.2.7 Management

The management of concussions requires the periodic monitoring of symptom recovery, treatment effectiveness, identification of comorbid conditions, education and guidance to return to work, school and sport.[2,3] The clinical signs and symptoms of concussion will typically resolve spontaneously within 14 days for 80-90% of adolescents and adults and may take up to 4 weeks in younger adolescents and children.[2]

1.2.7.1 Education

One of the most important aspects of the management of concussion is educating individuals throughout the recovery process. It is recommended that educational materials be provided and reviewed with patients at the time of diagnosis, during follow-up appointments and during any treatments that they are receiving.[3,32] At the time of diagnosis, individuals should be given general information about concussions, be educated regarding any warning signs and be provided information about typical recovery timelines and milestones.[3,32] During follow-up appointments and treatments additional information about managing persistent symptoms, treatment milestones and safe return information needs to be reviewed.[3,32]

1.2.7.2 Return to school

As a concussion can impact individuals cognitive processing, learning, attention and memory the return to learning process needs to follow a gradual, progressive and must take an individualized approach.[2,3] Additional education support, extensions to deadlines and a reduced work load should be implemented and follow a stepwise progress following their recovery. Successful reintroduction to school requires the coordination of clinicians and educators in order to ensure the necessary accommodations and adjustments are in place.[2,3]

1.2.7.3 Return to play

The safe return to sport after a concussion requires the careful monitoring of clinical recovery and should follow an individualized step-wise progression. One of the most widely used return to play recommendations requires an individual to follow a 6-step process to safely return to sport.[2,3] Each stage requires a minimum of 24 hours to pass before progressing to the next stage and is designed to slowly reintroduce progressive levels of physical and cognitive activity. Stage 1 requires the individual to reintroduce normal activities of their daily life, stage 2 reintroduces light cardiovascular activity, stage 3 progresses to sport-specific cardiovascular activity, stage 4 permits participation in practice without physical contact, stage 5 is a full-contact practice and stage 6 is the return to sport without restriction.[2,3] Athletes should be monitored throughout this process by a medical professional and should include recommendations by coaches on appropriate activities to ensure athletes are physically and psychological ready to return to the demands of their sport.[2,3]

1.2.7.4 Persistent symptoms

While most individuals will have spontaneous recovery within a few weeks post-injury, a small percentage of concussions will result in persistent symptoms that remain past the expected time frames 10–14 days in adults and less than 28 days in children.[3,32] The exact cause of persistent symptoms is unknown however, prolonged recovery occurs in approximately 30% of pediatric cases and may occur in older adults and adolescents,

females, individuals who return to sport, work or school too early, have a past history of concussion, migraine, depression, anxiety, poor sleep quality, vestibular or visual abnormalities.[3,5,32] Because of the individualized nature of each concussion, persistent symptoms must be managed case by case and treatments should be targeted towards the individual.[3,32]

1.2.7.5 Risks

Most concussions do not typically result in life altering changes however, there are some rare but serious risks due to concussion. Individuals who continue to participate in sport immediately following a concussion often experience more severe symptoms, prolong their recovery and may increase the risk of concussion and musculoskeletal injury.[2] There is also a rare and controversial condition called Second Impact Syndrome that may reflect a combination of complications due to reinjury in children and adolescents however, the pathology is not fully understood or accepted.[2] There is limited evidence supporting the increased risk of developing mental health problems due to concussion as well and may be an incidental finding as these problems are common, multifactorial and present in individuals who do not participate in contact sport.[2] Another evolving and potentially long-term risk is Chronic traumatic encephalopathy (CTE) which is a neurodegerative disease that has been discovered in former athletes who have had multiple concussions and experienced behavioral changes.[2] The prevalence of CTE in the general public and former athletes with and without a history of concussion is currently unknown however, the causal relationship between pre-morbid behavioral changes and cognitive issues and post-mortem discovery of CTE has not been established.[2]

1.3 Psychometric Measurement

The concept of psychometric measurement was made popular by psychology and was a method intended to be used for mental measurement.[33,34] The popularity of questionnaires, scales and clinical tests in other disciplines has expanded the field of psychometrics and there are now a variety of evolving methodologies, approaches and

sophisticated models that can be applied.[33,34] The overall intention of psychometrics is to ensure that the resulting questionnaires, scales and clinical tests are accurately and reliability measuring the intended latent construct and to provide the necessary evidence to support their use.[33,34]

1.3.1 Test Development

In order for clinical tests and scales to have clinical utility, the psychometric and measurement properties must be taken into consideration in order to ensure that it is a reliable and valid measure of the underlying construct.[33,34] In order to accomplish this, clinical tests must be developed following a rigorous methodology and be subjected to psychometric evaluation in order to ensure that the test is measuring the latest construct (which is the theoretical variable that is not directly measurable and is the focus of the test) and produce consistent results.[33,34] There are multiple published approaches to test development however, the general stages are similar: define the purpose and specifications of the test, item and scale development and item and scale evaluation.[33,34] Irwing and Hughes break the stages down into multiple targeted stages[34]:

1. Construct definition, specification of test need and test structure
2. Over all planning
3. Item development
4. Scale construction
5. Reliability
6. Validation
7. Test scoring and norming
8. Test specification
9. Implementation and testing
10. Technical Manual

The goal of each stage is to ensure a systematic methodology is followed to guarantee the validity and reliability of the product. The construct that the test intends to measure must be clear and somewhat broad and may require the use of a systematic literature review to identify existing tests and uncover more information about the latent

construct.[33,34] The planning stage should focus on answering a range of questions including identifying the number of items needed, the response scale, the scoring of the test, the psychometric model to be used for modeling the test, the process to be followed when developing the items and general guidelines on how the test will be administered.[33,34] During the item development stage, items will be developed, reviewed and piloted. As input from subject matter experts is essential for item development and revision the delphi technique can be used to establish consensus. The delphi approach provides a systematic approach involving multiple rounds of voting by the expert panel. [33,34] The approach used to construct the scale may involve one or more statistical models or techniques but should focus on ensuring that the scale is unidimensional, accurate, reliable and covers the range of traits to ensure construct representation.[33,34] Confirmatory factor analysis may be employed during this stage to provide an estimate of the number of dimensions being studies, evaluate the convergent and discriminant validity and to provide an estimate of reliability. Additionally, the application of a classical test theory (CTT) or item response theory (IRT) at this stage will provide information regarding item difficulty and reliability and a combination of CTT and IRT may provide a more comprehensive overview of the psychometric properties of the scales.[33,34]

The reliability and validity of the test must be measured in order to identify and address malfunctioning items as well as to provide the necessary evidence of the measurement properties to the eventual end user.[33,34] Reliability is calculated by obtaining the ratio of the true score variance to the total observed variance and helps address potential sources of error. These sources of error can vary and may include individual cognitive and physical factors, the quality of items, situational factors and practice effects. In order to evaluate a test for reliability three different estimates of reliability can be used: internal consistency (to account for random and specific errors), test-retest reliability (to ensure reliable results during repeated administrations of the test) and coefficients of equivalence (correlates two parallel forms that are administered at two points in time). The most commonly reported measure of internal consistency is Cronbach's alpha however, MacDonald's Omega provides a more accurate estimate.[33,34] Validity is measurement of how well a test measures what it claims to measure and can be established by evaluating the response process of participants taking the test in

addition to the content and structure of the test.[33,34] There are multiple types of validity that a test can exhibit including construct (accurate measurement of the latent construct), convergent (correlation between multiple measurements), discriminant (is not measuring an undesired construct), criterion (measurement correlates with a known standard), concurrent (measurement correlates with another test), content (the extent to which the measurement represent all facets of the latent construct) and face (the superficial appearance that the measurement appears to be measuring the latent construct).[33,34]

The final stages of test develop focus on developing methods to score the test using either an IRT approach or a weighted scoring approach based on stanine, sten and t-scores. Depending on the complexity of the test and it's intended use the test may or may not require standardization and these characterizes will help determine the most appropriate method.[33,34] Once the test has been trialed, validated and scored the specifications of the test can be developed including the scoring algorithm, the design of the published form of the test and the administration method. Finally, the production version of the test needs to be implemented, tested to ensure it functions correctly and a technical manual can be produced covering all aspects of the development, psychometric properties and administration of the test.[33,34]

1.3.1.1 Classical Test Theory

Classical Test Theory (CTT) is a psychometric model used in test development and is a test-level model that uses a conceptual true score. During the administration of a test an observed score is obtained and if the test could be administered repeatedly under the exact same conditions, including the individual's physiological state, the CTT true score would reflect the expected value obtained from the observed scores that were obtained during the repeated administrations of the test.[33,34] CTT requires some assumptions to be made and has been one of the most popular psychometric models in the past since these assumptions are relatively easy to meet.[35] The primary assumptions are that the amount of error associated with an item is unrelated to the true score and the sum of the error for all items will eventually equal zero which means that an increase in items will reduce the amount of random error associated with the total.[35] There are

however, three serious problems that arise from CTT: 1 the psychometric properties dependence on the sample that the scale was tested on, 2 the assumption that all items contribute equally to the total score and 3 the assumption that there is one standard error of measurement (SEM) that applies to the entire scale.[35] The first of these issues results in the requirement to reevaluate the psychometric properties of the test whenever a new item is added or removed or when the test is being used with a different population.[35] The issue of item equivalence results from the assumption that the items are measured on an interval scale and CTT takes not steps to correct for this and applies this assumption blindly.[35] Lastly, the assumption that there is only one SEM that applies to the entire scale is incorrect as the scores at the extreme ends of the scale typically have a greater amount of error associated with them but CTT does not correct for this.[35]

1.3.1.2 Item Response Theory

One solution to overcoming the issues that CTT presents is another psychometric model called Item Response Theory (IRT). Unlike CTT, IRT is an item-level model that requires two strong assumptions to be made: the scale must be unidimensional (only measure one trait) and must have local independence (the probability of endorsing one item is unrelated to the probability of endorsing any other item).[34,35] Any violation of these two assumptions would render the IRT model invalid and the results meaningless.[34,35] There are multiple IRT models that can be applied and are distinguished based on being unidimensional or multidimensional and if the response scale is dichotomous or polytomous.[34,35]

1.3.2 Rasch Model

One specific application of IRT is the Rasch model and is a method of testing a rating scale against a statistical measurement model which assumes person-level responses to an individual item that are able to estimable their actual position on the continuum of the latent construct, and that their position on the latent construct should be estimable only by their responses to each individual item.[36,37] The Rasch model separates persons based on their location on a theoretical logit-based continuum of the latest

construct by locating the response thresholds that separate adjacent response options for each item. The scale is tested against this model using the logit-based location and once the scale fits the Rasch model the position of the response thresholds is translated into an interval level scale.[36,37]

In order to test a scale against the Rasch model all possible response options to all items and all persons along a unitless logit-based continuum representing the levels of the latent construct are ordered from very low to very high.[36,37] Then the hypothesis that people located higher on the continuum should show a higher likelihood of choosing a response option that is located higher on that same continuum is statistically tested.[36,37] This requires the use of Guttmann scaling, which is a deterministic pattern with a strict hierarchical ordering that expects agreeance with all lower ranked items when a particular item is endorsed, in order to locate and order persons and item difficulty.[36–38] This allows for the psychometric properties of Rating scales to be determined by evaluating them against the Rasch model and estimates of consistency, reliability and responsiveness can be obtained.[38,39] Applying the Rasch model allows for the development of new rating scales, the analysis of the psychometric properties of existing scales, testing of the structure of ordinal scales, the development of item banks for calculating change scores from ordinal scales.[38] Additionally, the robust nature of the Rasch model allows for it to be applied to both dichotomous and polytomous data using the dichotomous model or one of two polytomous models (Andrich Rating Scale Model and Partial Credit Model).[37,38]

1.3.2.1 Fit statistics

The Rasch model takes into account three different types of fit statistics: two item-person interaction statistics and one item-trait interaction statistic.[38,40] The item-person interaction statistics provide an overview of all the item or person deviations from the Rasch model by standardizing the individual item and person fit residuals (the difference between the observed and expected scores) using Z-scores and an obtained Z-Score ± 2.5 indicates an acceptable fit to the Rasch model. [38,40,41] Item fit can also be represented graphically by plotting the responses for each of the class intervals against

the Rasch model's item characteristic curve.[40] Two Chi-square ratios, infit and outfit mean square statistics are used to determine how well the data fits the Rasch model.[41] The chi-square values are divided by their degrees of freedom in order to establish a ratio scale with an expected value of +1 and can range from 0 to infinity.[41] For the item-trait interactions chi-square values for each of the individual items are obtained , combined then tested for statistical significance using the summed degrees of freedom.[40] The obtained Chi-square statistics should be non-significant in order to fit the Rasch model.[38]

1.3.2.2 Unidimensionality

The unidimensionality of a rating scale refers to the measurement of a singular latent trait at a time. A scale should be unidimensionality to ensure that only the desired trait is being measured in order to guarantee the accuracy of the measurement.[41] Unidimensionality can be evaluated by using Principal Component Analysis (PCA) to evaluate the residuals for meaningful patterns, when absent indicate unidimensionality.[42]

1.3.2.3 Category thresholds

The Rasch model requires the analysis of the rating scale's category thresholds. Which are the point at which a person is equally likely to select two adjacent response options.[42,43] Category thresholds are examined by evaluating the category probability curves to determine if the response probability are in ascending order with the categories to determine if the category thresholds are ordered or disordered.[42–44] Too many options or poor category labeling can results in disordered category thresholds resulting in misfitting items and inconsistent responses.[42,43] Disordered category thresholds can be corrected by collapsing categories so long as it logical and there should be an attempt to create uniform frequency distributions across the new categories.[41] The reliability and validity estimates of resulting category thresholds should then be re-assessed in order to evaluate how the new rating scale is functioning.[41]

1.3.2.4 Differential Item Functioning and Item Bias

Fitting Rasch model also requires items to be evaluated for differential item functioning (DIF), also referred to as item bias. DIF occurs when different groups that possess comparable levels of the latent trait being measured by respond differently to the individual items.[38,45] Two types of DIF can occurs, uniform and non-uniform DIF.[37] Uniform DIF occurs when the group displays a consistent difference in their responses where nonuniform DIF occurs when the group displays inconsistent differences in their responses.[37,45] Uniform DIF can be resolved by splitting items into the different person factor groups where the DIF was identified or the items with DIF can be grouped together in a subtest to determine if the DIF cancels out at the test level.[46] Non-uniform DIF however, requires the removal of the particular item.[38,45] After any correction for DIF the remaining items need to be retested to determine the effect on the scale or changes to statistical power.[37,38,42,46]

1.3.2.5 Local independence

The Rasch model requires an assumption of local independence, which is the absence of a response dependency between items that are linked in such a manner that sees the response to one item determine the response to another item.[37,38,42] The relationship between the underlying construct for each item can be identified by inspecting the residual correlation matrix and it considers correlations less than 0.28 to be an acceptable fit to the Rasch model.[38,47] When a violation of this assumption occurs, items may have to be removed, or correlating items may have to be grouped together in order to help improve the model fit.[38,42]

1.3.2.6 Person Separation Index

The Person Separation Index (PSI) is an indication of reliability used by the Rasch model and reflects the rating scale's ability to differentiate between the different levels of the underlying construct.[37,38] PSI is interpreted in a similar fashion as Cronbach's alpha and uses the logit value rather than a raw value.[37]

1.3.2.7 Rasch Analysis Plan

Analysis Plan: The analysis plan followed the same recommendations used by a similar study for the examination of polytomous rating scales using Rasch analysis.[38,48] This analysis plan will be used in Chapter 2 and 3.

1. To determine the appropriate Rasch model to use, a log-likelihood ratio test was performed. The purpose of the log-likelihood ratio test is to take the unrestricted parameterization of the model (i.e. no contains were placed on the items parameters) and assess it against the rating re-parameterization of the same model.[49]
2. A statistically non-significant result indicates that the rating scale model should be used, whereas a statistically significant result indicates that the partial credit model should be used instead.[38]
3. Category probability plots were constructed to establish the category thresholds for the rating scale. The re-scoring of disordered thresholds were corrected by collapsing categories then re-constructing the probability plots to ensure that the disordered thresholds were eliminated.[38]
4. Item fit was evaluated by analyzing the item fit residual statistics and an item-trait interaction Chi-Square statistic.[38] Item fit z-score transformed residuals between ± 2.5 are deemed to indicate adequate fit to the model.[38]
5. Person fit was evaluated by using the same procedure as above for item fit.
6. The Person Separation Index (PSI) is a measure of reliability and is interpreted in the same way as Cronbach's alpha.[36,38] The PSI determines the number of distinct subgroups within the data set, the number of comparative groups exist within the data set and if the rating scale is sufficiently robust to allow for group or individual comparisons.[38,50]
7. Differential Item Functioning (DIF) was then evaluated to determine if different groups of respondents, who possessed equal levels of the trait being measured, responded differently to the question.[36,38,51] DIF was evaluated by examining the item residuals statistically with a between groups analysis of variance (ANOVA), and graphically by plotting item characteristic curves (ICC) for sex.[37,38,51]

8. To check for local dependency within the items, an analysis of the correlation of item residuals was performed.[38] This analysis looked for correlations > 0.2 above the mean which identified response linked items.[37,38]
9. The unidimensionality of the subscales was analyzed in order to verify that each scale was only measuring one underlying construct.[36,48,52] Factor analysis was performed to evaluate principle component item loadings and then paired t-tests were conducted using the positively and negatively loaded items.[36,38] Unidimensionality is present if the percentage of significant t-test (at $P < 0.05$) is less than 5%.[36–38,52,53]

1.3.3 Responsiveness

The responsiveness of a measurement can be defined two different ways, internal and external responsiveness. The internal responsiveness of a measurement is the ability of a measure to change over time where external responsiveness is the extent to which changes in the measurement over time relate to the corresponding changes in health status.[54] There is considerable disagreement regarding the best measure of responsiveness and the most frequently used measurements of responsiveness relate to internal not external responsiveness.[54] There are three common approaches to measure internal responsiveness: paired t-test (used to test the hypothesis that no change occurred in the average response on a measure between two time points), effect size statistics (the difference between the mean baseline scores and follow-up scores on the measure) and standardized response mean (SRM; ratio of observed change and the standard deviation to reflect the variability of the change scores).[54] Of the three most common options, none have been identified as being the best or most preferred and preference should be given based on opinion and study design. [54]

1.3.4 Minimal Clinically Important Differences

Self-reported rating scales provide clinicians with a standardized method of tracking symptoms or other measures of health by allowing patients to provide a subjective rating of their health. One method that can be used to determine if the patient

has experienced a change in health status is the minimal clinical important difference (MCID).[55] The MCID is an estimation of the smallest change in the measure that could be considered clinically important and represents a meaningful change in health status.[56] Two approaches, distribution or anchor based can be taken to estimate the MCID. The distribution based estimations uses the standard deviation, standard error of the mean and effect size where the anchor based approaches use the patient or clinician as a reference anchor to determine clinical improvement or recovery and compares this measure with the baseline measure.[57] The anchor based approach is preferred as it takes into account other clinical factors not captured by the measure being investigated.[57]

In order to determine if the MCID is significant and representative of a true clinical change the minimal detectible change (MDC) must be obtained. If the MCID estimate is larger than the MDC estimate then the MCID can be considered to be a reliable representation of true clinical change and not a result of change or error.[58,59]

1.3.4.1 MCID Analysis Plan

The same analysis plan is used in Chapters 4 and 5. Individuals completed the 22 item SCAT5 symptom evaluation during their initial visit (T1) and their responses during the final, clearance appointment were used as the final values (T2) and physician's determination of recovery from the concussion was used as the anchor. Due to the unique nature of each individual's concussion the 22 symptoms are not always endorsed and responses who did not endorse a symptom at T1 were not included in the calculation.[3] The MCID was determined using a clinical anchor based approach (physician judgement) and calculated by subtracting each individual's T2 score from their T1 score for each symptom, total of all symptom scores and number of symptoms endorsed and then obtaining a mean score for each symptom.[60] The standardized response mean, or Responsiveness-Treatment (RT) coefficient was calculated by dividing the mean change in score by the standard deviation for each symptom and is interpreted in the same manner as effect size (< 0.20 trivial, 0.20-0.50 small, 0.50-0.80 moderate, > 0.80 large).[54,61] The MED was calculated by multiplying the standard error of the mean by 1.96 then multiplying this value by the square root of 2.[62]

1.3.5 Qualitative Interview/Survey

One of the most important early stages of test development is the development, review and piloting of the items to ensure that use simple language, do not have ambiguous meanings, not be leading or create a prestige bias.[34] In order to accomplish this, items should be generated by interviewing a representative population to determine the key items that relate to the topic, then another representative population should be interviewed to determine their personal opinion on the items generated from the first group finally the results should be aggregated and group into unidimensional scales for each latent trait.[34] Additionally, a systematic review of literature and content experts can be used to further refine the raw results which then can be used to generate the actual items.[34] One method that can be used to survey the representative groups is a qualitative interview.[63] A qualitative interview allows subjects to provide open-ended answers to guided questions or prompts in order to determine their interpretation, opinion or understanding of a topic. Qualitative interviews can be administered in-person, over the phone or through self-interviews where the respondents record their answers on paper or on a computer.[63] Through qualitative interviews, the content validity of the tool can be established ensuring that the tool is a representative measurement of the concepts it is intended to measure.[64]

Once survey or interview data is compiled the results can be subjected to thematic analysis in order to identify, analyses and report patterns within the responses to the open-ended questions. Once these themes are identified, the common responses can be identified providing justification to the phrasing of items.[65]

1.4 Relevance and Objective

The motivation for this thesis arose from a clinical question that I started developing early in my clinical career. I am a Certified Athletic Therapist and while working at a high school in West Virginia I started to question the reliability of the baseline responses to the SCAT3 symptom evaluation and conducted a study to evaluate the day to day reliability of the baseline symptom evaluation. I was fortunate enough to present this

study at the 5th Conference on Concussion in sport in Berlin, Germany. I wanted to continue to study and improve the SCAT5 symptom evaluation as it is freely available and is widely used by clinicians all over the world. The improved accuracy will help increase the trust athletes have in the process as the over diagnosis of concussion can be as dangerous as it can result in unnecessary time away from sport and discourage athletes from bring forthcoming with reporting their concussion or symptoms.

This literature review has provided the necessary theoretical background to understand concussions, concussion assessment, clinical test development and psychometric measurement. While this literature review is extensive is does not represent a complete review of all facets of the topics in question but does provide the necessary rationale and framework for the following studies. As there is an increased awareness of concussion in sport there is a need to ensure that the clinicians tasked with assessing and managing concussions have access to the most reliable, valid and clinically relevant tools possible in order to effectively fulfill their mandate. The most commonly used of these tools, symptom checklists, provide patients with a standardized method to express the presence and severity of symptoms to clinicians while ensuring they are not omitting the reporting of potential concussion symptoms. Of all of the available symptom checklists, the adult and child versions of the 5th version of the Sport Concussion Assessment Tool symptom evaluation are widely distributed and employed worldwide. Due to the nature of the development of these two symptom checklists, little is known regarding the psychometric and measurement properties of them and their development did not use an accepted test development methodology.

Due to the lack of evidence regarding the validity and reliability of the Adult and Child-SCAT5 symptom evaluation it was hypothesized that there would be significant issues with the psychometric properties of both tools when subjected to an examination of their psychometric and measurement properties. The objectives of the following studies is to examine the psychometric and measurement properties of the adult SCAT5 symptom evaluation, to examine the psychometric and measurement properties of the Child SCAT5 symptom evaluation, to determine the minimal clinically important differences and responsiveness for the items, total symptom score and total number of

symptoms endorsed for the adult SCAT5 symptom evaluation and the Child SCAT5 symptom evaluation and finally the underlying interpretation of the items that comprise the adult SCAT5 will be explored using a qualitative survey approach. This multifaceted approach to evaluating the psychometric and measurement properties of the adult SCAT5 symptom evaluation and Child SCAT5 symptom evaluation should permit the identification of any significant measurement issues and provide the necessary framework to correct them resulting in a more valid and reliable tool that clinicians and individuals can trust and rely on.

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Chapter 2

2 Measurement properties of the Adult Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation using Rasch analysis

2.1 Introduction

The Sport Concussion Assessment Tool (SCAT) was originally developed during the 2nd International Conference on Concussion in Sport in 2004 and was revised in 2008, 2012 and 2016 during subsequent conferences.[1,2] The most current version, the SCAT5, was updated during the 5th International Consensus Conference on Concussion in Sport with the symptom evaluation not having a material change since it was originally developed.[1,3] The SCAT was intended to be a standardized tool used during the assessment of a sports concussion as well as an educational tool.[2] The SCAT was not developed using accepted psychometric techniques, rather it was developed by a group of experts by combining 8 existing tools: Sideline evaluation of concussion, Management of concussion sports palm card, Standardized assessment of concussion, Sideline concussion check, McGill abbreviated concussion evaluation, National Hockey League physician evaluation form, UK Jockey Club assessment of concession and the Maddocks questions.[1,3]

The SCAT5 is comprised of 5 sections: immediate on field assessment, symptom evaluation, cognitive screening, neurological screening and delayed recall. Next to a clinical examination, symptom evaluations are the most commonly used tool by clinicians when assessing or managing a concussion.[1,4] The symptom evaluation is comprised of 22 symptoms on a 7-point Likert-scale, from 0 to 6.[2] The symptoms that comprise the SCAT5 are: headache, pressure in head, neck pain, nausea or vomiting, dizziness, blurred vision, balance problems, sensitivity to light, sensitivity to noise, feeling slowed down, feeling like in a fog, don’t feel right, difficulty concentrating,

difficulty remembering, fatigue or low energy, confusion, drowsiness, more emotional, irritability, sadness, nervous or anxious and trouble falling asleep.[3]

The methodology for developing clinical tests is well established and a systematic process should be followed to ensure construct validity of the items that comprise the test.[5,6] Irwing and Hughes offers a multi-step process beginning with defining the construct to be tested and the specifications of the test, developing a comprehensive plan, develop and review items, construct a scale using Item Response Theory (IRT), assess the test for reliability and validity finishing with implementation and testing.[5,6] The original SCAT and subsequent revisions did not follow a systematic process, rather deferring to consensus from content experts and lacking an evaluation of the test's psychometric properties in order to ensure that the test is a reliable and valid measure of concussion symptoms.[1,2]

2.1.1 Rasch

The Rasch model, developed by George Rasch, is a mathematical measurement model used to evaluate rating scales. This model assumes that person-level responses to an individual item allows for the estimation of their actual position on the continuum of the latest construct with this position being estimable only by their responses to each individual item.[7,8] Rasch analysis separates persons by their location on a theoretical continuum of the underlying construct by locating the response thresholds between adjacent response options for each item long a logit continuum. The scale is then tested against the Rasch model using the logit based location, and once the scale is fitted to the model, the position of the response thresholds can be transformed from an ordinal to interval scale.[7,8]

Rasch analysis requires the ordering of all possible response options to all items and all persons on a unit-less logit continuum representing the levels of the latent construct. The hypothesis that persons located higher on the continuum shoulder show a higher likelihood of choosing response options that are also located on the higher end of the same continuum is then tested using Guttmann Scaling.[7,9] Guttmann scaling is a deterministic pattern with strict hierarchical ordering of items that assumes that there is

agreement with all items of lower rank when a particular item is endorsed.[7,9] Rating scales that are evaluated using Rasch analysis can then be psychometrically evaluated for consistency, reliability and responsiveness.[7,9,10]

2.1.2 Fit Statistics

Rasch analysis uses three different types of fit statistics, two item-personal interaction statistics and one item-trait interaction statistic.[9,11] The item-person interaction statistics provide a summary of all the item or person deviations from the Rasch model and accomplishes this by standardizing the fit residuals (the difference between the observed and expected scores) to approximate a Z-Score (with Z-scores ±2.5 indicating an adequate fit to the model).[9,11,12] Two Chi-Square ratios and infit and outfit mean squares statistics are used to determine how well the data fits the requirements of the Rasch model.[12] The Chi-square values are divided by their respective degrees of freedom in order to establish a ratio scale with an excepted value of +1 and a range of 0 to infinity.[12] For the item-trait interactions, Chi-square values for each of the individual items are obtained, combined then evaluated for statistical significant using the summed degrees of freedom.[9,11] The Chi-square statistics should indicate a non-significant deviations from the Rasch model after adjustments for multiple tests.[9,11]

2.1.3 Unidimensionality

Unidimensionality is the ability of the rating scale to focus on and measure one attribute at a time.[7,12] Principal Component Analysis (PCA) is one method that can be used to detect signs of multidimensionality by evaluating the residuals for meaningful patterns, with the absence of meaningful patterns indicating unidimensionality.[13,14]

2.1.4 Category Thresholds

Category thresholds of rating scales are the point at which a person is equally likely to select two adjacent response options.[15,16] The examination of category thresholds involves the inspection of category probability curves to determine if the response probabilities are arranged in ascending order concordant with the categories, which

would indicate ordered thresholds. If response probabilities are in reverse order, this would indicate the presence of disordered thresholds.[15,17] Too many response options or poor category definitions are sources of disordered categories which can result in item misfit due to inconsistent responses from patients.[15,16] When disordered thresholds are often identified when there are too many response options and can usually be resolved by collapsing responses so long as some general guidelines are followed.[15,16] The collapsed category thresholds must be logical and there should be an attempt to create a uniform frequency distribution across the new categories.[12] The reliability and validity indicators of the collapsed category thresholds should be re-assessed in order to evaluate the overall functioning of the new rating scale.[12]

2.1.5 Differential Item Functioning and Item Bias

Differential item functioning (DIF), or item bias, occurs when different groups possess comparable levels of the trait being measured but respond differential to the individual items.[9,18,19] There are two types of DIF that can be identified using Rasch analysis, uniform and non-uniform.[8] Uniform DIF occurs when the group displays a consistent difference in their responses whereas nonuniform DIF occurs when group displays inconsistent differences in their responses.[8,9,18] Uniform DIF can be resolved by splitting items into different person factor groups where the DIF was identified. An alternative approach to resolving uniform DIF is to group the items together in a subtest to determine if the DIF cancels out at the test level.[13] Non-uniform DIF requires the removal of the particular item.[9,20] If any modifications to resolve DIF are implemented the remaining items should be retested to determine if it had an affect to the scale or results in issues with statistical power.[8,9,13,15]

2.1.6 Local Independence

Local independence is a critical assumption of the Rasch model and uses response dependency which occurs when items are linked in such a manner that sees the response to an item determining the response to another item.[8,9,13] The relationship between the underlying construct for each item was identified by examining the residual correlation

matrix and correlations less than 0.2 above the average are considered acceptable to fit the Rasch model.[9,14,21]

2.1.7 Person Separation Index

The person separation index, PSI, is an indication of reliability and reflects the ability to differentiate between different levels of the underlying construct.[8,9] The PSI is interpreted in the same manner as Cronbach's alpha and is calculated in a similar fashion using logits rather than the raw values.[8]

2.2 Methods

2.2.1 Participants

This study is based on data collected using the Concussion Electronic Data Collection System as part of a concussion data registry collection project at the Fowler Kennedy Sports Medicine Clinic in London, Ontario using the REDCap electronic data capture tool.[22] A total of 284 subjects were included (130 males, 154 females, mean age 20.8 ±10.4 years) and a total of 810 responses for the SCAT5 symptom evaluation being used for the analysis. Participants had to be 13 years of age or older and must have been diagnosed with a concussion by a primary care physician practicing in sport and exercise medicine who had e a diploma in sport and exercise medicine from the Canadian Academy of Sport and Exercise Medicine.

2.2.2 Procedure

The objective of the analysis plan is to subject the SCAT5 data set to Rasch analysis using RUMM 2030. To accomplish this first the data set was imported into RUMM 2030 version 5.4 (RUMM Laboratory Pty Ltd, Perth, Australia). Then the SCAT5 symptom evaluation data was evaluated for construct validity by using Rasch analysis to evaluate it for unidimensionality and reliability, for fit to the Rasch model by examining the interval properties and ordering of item thresholds of the items and to

determine if there was an sex-linked item bias. The analysis plan followed the steps outlined in Chapter 1.3.2.7.

2.3 Results

2.3.1 Fit to the Rasch Model

The results of the Log-likelihood ratio were significant therefore the unrestricted partial credit model was used. Table 2-1 displays the results of the Rasch analysis for all items, after splitting for DIF and after removing items for DIF. Analysis of the fit of the SCAT5 Symptom Evaluation to the Rasch model determined a significant chi-square value for item-trait interaction in all 3 instances: all items (χ (198) 547.3075 p = 0), split for DIF (χ (297) 650.1402 p = 0) and removed for DIF (χ (99) 239.7029 p = 0). The statistically significant chi-square results suggest that the SCAT5 symptom evaluation data does not adequately fit the Rasch model despite the attempts to correct for DIF.

Table 2-1: Rasch Tracking Table

	Item Fit Residual[1]		Person Fit Residual[1]		Chi-Square[2]		PSI[3]		UNID T-Test[4]
					DF	p	With	Without	
All Items	0	0.5621	-0.708	3.2425	547.3075		0.92101	0.9273	17.15%
					198	0			
Split for DIF	0	0.6599	-0.7543	2.7102	650.1402		0.92214	0.92871	N/A
					297	0			
Removed for DIF	0	0.2989	0.6388	2.55	239.7029		0.8526	0.85368	9.73%
					99	0			

1. The fit residuals should have mean of 0 ± 2.5 and a standard deviation of 1 ± 2.5.
2. The Chi-Square statistic should be small and statistically non-significant.
3. A Person Separation Index (PSI) or Cronbach's Alpha should be >0.70 to be statistically reliable.
4. Unidimensionality is present if the percentage of statistically significant t-tests is <5%.

2.3.2 Distribution of Responses

An analysis of the initial frequency of item endorsements (displayed in table 2-2) revealed that all items and categories were endorsed at least once with 2 categories falling below the recommended endorsement frequency of at least 5. An analysis of the final frequency of item endorsements (displayed in table 2-3) revealed that all items and categories were endorsed at least once with 2 categories falling below the recommended endorsement frequency of at least 5.

Table 2-2: Frequency of initial item endorsements

Item	Frequency						
	0	1	2	3	4	5	6
Headache	112	135	156	138	168	65	19
Pressure in head	166	189	130	121	114	53	20
Neck Pain	255	149	116	113	88	44	28
Nausea or vomiting	535	122	55	42	23	9	7
Dizziness	376	166	105	86	33	21	6
Blurred vision	555	114	59	32	24	8	1[a]
Balance problems	432	169	80	60	37	11	4[a]
Sensitivity to light	202	233	129	105	51	50	23
Sensitivity to noise	279	174	146	85	63	33	13
Feeling slowed down	262	193	123	89	55	52	19
Feeling like in a fog	385	138	101	69	49	37	14
Don’t feel right	233	188	113	100	64	59	36
Difficulty concentrating	180	178	123	96	99	65	52
Difficulty remembering	301	157	126	80	60	35	34
Fatigue or low energy	186	187	139	111	86	52	32
Confusion	452	154	68	62	31	19	7
Drowsiness	352	152	104	88	52	31	14
More emotional	384	121	97	71	58	38	24
Irritability	300	163	123	73	60	51	23
Sadness	445	128	89	52	42	24	13
Nervousness or Anxiousness	307	166	133	80	56	34	17
Trouble Falling Asleep	334	147	96	77	56	45	38

a Falls below recommended levels.

Table 2-3: Frequency of final item endorsements

Item	Frequency						
	0	1	2	3	4	5	6
Headache	112	135	156	138	168	65	19
Pressure in head	166	189	130	121	114	53	20
Neck Pain	255	265	113	88	44	28	
Nausea or vomiting	535	177	81				
Dizziness	376	166	105	86	33	21	6
Blurred vision	555	173	56	8	1		
Balance problems	432	169	80	60	37	11	4[a]
Sensitivity to light	202	233	129	105	51	50	23
Sensitivity to noise	279	174	146	85	63	33	13
Feeling slowed down	262	193	123	89	55	52	19
Feeling like in a fog	385	138	101	69	49	37	14
Don’t feel right	233	188	113	100	64	59	36
Difficulty concentrating	180	178	123	96	99	65	52
Difficulty remembering	301	283	175	34			
Fatigue or low energy	186	187	139	111	86	52	32
Confusion	452	154	68	62	31	19	7
Drowsiness	352	152	104	88	52	31	14
More emotional	384	218	191				
Irritability	300	163	123	73	60	51	23
Sadness	445	217	131				
Nervousness or Anxiousness	307	166	133	80	56	34	17
Trouble Falling Asleep	334	243	216				

a Falls below recommended levels.

2.3.3 Category Thresholds

The initial category thresholds for the SCAT5 symptom evaluation were disordered. These items were re-scored by collapsing the categories until a logical sequence of difficulty levels was achieved. This resulted in a decreased number of response categories as illustrated in table 2-4 for the 7 items.

Table 2-4: Re-scoring of disordered thresholds

Item	Re-Scored	Scale						
		0	1	2	3	4	5	6
Headache	No	0	1	2	3	4	5	6
Pressure in head	No	0	1	2	3	4	5	6
Neck Pain	No	0	1	2	3	4	5	6
Nausea or vomiting	Yes	0	1	1	2	3	4	5
Dizziness	Yes	0	1	1	2	2	2	2
Blurred vision	No	0	1	2	3	4	5	6
Balance problems	Yes	0	1	1	2	2	3	4
Sensitivity to light	No	0	1	2	3	4	5	6
Sensitivity to noise	No	0	1	2	3	4	5	6
Feeling slowed down	No	0	1	2	3	4	5	6
Feeling like in a fog	No	0	1	2	3	4	5	6
Don’t feel right	No	0	1	2	3	4	5	6
Difficulty concentrating	No	0	1	2	3	4	5	6
Difficulty remembering	No	0	1	2	3	4	5	6
Fatigue or low energy	Yes	0	1	1	2	2	2	3
Confusion	No	0	1	2	3	4	5	6
Drowsiness	No	0	1	2	3	4	5	6
More emotional	No	0	1	2	3	4	5	6
Irritability	Yes	0	1	1	2	2	2	2
Sadness	No	0	1	2	3	4	5	6
Nervousness or Anxiousness	Yes	0	1	1	2	2	2	2
Trouble Falling Asleep	No	0	1	2	3	4	5	6

2.3.4 Individual Person Fit

The initial person fit residual mean and standard deviation, -0.71 and 3.24 respectively, is outside the tolerances for fitting to the Rasch model (the mean should be ±2.5 and the standard deviation should be 1 ±2.5). After attempting to correct for DIF by splitting and removing items the person fit residual mean and standard deviation still fall outside the tolerances for fitting to the Rasch model. Splitting for DIF yielded a mean of -0.7543 and a standard deviation of 2.7102 while removing items yielded a mean of -0.6388 and a standard deviation of 2.55.

2.3.5 Individual Item Fit

The item fit residual mean and standard deviation, 0 and 0.5621 respectively, is within the tolerances for fitting to the Rasch model (the mean should be 0 ±2.5 and the standard deviation should be 1 ± 2.5). Items that displayed fit residuals greater than ±2.5 with a Bonferroni correction of $p < 0.01$ were reviewed. Items flagged as not fitting the Rasch model due to their mean fit residuals were: "Neck Pain" ($z = 8.96$), "Sensitivity to noise" ($z = 3.13$), "Feeling slowed down" ($z = -5.51$), "Feeling like in a fog" ($z = -3.10$), "Don't feel right" ($z = -5.68$), "Difficulty concentrating" ($z = -4.22$), "More emotional" ($z = -3.34$) and "Sadness" ($z = -2.92$). After attempting to correct for DIF the item fit residual mean remained at 0 for both cases and the standard deviations were acceptable for fitting to the Rasch model (split SD 0.6599, removed SD 0.2989).

2.3.6 Person Separation Index

Cronbach's alpha was calculated at 0.95 with a PSI of 0.92 for all items after the disordered thresholds were re-scored. Splitting for DIF yielded PSI of 0.92 for all items (due to missing data no Cronbach's alpha is reported) and removing for DIF yielded a Cronbach's alpha of and a PSI 0.88 of 0.8526 for all items.

2.3.7 Local Dependency

Local dependence was identified in 15 pairs of items indicating that there is a response dependency between the pairs of items.

Table 2-5: Item Pairs Exhibiting Local Dependence

Item 1	Item 2
Headache	Pressure in head
Dizziness	Blurred vision
Dizziness	Balance problems
Sensitivity to light	Sensitivity to noise
Feeling slowed down	Feeling like in a fog
Feeling slowed down	Don’t feel right
Feeling slowed down	Fatigue or low energy
Feeling like in a fog	Don’t feel right
Difficulty concentrating	Difficulty remembering
Difficulty concentrating	Confusion
More emotional	Irritability
More emotional	Sadness
More emotional	Nervousness or Anxiousness
Irritability	Sadness
Sadness	Nervousness or Anxiousness

2.3.8 Differential Item Functioning (DIF)

Uniform DIF for sex was detected in 11 items: "Dizziness", "Blurred vision", "Balance problems", "Sensitivity to light", "Feeling slowed down", "Feeling like in a fog", "Don't feel right", "Difficulty concentrating", "Confusion", "More emotional" and "Irritability". Non-uniform DIF for sex was only detected in 1 item: "Dizziness".

2.3.9 Unidimensionality

The complete SCAT5 Symptom Evaluation failed the test of unidimensionality as 17.15% of the t-tests performed were significant which is greater than the 5% cutoff. After removing items that were displaying DIF there was still a failure of the test of unidimensionality with 9.74% of the t-tests being significant.

2.4 Discussion

2.4.1 Summary

The SCAT5 symptom evaluation exhibits high reliability (PSI > 0.80) and is able to differentiate between at least 4 levels of the underlying construct.[15,23] The obtained item fit residual statistics are < 2.5 suggesting a redundancy within the items. Overall, the SCAT5 symptom evaluation exhibits a poor fit to the Rasch model due to the multidimensionality, poorly fitting items, redundancy within items and multiple biased items.

2.4.2 Item Endorsement and Category Thresholds

The evaluation of the initial item endorsement frequencies revealed two items and one category with unacceptably low values. After the disorganized category thresholds were collapsed, the same two items still had unacceptably low endorsement frequencies for the largest magnitude category. Of the 22 items, 7 required categories to be collapsed due to disorganized category thresholds.

2.4.3 Local Dependency

Local dependence was identified in 15 pairs of items indicating a response dependency between the pairs of items. This suggests that the pairs of items are linked in such a manner the response for one item determines the response to the paired item. Using the overlapping clinical profiles of concussion as described by Harmon et al. the common clinical profiles for each pair were identified and displayed in table 6.[24] In all 15 pairs there is at least one overlapping clinical profile for each symptom suggesting that

the observed response dependence in the item pairs may be representative of components of the underlying construct being measured rather than a duplication of the same construct.

Table 2-6: Item pairs that displayed local dependence with the associated overlapping clinical profiles

Symptom Pairs	Common Clinical Domains	
Headache	Anxiety-Mood	Headache-Migraine
Pressure in head		
Dizziness	Ocular	
Blurred vision		
Dizziness	Ocular	Vestibular
Balance problems		
Sensitivity to light	Headache-Migraine	
Sensitivity to noise		
Feeling slowed down	Cognitive	
Feeling like in a fog		
Feeling slowed down	Fatigue	Cognitive
Don’t feel right		
Feeling slowed down	Fatigue	Cognitive
Fatigue or low energy		
Feeling like in a fog	Vestibular	Cognitive
Don’t feel right		
Difficulty concentrating	Cognitive	
Difficulty remembering		
Difficulty concentrating	Fatigue	Cognitive

Confusion		
More emotional	Anxiety-Mood	
Irritability		
More emotional	Anxiety-Mood	
Sadness		
More emotional	Anxiety-Mood	
Nervousness or Anxiousness		
Irritability	Anxiety-Mood	
Sadness		
Sadness	Anxiety-Mood	
Nervousness or Anxiousness		

2.4.4 Differential Item Functioning (DIF)

Of the 22 items that comprise the SCAT5 symptom evaluation only 10 items exhibited uniform DIF for sex and one of the items exhibited both uniform non-uniform DIF for sex. The 10 items that exhibited uniform DIF suggest that there is a increased probability of an individual endorsing a symptom based on their sex and this increased endorsement is consistent across all individuals of that sex. Uniform DIF for sex was detected in 11 items: "Dizziness", "Blurred vision", "Balance problems", "Sensitivity to light", "Feeling slowed down", "Feeling like in a fog", "Don't feel right", "Difficulty concentrating", "Confusion", "More emotional" and "Irritability". One of the items, dizziness, exhibited both uniform and non-uniform DIF meaning there is inconsistent endorsement of the item by males and females depending on the location on the continuum of the underlying construct. This may be problematic as it may suggest that endorsement of the item is sex linked depending on the severity of the symptom.

Two attempts were made to correct for DIF, splitting and removing the items.[8] Splitting the items for DIF separates each of the 11 items into two distinct items, one for males and one for females allowing for a different item difficulty based on sex. Splitting the items for DIF did resolve the uniform DIF that was detected however, it did not improve the overall fit to the Rasch model. Removing the items exhibiting DIF involved removing the items from the symptom evaluation all together without having an impact on the person fit residual standard deviation's fit to the Rasch model.

While DIF can often be accepted if there is a logical reason or intended bias within the item this is not the case for the SCAT5 symptom evaluation. There was no intention to include a sex-linked bias within the items nor is there a logical reason to explain why there is uniform DIF within them.

2.4.5 Unidimensionality

The unidimensionality of the SCAT5 symptom evaluation was examined to ensure that the scale is targeted towards one main construct and is consistently only measuring that construct. The initial t-tests resulted in 17.15% being significant and the t-tests performed after removing items for DIF resulted in 9.73% being significant. Both irritations are violations of the Rasch model and suggest that the scale is measuring multiple constructs.

2.4.6 Person Separation Index and Reliability

The initial Cronbach's alpha and PSI were 0.95 and 0.92 and removing items for DIF the obtained values were 0.88 and 0.8526 respectively. The strong initial PSI and Cronbach's alpha suggests that the scale is capable of differentiating between at least 4 levels of patients, has good reliability but may contain redundant questions (as the values are < 0.9) which is supported by identification of 15 pairs of items with response dependencies.[14,25] The PSI and Cronbach's alpha obtained after removing items for DIF fell below the redundancy threshold but is still capable of differentiating between at least 4 levels of patients and has good reliability.[14,25]

2.5 Conclusion

The SCAT5 symptom evaluation exhibits a poor fit to the Rasch model, suggesting that there are psychometric issues with the scale and further analysis and refinement is required in order to improve its reliability and validity. The validity of the SCAT5 is questionable as the scale is multidimensional, has poor fitting items, and exhibits sex linked differential item functioning. The SCAT5 does possess good reliability and is extremely capable of differentiating different levels of patients but does require refinement in order to reduce the number of redundant items and better target the scale. The identification of sex-linked items also suggests the need for scale redevelopment and may require the development of sex specific versions of the scale.

Interestingly, the 15 pairs of response dependent items all have overlapping clinical profiles which is the manifestation of the item redundancy identified by the strong PSI and Cronbach's alpha. Further investigation of these items is required to produce more independent and valid items. However, the overlapping clinical profiles may have been intentional as the items were all included due to their representation of larger, parent categories and high reporting frequency.[26]

In conclusion, the SCAT5 symptom evaluation is a reliable scale but is not the valid measure of concussion it purports to be. The poor fit to the Rasch model is likely due to the lack of systematic development and failure to follow traditional stages of test development. Of the 10 stages identified by Irwing and Hughes, the SCAT5 only completed the initial stage defining the construct and specifications of the test replacing a systematic process for the development of items to ensure construct validity with input from content experts achieving content validity. Using the already established framework, and following a systematic process, the validity of the SCAT5 symptom evaluation can be improved resulting in an increase in trust by clinicians and providing more effective and targeted care to patients.[6]

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Chapter 3

3 Measurement properties of the Child Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation using Rasch analysis

3.1 Introduction

Concussions comprise between 1.6-3.8 million sport-related injuries annually in the United States and between 2009 and 2016 there were 8934 diagnosed concussions in youth under the age of 18 in Ontario, Canada.[1–4] A concussion is a traumatic brain injury caused by a biomechanical force either directly to the head, face, neck or somewhere else on the body that causes the force to be transmitted to the head. A concussion will result in the rapid onset of transient symptoms, short-term impairment of neurological function that is functional and is not detected using neuroimaging studies.[5] In order to accurately diagnose and manage a concussion, a multifaceted approach using assessment tools, symptom evaluation checklists and clinical judgement.[5,6] Second only to a clinical examination, symptom checklists are the next most widely used tool for clinical assessment and management of concussions.[5,6]

The Child SCAT5 is the second and most recent version of the pediatric version of the Sport Concussion Assessment Tool. The first version, the Child SCAT3, was developed during the 4th International Consensus Conference on Concussion in Sport in 2012 by an expert panel using the principles used to develop the adult version.[7] Similar to the SCAT5, the Child SCAT5 was not developed using traditional psychometric techniques and relied in the consensus of the expert panel instead.[7,8] The Child SCAT5 was intended to be a standardized tool used to aid in the assessment and management of sport concussion in children between the ages of 5 and 12.[9] The Child SCAT5 is comprised of 5 sections: an on-field evaluation section, a child and parent symptom evaluation, a cognitive screening section that includes memory and concentration tasks, a neurological screening section that includes the modified balance error scoring system accompanied by some basic screening questions, a delayed memory recall section and a final decision section to summarize the results.[7,9] The Child SCAT5 represents the second

version and was modified from the Child SCAT3 during the 5th International Consensus Conference on Concussion in Sport.[10] Major differences between the two versions include the removal of the modified Maddocks questions, a recommendation to administer the symptom evaluation with the child in a resting state, the inclusion of an overall rating scale, removal of the orientation questions, the inclusion of 2 additional digit backwards lists with an additional 2 digit string in each, a rapid neurological screening section, and the inclusion of the most recent return to school and play guidelines.[10,11]

The Child SCAT5 symptom evaluation is one of the only sections that differs dramatically from the adult version of the SCAT5. The Child SCAT5 splits the symptom evaluation section into a child and adult report and consists of 21 pairs of statements/symptoms and asks the child and parent to rate the frequency of the symptom (rather than the severity as in the case of the adult version of the SCAT5) on a 4 point Likert-scale from 0-4 (0 – not at all, 1 – a little\rarely, 2 – somewhat\some, 3 – a lot\often).[10,11] The pairs of symptom statements that comprise the Child SCAT5 are displayed in Table 3-1.[11]

Table 3-1: List of Symptoms that Comprise the Child and Adult (Parent/Guardian) Sections of the Child SCAT5 Symptom Evaluation

Child Section	Adult (Parent/Guardian) Section
I have headaches	has headaches
I feel dizzy	feels dizzy
I feel like the room is spinning	has a feeling that the room is spinning
I feel like I'm going to faint	feels faint
Things are blurry when I look at them	has blurred vision
I see double	has double vision
I feel sick to my stomach	experiences nausea
My neck hurts	has a sore neck
I get tired a lot	gets tired a lot
I get tired easily	gets tired easily
I have trouble paying attention	has trouble sustaining attention
I get distracted easily	is easily distracted
I have a hard time concentrating	has difficulty concentrating
I have problems remembering what people tell me	has problems remembering what he/she is told
I have problems following directions	has difficulty following directions
I daydream too much	tends to daydream
I get confused	gets confused
I forget things	is forgetful
I have problems finishing things	has difficulty completing tasks
I have trouble figuring things out	has poor problem-solving skills
It's hard for me to learn new things	has problems learning

Clinical tests are normally developed by following a well-established methodology in order to ensure that the test is reliable and valid, and to prove clinicians with clinical tools that they can trust when used in production environments.[8,12] One proposed methodology by Irwing and Hughes outlines a multi-step process: the construct to be tested is identified and defined, the specifications of the test are developed, a comprehensive plan is developed, items are developed and reviewed, the scale is constructed using a technique like Item Response Theory (IRT), the reliability and validity of the test is measured, finally the completed test is subjected to testing by clinicians in clinical-teaching environments and then published and implemented.[8,12] The Child SCAT5 did not follow this type of methodology, rather relied on the consensus from a group of invited content experts and no attempt to evaluate the final test's psychometric properties was attempted.[7,9,11]

3.1.1 Rasch

The Rasch model is a mathematical measurement model developed by George Rasch that us used to evaluate rating scales. The Rash model assumes that person-level responses to individual items permits the estimation of their actual position on a logit-based continuum of the latent construct. Rasch analysis requires persons to be separated by their location on this theoretical continuum by the response thresholds between adjacent options for each item. The scale is then tested against the Rasch model using the logit-based location and once the scale fits the model the category thresholds can be then transformed from an ordinal to interval scale.[13,14]

Rasch analysis requires the ordering of all possible response options to all items and all persons on a unit-less logit continuum representing the levels of the latent construct. Rasch analysis assumes that persons located higher on the continuum shoulder show a higher likelihood of choosing response options that are also located on the higher end of the same continuum is then tested using Guttmann Scaling.[13,15] Guttmann scaling is a deterministic pattern with strict hierarchical ordering of items that assumes that there is agreement with all items of lower rank when a particular item is endorsed.[13,15] Rasch analysis allows for the of rating scales to be\e psychometrically evaluated for consistency, reliability and responsiveness.[13,15,16]

3.1.2 Fit Statistics

Two types of fit statistics are taken into account: two item-personal interaction statistics and one item-trait interaction statistic.[15,17] The item-person statistics provide a summary of all the item or person deviations from the Rasch model and accomplishes this by standardizing the fit residuals (the difference between the observed and expected scores) to approximate a Z-Score (with Z-scores ±2.5 indicating an adequate fit to the model).[15,17,18] The item-person statistics are obtained from a Chi-Square ratios and infit and outfit mean squares statistics are used to determine how well the data fits the requirements of the Rasch model.[18] The item-person interaction statistics provide a Chi-square values are divided by their respective degrees of freedom in order to establish a ratio scale with an excepted value of +1 and a range of 0 to infinity.[18] For the item-trait statistics, Chi-square values for each of the individual items are obtained, combined then evaluated for statistical significance.[15,17] In order to fit the Rasch model the the Chi-square statistics should indicate a non-significant deviations.[15,17]

3.1.3 Unidimensionality

In order to evaluate the unidimensionality of a scale Principal Component Analysis (PCA) is used. PCA can be used to detect signs of multidimensionality by evaluating the residuals for meaningful patterns, with the absence of meaningful patterns indicating unidimensionality. [13,18],[19,20]

3.1.4 Category Thresholds

The examination of the category thresholds of a rating scale, or the point at which a person is equally likely to select two adjacent response options, involves the examination of the response probabilities to determine if they are arranged in ascending order concordant with the categories, which would indicate ordered thresholds.[21,22] Disordered thresholds would manifest in a reversed ordering of the response probabilities. This can be caused by too many response options or poor category definitions.[21,22] In order to correct for this the category thresholds can be collapsed however they must be logical and there should be an attempt to create a uniform frequency distribution across the new categories.[18]

3.1.5 Differential Item Functioning and Item Bias

Differential item functioning (DIF), or item bias, occurs when different groups possess comparable levels of the trait being measured but respond differential to the individual items.[15,24,25] Two types of DIF that can be identified using Rasch analysis: uniform and non-uniform.[14] Uniform DIF occurs when the group displays a consistent difference in their responses and nonuniform DIF occurs when group displays inconsistent differences in their responses.[14,15,24] Non-uniform DIF requires the item to be removed however uniform DIF can be resolved by splitting the items by person factors or subjecting the items to a subtest to determine if the DIF is eliminated at the test level.[15,19,26]

3.1.6 Local Independence

One of the main assumptions of the Rasch model is local dependence which occurs when items are linked in such a manner that sees the response to an item determining the response to another item.[14,15,19] The correlation between the underlying construct for each item was identified by evaluating the residual correlation matrix and correlations less than 0.2 above the mean are considered to be an acceptable to fit.[15,20,27]

3.1.7 Person Separation Index

The person separation index (PSI), is a measure of reliability and represents a scales ability to differentiate between different levels of the underlying construct.[14,15] The PSI is interpreted in the same manner as Cronbach's alpha and is calculated in a similar fashion but uses logits rather than the raw values.[14]

3.2 Methods

3.2.1 Participants

This study is based on data collected using the Concussion Electronic Data Collection System as part of a concussion data registry collection project at the Fowler Kennedy Sports Medicine Clinic in London, Ontario using the REDCap electronic data capture tool.[28] A total of 44 subjects were included (30 males, 14 females, mean age 10.8

± 1.4) and a total of 93 responses for the SCAT being used for the analysis. Participants had to be between 5 and 12 years of age and must have been diagnosed with a concussion by a primary care physician practicing in sport and exercise medicine who hold a diploma in sport and exercise medicine from the Canadian Academy of Sport and Exercise Medicine.

3.2.2 Procedure

The objective of the analysis plan is to subject the Child SCAT5 data set to Rasch analysis using RUMM 2030. The child and parent sections of the Child SCAT5 symptom evaluation were analyzed independently of one and other as they are two distinct scales. To accomplish this first the data set was imported into RUMM 2030 version 5.4 (RUMM Laboratory Pty Ltd, Perth, Australia). Then the two sections of the Child SCAT5 symptom evaluation was evaluated for construct validity by using Rasch analysis to evaluate it for unidimensionality and reliability, for fit to the Rasch model by examining the interval properties and ordering of item thresholds of the items and to determine if there was a sex-linked item bias. The analysis plan followed the steps outlined in Chapter 1.3.2.7.

3.3 Results

3.3.1 Fit to the Rasch Model

The results of the Log-likelihood ratio for the child section were not significant therefore the rating scale model was used and the results for the adult (parent/guardian) section were significant therefore the unrestricted partial credit model was used. Table 3-2 (child section) and Table 3-3 (adult (parent/guardian) section) display the results of the Rasch analysis for all items, after splitting for DIF and after removing items for DIF. Analysis of the fit of the child and adult (parent/guardian) sections to the Rasch model determined a significant chi-square value for item-trait interaction: child section (χ (42) 75.7193 $p < 0.0005$) and adult (parent/guardian) section (χ (42) 83.2776 $p < 0.0005$). The statistically significant chi-square results suggest misfitting to the Rasch model.

Table 3-2: Rasch Tracking Table

	Item Fit Residual[1]		Person Fit Residual[1]		Chi-Square[2]		PSI[3]		UNID T-Test[4]
					DF	p	With	Without	
Child Section	0	0.9372	-0.5508	1.5546	75.7193		0.8398	0.8474	18.82
					42	0.00			
Adult (Parent/Guardian) Section	0	2.1627	-0.5624	1.3254	83.2776		0.8261	0.8361	19.28
					42	0.00			

1. The fit residuals should have mean of 0 ± 2.5 and a standard deviation of 1 ± 2.5.
2. The Chi-Square statistic should be small and statistically non-significant.
3. A Person Separation Index (PSI) or Cronbach's Alpha should be >0.70 to be statistically reliable.
4. Unidimensionality is present if the percentage of statistically significant t-tests is <5%.

3.3.2 Distribution of Responses

An analysis of the initial frequency of item endorsements (the child section is displayed in Table 3-3 and the adult (parent/guardian) section is in Table 3-4) revealed that the child sections had 3 categories that were not endorsed and 18 categories that fell below the recommended minimum endorsement frequency of 5 and the adult (parent/guardian) section had 4 categories that were not endorsed and 15 items that fell below the recommended minimum endorsement frequency of 5. An analysis of the final frequency of item endorsements revelated 18 categories in the child section and 12 categories in the adult (parent/guardian) section that fell below the recommended endorsement frequency of at least 5 and 3 categories in the child section and 15 categories in the adult (parent/guardian) section that were not endorsed.

Table 3-3: Frequency of item endorsements – Child Section

Item	Initial				Final			
	0	1	2	3	0	1	2	3
I have headaches	9	26	36	14	9	26	36	14
I feel dizzy	43	27	10	5	43	27	10	5
I feel like the room is spinning	72	10	3[a]	0	72	10	3[a]	0
I feel like I'm going to faint	69	13	3[a]	0	69	13	3[a]	0
Things are blurry when I look at them	51	29	4	1[a]	51	29	4	1[a]
I see double	82	2	1[a]	0	82	2	1[a]	0
I feel sick to my stomach	53	19	12	1[a]	53	19	12	1[a]
My neck hurts	54	14	13	4 [a]	54	14	13	4[a]
I get tired a lot	31	24	17	13	31	24	17	13
I get tired easily	30	31	15	9	30	31	15	9
I have trouble paying attention	40	25	15	5	40	25	15	5
I get distracted easily	38	26	13	8	38	26	13	8
I have a hard time concentrating	38	29	10	8	38	29	10	8
I have problems remembering what people tell me	53	19	9	4[a]	53	19	9	4[a]
I have problems following directions	63	16	5	1[a]	63	16	5	1[a]
I daydream too much	63	15	4	3[a]	63	15	4	3[a]
I get confused	50	20	12	3[a]	50	20	12	3[a]
I forget things	53	19	11	2[a]	53	19	11	2[a]
I have problems finishing things	62	13	8	2[a]	62	13	8	2[a]
I have trouble figuring things out	50	25	8	2[a]	50	25	8	2[a]
It's hard for me to learn new things	61	20	3[a]	1[a]	61	20	3	1[a]
a Falls below recommended levels								

Table 3-4: Frequency of item endorsements – Adult (Parent/Guardian) Section

Item	Initial				Final			
	0	1	2	3	0	1	2	3
has headaches	9	32	31	12	8	32	31	12
feels dizzy	49	23	12	0	48	23	12	0
has a feeling that the room is spinning	78	5	1[a]	0	82	1[a]	0	0
feels faint	76	7	1[a]	0	75	7	1[a]	0
has blurred vision	72	8	3[a]	1[a]	71	11	1[a]	0
has double vision	81	2	1[a]	0	82	1[a]	0	0
experiences nausea	57	16	10	1[a]	56	16	10	1[a]
has a sore neck	53	17	12	2	69	12	2	0
gets tired a lot	35	32	11	6	34	32	11	6
gets tired easily	36	27	16	5	35	27	16	5
has trouble sustaining attention	46	24	6	8	45	24	14	0
is easily distracted	46	24	7	7	45	24	14	0
has difficulty concentrating	42	27	10	5	41	27	10	5
has problems remembering what he/she is told	52	17	9	6	51	17	9	6
has difficulty following directions	54	19	8	3[a]	53	19	8	3[a]
tends to daydream	62	14	7	1	61	14	7	1[a]
gets confused	64	14	3[a]	3[a]	63	17	3[a]	0
is forgetful	52	19	5	8	51	24	8	0
has difficulty completing tasks	59	16	6	3[a]	58	16	6	3[a]
has poor problem solving skills	64	17	3[a]	0	63	17	3[a]	0
has problems learning	71	9	4[a]	0	79	4	0	0

a Falls below recommended levels.

3.3.3 Category Thresholds

The initial category thresholds for the child section were not disordered however, the adult (parent/guardian) section were. These items were re-scored by collapsing the categories until a logical sequence of difficulty levels was achieved. This resulted in a decreased number of response categories as illustrated in table 3-6 for the 9 items.

Table 3-5: Re-scoring of disordered thresholds – Child Section

Item	Re-Scored	Scale			
		0	1	2	3
I have headaches	No	0	1	2	3
I feel dizzy	No	0	1	2	3
I feel like the room is spinning	No	0	1	2	3
I feel like I'm going to faint	No	0	1	2	3
Things are blurry when I look at them	No	0	1	2	3
I see double	No	0	1	2	3
I feel sick to my stomach	No	0	1	2	3
My neck hurts	No	0	1	2	3
I get tired a lot	No	0	1	2	3
I get tired easily	No	0	1	2	3
I have trouble paying attention	No	0	1	2	3
I get distracted easily	No	0	1	2	3
I have a hard time concentrating	No	0	1	2	3
I have problems remembering what people tell me	No	0	1	2	3
I have problems following directions	No	0	1	2	3
I daydream too much	No	0	1	2	3
I get confused	No	0	1	2	3
I forget things	No	0	1	2	3
I have problems finishing things	No	0	1	2	3
I have trouble figuring things out	No	0	1	2	3
It's hard for me to learn new things	No	0	1	2	3

Table 3-6: Re-scoring of disordered thresholds – Adult (Parent/Guardian) Section

	Re-Scored	Scale			
		0	1	2	3
has headaches	No	0	1	2	3
feels dizzy	No	0	1	2	3
has a feeling that the room is spinning	No	0	1	2	3
feels faint	Yes	0	0	1	2
has blurred vision	No	0	1	2	3
has double vision	Yes	0	1	1	2
experiences nausea	Yes	0	0	1	2
has a sore neck	No	0	1	2	3
gets tired a lot	Yes	0	0	1	2
gets tired easily	No	0	1	2	3
has trouble sustaining attention	No	0	1	2	3
is easily distracted	Yes	0	1	2	2
has difficulty concentrating	Yes	0	1	2	2
has problems remembering what he/she is told	No	0	1	2	3
has difficulty following directions	No	0	1	2	3
tends to daydream	No	0	1	2	3
gets confused	No	0	1	2	3
is forgetful	Yes	0	1	1	2
has difficulty completing tasks	Yes	0	1	1	2
has poor problem solving skills	Yes	0	1	2	3
has problems learning	No	0	1	2	3

3.3.4 Individual Person Fit

The person fit residual mean and standard deviation for the child section, -0.55 and 1.55 respectively, and adult (parent/guardian) section, -0.56 and 1.32 respectively, are within the tolerances for fitting to the Rasch model (the mean should be 0±2.5 and the standard deviation should be 1 ±2.5).

3.3.5 Individual Item Fit

The item fit residual mean and standard deviation for the child section, 0 and 0.9372 respectively, and adult (parent/guardian) section, 0 and 2.1627 respectively, are within the tolerances for fitting to the Rasch model (the mean should be 0±2.5 and the standard deviation should be 1 ±2.5).

3.3.6 Person Separation Index

Cronbach's alpha was calculated at 0.9133 with a PSI of 0.8398 for the child section and 0.9146 with a PSI of 0.8261 for the adult (parent/guardian) section.

3.3.7 Local Dependency

Local dependence was identified in 26 pairs of items on the child section and 28 pairs of items on the adult (parent/guardian) section indicating that there is a response dependency between the pairs of items. Using the overlapping clinical profiles published by Harmon et al. in the 2019 American Medical Society for Sports Medicine position statement on concussion in sport, when present and defined, the common profiles for each of the item pairs is provided and displayed in Table 3-7 for the child section and Table 3-8 for the adult (parent/guardian) section.[29]

Table 3-7: Item pairs that displayed local dependence with the associated overlapping clinical profiles – Child Section

Item Pairs	Overlapping Clinical Profile
I have headaches I feel like I'm going to faint	NONE
I have headaches Things are blurry when I look at them	Headache-Migraine Ocular
I have headaches I get tired easily	NONE
I feel dizzy I feel like the room is spinning	Vestibular Ocular
I feel dizzy Things are blurry when I look at them	Ocular
I feel dizzy I have problems remembering what people tell me	NONE
I feel dizzy I daydream too much	NONE
Things are blurry when I look at them I see double	N/A
My neck hurts I get tired easily	NONE
I get tired a lot I get tired easily	Fatigue
I have trouble paying attention I get distracted easily	Cognitive

I have trouble paying attention	Cognitive
I have a hard time concentrating	
I have trouble paying attention	Cognitive
I get confused	
I get distracted easily	Cognitive
I have a hard time concentrating	
I get distracted easily	Cognitive
I daydream too much	
I have problems remembering what people tell me	N/A
I have problems following directions	
I have problems remembering what people tell me	Cognitive
I forget things	
I have problems remembering what people tell me	N/A
I have problems finishing things	
I have problems following directions	Cognitive
I get confused	
I have problems following directions	Cognitive
I forget things	
I have problems following directions	N/A
I have problems finishing things	
I daydream too much	N/A
I have problems finishing things	
I get confused	Cognitive
I forget things	

I get confused	N/A
It's hard for me to learn new things	
I forget things	N/A
I have problems finishing things	
I have problems finishing things	N/A
I have trouble figuring things out	
N/A – items without a clear association to a symptom on the adult SCAT5 NONE – items do not share an overlapping clinical profile	

Table 3-8: Item pairs that displayed local dependence with the associated overlapping clinical profiles – Adult (Parent/Guardian) Section

Item Pairs	Overlapping Clinical Profile
has headaches	Headache-Migraine
has a sore neck	
feels dizzy	Vestibular Ocular
has a feeling that the room is spinning	
feels dizzy	Ocular
has blurred vision	
feels dizzy	Headache-Migraine Ocular
experiences nausea	
has a feeling that the room is spinning	Ocular
has blurred vision	
has a feeling that the room is spinning	Headache-Migraine Ocular
experiences nausea	
feels faint	N/A

experiences nausea	
has blurred vision	N/A
has double vision	
gets tired a lot	Fatigue
gets tired easily	
has trouble sustaining attention	Cognitive
is easily distracted	
has trouble sustaining attention	Cognitive
has difficulty concentrating	
has trouble sustaining attention	Cognitive
has problems remembering what he/she is told	
has trouble sustaining attention	Cognitive
is forgetful	
has trouble sustaining attention	N/A
has difficulty completing tasks	
is easily distracted	Cognitive
has problems remembering what he/she is told	
is easily distracted	N/A
tends to daydream	
is easily distracted	Cognitive
is forgetful	
has difficulty concentrating	N/A
has difficulty completing tasks	
has problems remembering what he/she is told	N/A

has difficulty following directions	
has problems remembering what he/she is told	N/A
tends to daydream	
has problems remembering what he/she is told	Cognitive
is forgetful	
has difficulty following directions	N/A
has difficulty completing tasks	
tends to daydream	N/A
is forgetful	
gets confused	Cognitive
is forgetful	
gets confused	N/A
has difficulty completing tasks	
is forgetful	N/A
has difficulty completing tasks	
has difficulty completing tasks	N/A
has problems learning	
has poor problem solving skills	N/A
has problems learning	
N/A – items without a clear association to a symptom on the adult SCAT5 NONE – items do not share an overlapping clinical profile	

3.3.8 Differential Item Functioning (DIF)

DIF for sex was not detected in either the child or adult (parent/guardian) section of the Child-SCAT5.

3.3.9 Unidimensionality

Both the child and adult (parent/guardian) sections of the Child-SCAT5 failed the test of unidimensionality as 18.82% and 19.28% (child and adult (parent/guardian) sections respectively) of the t-tests performed were significant which is greater than the 5% cutoff.

3.4 Discussion

Both the child and adult (parent/guardian) section of the Child SCAT5 symptom evaluation exhibit high reliability (PSI > 0.80) and are able to differentiate between at least 4 levels of patients.[21,35] The obtained item fit residual statistics for both sections are < 2.5 suggesting redundancy within the items. Overall, the Child-SCAT5 symptom evaluation exhibits a poor fit to the Rasch model due to the multidimensionality and redundancy within the items.

3.4.1 Item Endorsement and Category Thresholds

The evaluation of the initial item endorsement frequencies for the child section revealed 18 items and 3 categories with unacceptably low values and the adult (parent/guardian) section Section revelated 15 items and 4 categories with unacceptably low values. After collapsing disordered category thresholds, the child section still had 18 items and 3 categories, and the adult (parent/guardian) section had 12 items and 15 categories below the endorsement threshold. There was no evidence of a sex-linked bias in either the child or adult (parent/guardian) sections, therefore DIF was not identified in any of the items.

3.4.2 Local Dependency

Local dependence was identified in 26 pairs of items in the child section and 28 pairs of items in the adult (parent/guardian) section. The high number of item pairs indicates a high level of response dependency meaning that the pairs of items are linked in such a manner the response for one item determines the response to the paired item. Of the 26 pairs of items in the child section, 5 item pairs did not share an overlapping clinical profile, 8 item pairs had at least one of the items without an identified overlapping clinical profile and 13 item pairs shared at least one common clinical profile.

The adult (parent/guardian) section had 13 item pairs without an identified overlapping clinical profile and 15 item pairs shared at least one common clinical profile. This suggests that the child section has 13 items and the adult (parent/guardian) section has 15 items that may be evaluating the same construct and the child section has 5 pairs of items that are not evaluating the same underlying construct but have an unknown response dependency. The 5 pairs of items with the unknown response dependency also do not have an obvious clinical correlation or connection, further suggesting that the items are malfunctioning. The item pairs that have at least one overlapping clinical profile for each symptom suggests that the observed response dependence in the item pairs may be representative of different components of the underlying construct being measured rather than a duplication of the same construct.

3.4.3 Unidimensionality

The unidimensionality of the child and adult (parent/guardian) section of the Child SCAT5 symptom evaluation was examined to ensure that the scale is targeted towards one main construct and is consistently only measuring that construct. The t-tests for the child and adult (parent/guardian) section resulted in 18.82% and 19.28% being significant. Both the child and adult (parent/guardian) sections violate the Rasch model and suggest that the scales are measuring multiple constructs.

3.4.4 Person Separation Index and Reliability

The initial Cronbach's alpha and PSI were 0.93 and 0.834 for the child section and 0.91 and 0.83 for the adult (parent/guardian) section. The strong initial PSI and Cronbach's alpha suggests that the scale is capable of differentiating between at least 4 levels of patients, has good reliability but may contain redundant questions (as the values are < 0.9) which is supported by identification of the pairs of items with response dependencies.[20,31]

3.5 Conclusion

The Child SCAT5 symptom evaluation exhibits a poor fit to the Rasch model due to the multidimensionality and redundancy within the items. This suggests that there are

fundamental psychometric issues with the scale and further analysis and redundant is required to improve the reliability and validity of the scale. Both sections of the Child SCAT5 symptom evaluation possess good reliability and can differentiate between different levels of patients but requires refinement to eliminate redundant items and make a better functioning, targeted scale.

The pairs of items that exhibit response dependence and have common overlapping clinical profiles do indicate item redundancy which is also supported by the strong PSI and Cronbach's alpha however, the item pairs without common overlapping clinical profiles are problematic as there is another response dependence present that is not linked to the underlying construct within these. The item pairs without a common overlapping clinical profile requires further investigation and refinement using a systematic process in order to produce correctly functioning, independent items. All of the item pairs that exhibit a response dependence may be a result of the methodology used to develop the items and only expert opinion was used to justify their inclusion and if a systematic methodology was applied this could have been identified and corrected.[8]

The Child SCAT symptom evaluation is a reliable scale but is not a valid measure of concussion based on the poor fit to the Rasch model. The underlying cause of the validity issue can be traced back to the methodology used to develop the tool and a redevelopment using an accepted test development methodology may solve these issues. Of the 10 stages of test development outlined by Irwing and Hughes, the Child SCAT5 only completed the initial stage (defining the construct and specifications of the test) and then completely relied on content experts, replacing construct validity with content validity. By redeveloping the Child SCAT5 symptom evaluation using a systematic test development process will improve the validity of it and increase clinician's trust in the tool allowing for more effective and targeted care to be delivered.[8]

One of the major limitations of this study was the small sample size. While the sample sized used was smaller than the recommended minimum of 50 the abundance of psychometric issues with both scales would not be resolved with a larger sample.

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Chapter 4

4 Establishing the Minimal Clinically Important Difference (MCID) for the Adult Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation

4.1 Introduction

There are an estimated 1.6 to 3.8 million sport related concussions annually in the United States and according to the Ontario Neurotrauma Foundation there were 148,710 concussions diagnosed in Ontario, Canada in 2013.[1,2] The diagnosis of concussion requires clinicians to employ a multifaceted approach combining clinical assessment tools, symptom evaluation checklists with a traditional clinical examination.[3] Second only to the clinical examination, symptom checklists are the most widely used tool clinicians use to aid in the assessment and management of concussion.[3–5] While there are numerous free and commercial symptom checklists available, the 5th edition of the Sport Concussion Assessment Tool's (SCAT5) symptom evaluation is freely available and revised every four years along with the Consensus Statement on Concussion in Sport.[3] The SCAT5 symptom evaluation consists of 22 symptoms and asks individuals to rate the severity of each symptom on a 7 point Likert scale ranging from 0 to 6 (0 being an absence of the symptom, 1-2 being mild, 3-4 being moderate and 5-6 being severe).[3,6,7] While this provides clinicians with a patient specific, subjective overview of which symptoms the patient is currently experiencing, along with the severity of each symptom, it does not account for symptoms with a non-concussion etiology nor does the SCAT5 symptom evaluation provide information on determining if a patient has recovered clinically or a change in health status.[3,6,8,9]

One method to identify if a patient has experienced a change in health status is the minimal clinical important difference (MCID).[10] The MCID is an estimate of the smallest change in a measure that could be considered clinically important and a meaningful change in the health status being measured.[11] There are two approaches to estimating the MCID, distribution based and anchor based. Distribution based estimations uses the standard deviation, standard error of the mean and effect size whereas, anchor based

approaches use the patient or clinician as a reference anchor to determine clinical improvement or recovery and compare this measure with the baseline measure.[12] Generally, the anchor based approach is preferred as it takes into account other clinical factors not captured by the measure being investigated.[12]

The minimal detectable change (MDC) is an estimation of the smallest change between two points on a measure that is not attributable to chance or measurement error. If the MCID estimate is larger than the MDC estimate, then the MCID is considered to represent a true clinical change rather than being caused by chance or error.[13,14] The standardized response mean (SRM), or response-treatment co-efficient, is a type of effect size estimation and is a ratio of the observed change in a measure divided by the standard deviation.[15] The SRM provides an estimation of the responsiveness of a measure which is the ability of the measure to detect change. This study aimed to determine the responsiveness of the SCAT5 symptom evaluation, to estimate the MCIDs for each for the symptoms using an anchor-based approach and determine the clinical significance of the MCID estimates by comparing size of the MCID estimate to the MDC estimate.

4.2 Methods

4.2.1 Participants

Participants were recruited as part of a larger data collection project conducted at the Fowler Kennedy Sport Medicine clinic. A total of 125 individuals (72 males, 53 females mean age 18.64 ± 8.66) 13 years of age and older who were diagnosed with a concussion during their first visit were included. Ethical approval from the University of Western Ontario was obtained. The initial diagnosis and subsequent determination of recovery were performed by a primary care physician practicing in sport and exercise medicine who hold a diploma in sport and exercise medicine from the Canadian Academy of Sport and Exercise Medicine. A sample size calculation was done using G*Power 3.1.9.4 which determined that a minimum sample size of 45 would yield a power of 0.95 and a sample size of 125 would yield 0.99. Patients were not involved in the research process for this study.

4.2.2 Procedure

The analysis plan followed the steps as outlined in Chapter 1.3.4.1.

4.3 Results

Results of the MCID, MDC, SRM, SEM estimates for the 22 symptoms, total symptom score and total number of symptoms endorsed are listed in Table 4-1. All of the 22 symptoms, the total symptom score and total number of symptoms had MCID estimates with 95% confidence intervals greater than 1 ensuring that the results have clinical utility. All 22 symptoms, the total symptom score and total number of symptoms endorsed had MCID estimates greater than the MDC estimates indicating that the results represented a true clinical change and are not caused by measurement error or chance. The MCID estimate for the total symptom score was 26.88 (± 4.37) and for the total number of symptoms endorsed was 9.57 (±1.12). Figure 4-1 provides a graphical representation of the MCID range.

Table 4-1: MCID, MDC, SRM, SEM, SD and 95% Confidence Intervals

	MCID	MDC	SRM	SEM	SD	95% CI
Headache	2.79	0.40	1.96	0.14	1.42	0.28
'Pressure in head'	2.34	0.44	1.52	0.16	1.54	0.31
Neck Pain	2.16	0.64	1.12	0.23	1.92	0.46
Nausea or vomiting	1.90	0.72	1.12	0.26	1.69	0.52
Dizziness	2.28	0.50	1.57	0.18	1.45	0.36
Blurred vision	1.64	0.67	1.04	0.24	1.57	0.48
Balance problems	1.70	0.64	1.11	0.23	1.53	0.46
Sensitivity to light	2.34	0.42	1.56	0.15	1.50	0.30
Sensitivity to noise	2.30	0.48	1.50	0.17	1.53	0.35
Feeling slowed down	2.28	0.50	1.47	0.18	1.55	0.35
Feeling like 'in a fog'	2.59	0.50	1.86	0.18	1.39	0.36
'Don't feel right'	2.70	0.47	1.67	0.17	1.62	0.34
Difficulty concentrating	2.43	0.49	1.52	0.18	1.59	0.35
Difficulty remembering	1.87	0.70	1.10	0.25	1.70	0.51
Fatigue or low energy	2.29	0.45	1.46	0.16	1.56	0.32
Confusion	1.93	0.71	1.15	0.26	1.68	0.51
Drowsiness	2.65	0.50	1.83	0.18	1.45	0.35
More emotional	2.20	0.71	1.27	0.26	1.73	0.51
Irritability	2.11	0.54	1.36	0.20	1.56	0.39
Sadness	2.05	0.65	1.38	0.23	1.48	0.47
Nervous or Anxious	2.07	0.55	1.37	0.20	1.51	0.39
Trouble falling asleep	2.77	0.63	1.56	0.23	1.78	0.45
Total Score Symptom Score	26.88	6.15	1.08	2.22	24.80	4.37
Number of Symptoms Endorsed	9.57	1.58	1.50	0.57	6.36	1.12

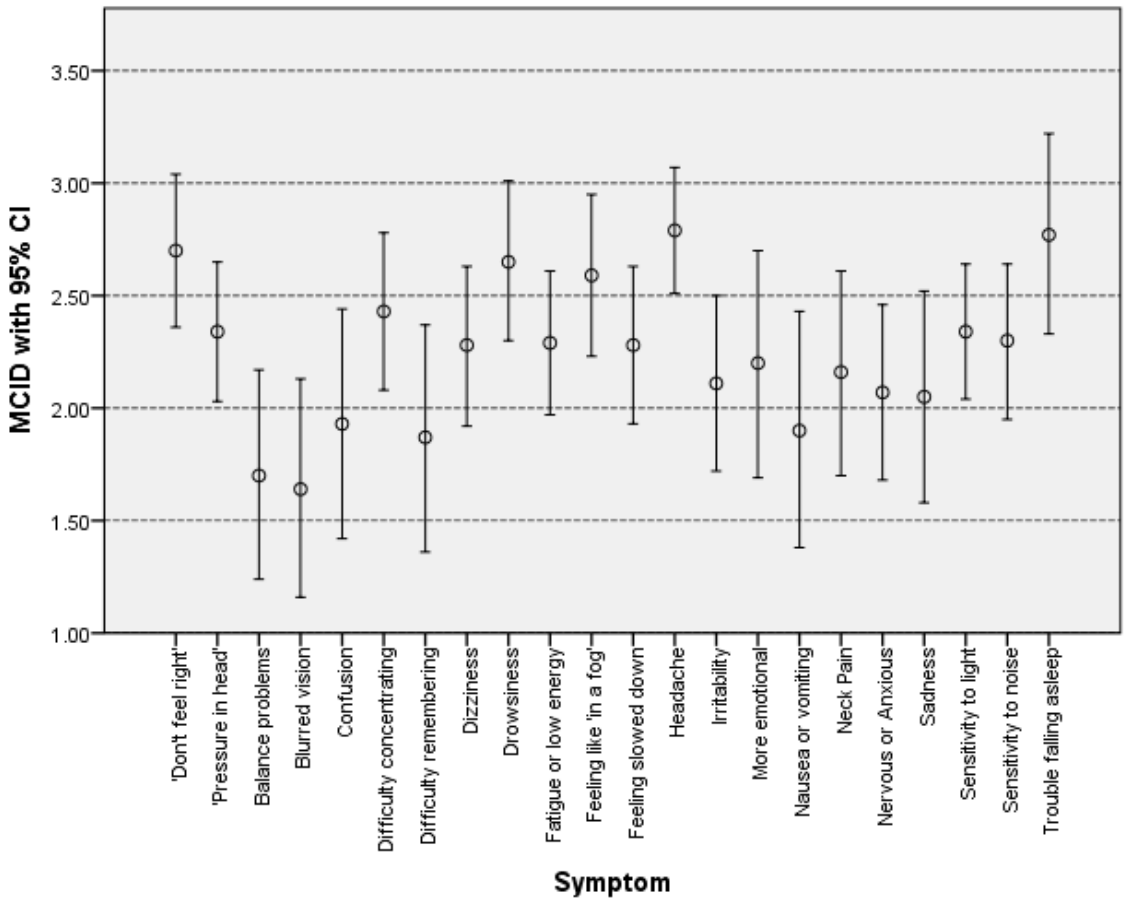

Figure 4-1: Graphical representation of the MCID and 95% confidence intervals for each symptom.

4.4 Discussion

The study aimed to identify the responsiveness and MCID for the 22 symptoms, total symptom severity score and total number of symptoms endorsed for the adult version of the SCAT5 symptom evaluation. The validity of the SCAT5 to detect a clinically important change requires an assumption that the tool is responsive to change. Overall, the SCAT5 symptom evaluation was highly responsive with all of the SRM estimates displaying a large effect as defined by Cohen.[16] The magnitude of the SRM estimates suggests that the SCAT5 symptom evaluation is sensitive to changes in

concussion symptom severity. The MDC estimates for all 22 symptoms, the total symptom score and the total number of symptoms endorsed were all lower than the associated MCID estimates. Therefore, the MCID estimates are a true representation of clinical change.[13]

The MCID estimates displayed in Table 4-1 provides clinicians with a guide to aid in the management of concussions by providing criteria for interpreting changes to patient's SCAT5 symptom evaluations. The MCID estimates provide clinicians with guidelines to help evaluate if changes in the individual symptom severity, total symptom severity and total number of symptoms endorsed reflects a meaningful change in the health status of the patient. These estimations can be used to determine if a change in a patient's self-reported symptom severity score, total symptom score or in the number of symptoms endorsed reflects a change in their health status.

While the MCID estimate for each of the symptoms can provide clinicians with a useful tool for the management of concussions it does introduce an extra level of complexity to the clinical encounter. As the MCID estimates are only intended to be a guide and require the application of traditional clinical skills it may be more useful to apply the average of the 22 MCID estimates (2.245) in clinical practice and refer to the exact MCID estimates when required.

4.5 Conclusion

This study provides a new tool to assist clinicians in the management of concussion and can assist with determining when a patient has a true change in health status. As the nature of the pathology requires the subjective disclosure of symptoms by the patient, the MCID estimate allows clinicians to better interpret the symptom scores and strengthens the return to work, play and learn decisions. Additional caution must also be taken due to psychometric issues identified in chapter 2 and while not serious enough to warrant discontinuing use of the SCAT5 symptom evaluation these limitations must be kept in mind.

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Chapter 5

5 Establishing the Minimal Clinically Important Difference (MCID) for the Child Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation

5.1 Introduction

While the exact prevalence is unknown it is estimated that there are 1.6 to 3.8 million sport related concussions annually in the United States and the Ontario Neurotrauma Foundation estimated that approximately 150,000 concussions were treated in the public health system in Ontario in 2013.[1,2] The diagnosis and management of concusisons in a clinical setting requires a multifacted apporach that incorporates clinical assessment tools and traditional clinical techniques.[3] One of the most often employed tools are symptom evaluation checklists. [3–5] There are a number of these checklists available however the Child Sport Concussion Assessment Tool is one of the most commonly used tools due in part to its simultaneous development alongside the Consensus Statement on Concussion in Sport.[3] The Child SCAT5 symptom evaluation consists of two sections, a child and adult report, each containing 21 symptoms.[6,7] The items that comprise the Child SCAT5 were derived from the adult SCAT5 symptom evaluation by an expert panel during the 4th Consensus Conference on Concussion in Sport.[6,7] Patients and their parent are asked to rate the frequency of the symptom (rather than the severity, as in the case of the adult version of the SCAT5) on a 4 point Likert-scale from 0-3 (0 – not at all, 1 – a little\rarely, 2 – somewhat\some, 3 – a lot\often).[6,7] The pairs of symptom statements that comprise the Child SCAT5 are presented in Table 5-1. [7]

Table 5-1: List of Symptoms that Comprise the Child and Adult (Parent/Guardian) Sections of the Child SCAT5 Symptom Evaluation7

Child Section	Adult (Parent/Guardian) Section
I have headaches	has headaches
I feel dizzy	feels dizzy
I feel like the room is spinning	has a feeling that the room is spinning
I feel like I'm going to faint	feels faint
Things are blurry when I look at them	has blurred vision
I see double	has double vision
I feel sick to my stomach	experiences nausea
My neck hurts	has a sore neck
I get tired a lot	gets tired a lot
I get tired easily	gets tired easily
I have trouble paying attention	has trouble sustaining attention
I get distracted easily	is easily distracted
I have a hard time concentrating	has difficulty concentrating
I have problems remembering what people tell me	has problems remembering what he/she is told
I have problems following directions	has difficulty following directions
I daydream too much	tends to daydream
I get confused	gets confused
I forget things	is forgetful
I have problems finishing things	has difficulty completing tasks
I have trouble figuring things out	has poor problem-solving skills
It's hard for me to learn new things	has problems learning

One method to determine if there has been a true change in a patient's health status is the minimal clinically important difference (MCID). The MCID is an estimate of the smallest change in a measure that could be considered clinically important.[8] There are two approaches to estimating the MCID: distribution-based, and anchor-based. Distribution-based estimations use the standard deviation, standard error of the mean and effect size while anchor-based approaches use the patient or clinician as a reference anchor to determine clinical improvement or recovery and compare this measure with the baseline measure.[9] The anchor-based approach is preferred, as it takes into account other clinical factors not captured by the measure being investigated.[9]

The minimal detectable change (MDC) is the estimation of the smallest change between two points on a measure that is not due to chance or measurement error and should be compared to the MCID estimate to ensure that the MCID estimate is larger which would represent a true clinical change and not due to error.[10,11] The standardized response mean (SRM), or response-treatment co-efficient, is a type of effect size estimation. The SRM is obtained from the ratio of the observed change in a measure divided by the standard deviation and provides an estimation of the responsiveness of a measure which is the ability of the measure to detect change. This study aimed to determine the responsiveness of the Child SCAT5 symptom evaluation, to estimate the MCIDs for each for the symptoms using an anchor-based approach and determining the clinical significance of the MCID estimates by comparing size of the MCID estimate to the MDC estimate.

5.2 Methods

5.2.1 Participants

Participants were recruited as part of a larger data collection project conducted at the Fowler Kennedy Sport Medicine clinic, at the University of Western Ontario, and a total of 27 individuals (21 males, 6 females mean age 10.6 ± 1.4) between the ages of 5 and 12 who were diagnosed with a concussion during their first visit were included. Ethical approval was obtained from the Health Sciences Research Ethics Board at the University of Western Ontario. The initial diagnosis and subsequent determination of

recovery were performed by a primary care physician practicing in sport and exercise medicine, who holds a diploma in sport and exercise medicine from the Canadian Academy of Sport and Exercise Medicine. A sample size calculation was done using G*Power 3.1.9.4 which determined that a minimum sample size of 45 would yield a power of 0.95 and a sample size of 125 would yield 0.99. Patients were not involved in the research process for this study.

5.2.2 Procedure

The analysis plan followed the steps as outlined in Chapter 1.3.4.1.

5.3 Results

Results of the MCID, MDC, SRM, SEM estimates for the 21 symptoms, total symptom score and total number of symptoms endorsed are listed in Table 5-2 for the child section and Table 5-3 for the adult (parent/guardian) section. One of the symptoms in the child section (“I see double”) and two symptoms in the adult (parent/guardian) section (“feels faint” and “has double vision”) did not have a sufficient number of responses in order to estimate the MCID for them. Of the 21 symptoms in the child section, 9 symptoms have MCID estimates with 95% confidence intervals that either round to 1 or are greater or equal to 1 and the adult (parent/guardian) section had 5 symptoms with MCID estimates with 95% confidence intervals that either round to 1 or are greater or equal to 1. The child section had 15 symptoms with MCID estimates greater than the MDC estimates and adult (parent/guardian) section had 12 symptoms, indicating that these results represented a true clinical change and are not caused by measurement error or chance. The MCID estimate for the total symptom score was 6.27 (± 4.52) for the child section and 5.65 (±1.75) for the adult (parent/guardian) section. The MCID estimate for the total number of symptoms endorsed was 9.69 (± 6.16) for the child section and 8.42 (±3.53) for the adult (parent/guardian) section.

Table 5-2: Child Section: MCID, MDC, SRM, SEM, SD and 95% Confidence Intervals

	MCID	MDC	SRM	SEM	SD	95% CI
I have headaches	1.65	0.42	2.46	0.15	0.67	0.31
I feel dizzy	1.44	0.50	1.98	0.18	0.73	0.38
I feel like the room is spinning	0.33[a]	1.85	0.29	0.67	1.15	2.34
I feel like I'm going to faint	1.67	0.92	2.89	0.33	0.58	1.17
Things are blurry when I look at them	1.23	0.34	2.81	0.12	0.44	0.25
I see double	N/A	N/A	N/A	N/A	N/A	N/A
I feel sick to my stomach	1.50	0.54	2.22	0.19	0.67	0.41
My neck hurts	0.86[a]	1.41	0.64	0.51	1.35	1.15
I get tired a lot	1.43	0.75	1.41	0.27	1.02	0.57
I get tired easily	1.15	0.69	1.28	0.25	0.90	0.52
I have trouble paying attention	0.91[a]	1.21	0.63	0.44	1.45	0.93
I get distracted easily	1.17	0.75	1.24	0.27	0.94	0.57
I have a hard time concentrating	1.17	0.75	1.24	0.27	0.94	0.57
I have problems remembering what people tell me	1.00	0.91	1.08	0.33	0.93	0.72
I have problems following directions	0.57[a]	2.33	0.26	0.84	2.23	1.91
I daydream too much	1.43	0.82	1.82	0.30	0.79	0.67
I get confused	1.44	0.49	2.74	0.18	0.53	0.38
I forget things	1.00	0.91	1.08	0.33	0.93	0.72
I have problems finishing things	1.00	0.91	1.08	0.33	0.93	0.72
I have trouble figuring things out	1.27	0.39	2.72	0.14	0.47	0.30
It's hard for me to learn new things	1.25	0.69	1.77	0.25	0.71	0.55
Total Score Symptom Score	6.27	2.40	1.42	0.87	4.41	1.75
Number of Symptoms Endorsed	9.69	4.84	1.09	1.75	8.90	3.53

a The MCID estimate is less than the MDC estimate and may not represent a true clinical change.

Table 5-3: Adult (Parent/Guardian) Section: MCID, MDC, SRM, SEM, SD and 95% Confidence Intervals

	MCID	MDC	SRM	SEM	SD	95% CI
has headaches	1.41	0.50	1.65	0.18	0.85	0.31
feels dizzy	1.31	0.33	2.74	0.12	0.48	0.38
has a feeling that the room is spinning	1.33	0.92	2.31	0.33	0.58	2.34
feels faint	N/A	N/A	N/A	N/A	N/A	N/A
has blurred vision	1.25	0.69	2.50	0.25	0.50	0.25
has double vision	N/A	N/A	N/A	N/A	N/A	N/A
experiences nausea	1.75	0.50	2.82	0.18	0.62	0.41
has a sore neck	0.86[a]	1.41	0.64	0.51	1.35	1.15
gets tired a lot	1.07	0.74	1.03	0.27	1.03	0.57
gets tired easily	0.92	0.80	0.92	0.29	1.00	0.52
has trouble sustaining attention	1.22[a]	1.29	0.88	0.46	1.39	0.93
is easily distracted	1.11	0.97	1.05	0.35	1.05	0.57
has difficulty concentrating	1.00[a]	1.08	0.74	0.39	1.35	0.57
has problems remembering what he/she is told	1.00	0.84	0.96	0.30	1.04	0.72
has difficulty following directions	0.92	0.91	0.78	0.33	1.19	1.91
tends to daydream	1.33	0.58	2.58	0.21	0.52	0.67
gets confused	1.13	1.10	1.00	0.40	1.13	0.38
is forgetful	0.82[a]	1.28	0.53	0.46	1.54	0.72
has difficulty completing tasks	0.75[a]	1.26	0.59	0.45	1.28	0.72
has poor problem solving skills	0.67[a]	0.92	0.67	0.33	1.00	0.30
has problems learning	1.25	0.69	2.50	0.25	0.50	0.55
Total Score Symptom Score	5.65	3.25	0.95	1.17	5.98	1.75
Number of Symptoms Endorsed	8.42	5.49	0.83	1.98	10.11	3.53

a The MCID estimate is less than the MDC estimate and may not represent a true clinical change.

5.4 Discussion

The aim of the study was to identify the responsiveness and MCID estimates for the 21 symptoms, total symptom severity score and total number of symptoms endorsed for the child and adult (parent/guardian) sections of the Child SCAT5. The validity of the Child SCAT5 to detect clinically important changes requires the assumption that the tool is responsive to change. A majority of the items in both sections of the Child SCAT5 were highly responsive, with 15 items in the child section and 13 items in the adult (parent/guardian) section having SRM estimates that displayed a large effect size, 3 items in the child section and 6 items in the adult (parent/guardian) section that displayed a medium effect size, and 2 items in the child section that displayed a small effect size, as defined by Cohen.[14,16] Additionally, the total symptom severity score and total number of symptoms endorsed in both the child and adult (parent/guardian) section displayed a large effect. The magnitude of the SRM estimates suggests that the Child SCAT5 symptom evaluation is sensitive to changes in concussion symptom severity.

The child section had 15 symptoms with MCID estimates greater than the MDC estimates and the adult (parent/guardian) section had 12 symptoms, indicating that these results represented a true clinical change and are not caused by measurement error or chance.[10] The MCID estimates displayed in Tables 1 and 2 can provide clinicians with a guide to aid in the management of concussions and help interpret the changes to the patient's symptoms in order to make decisions regarding returning to activity. The MCID estimates provide valuable insight for clinicians when trying to determine if changes in the patient's symptom score, total symptom score and total number of symptoms endorsed reflects a meaningful change in the health status of the patient.

The MCID estimates for the Child SCAT5 symptom are however, potentially problematic, as not all 21 symptoms in both the child and adult (parent/guardian) section have reliable MCID estimates. The items with MDC estimates greater than the MCID estimates may not reflect a true clinical change and should not be relied on in isolation to make clinical decisions. The Likert scale used in the Child SCAT5 symptom evaluation is a possible source for this error, given that there may not be enough points on the scale for reliable assessment (i.e., the range of possible responses may be insufficient to permit

individuals to discriminate amongst different levels of the construct).[17] Ideally, the Likert scale should contain 5 to 7 response categories, to permit discrimination between the levels of the levels.[17] In order to correct for this, and to provide clinicians with a less complex method for applying the MCID estimates, the average of the 21 MCID estimates for each section (1.3 for the child section and 1.2 for the adult (parent/guardian) section) could be used clinically as the MCID estimates are only intended to be a guide and must be applied alongside traditional clinical skills and when required, clinicians can always refer to the exact MCID estimates for each item.

5.5 Conclusion

This study provides a new tool to aid clinicians in the management of concussions and can be used to assist in determining when a patient has undergone a true change in their health status. As the assessment and management of concussions requires the subjective disclosure of symptoms, the MCID estimates provide a new method for clinicians to interpret the results of the Child SCAT5 and strengthens the return to learn and play decisions. The lack of a robust Likert scale does reduce the reliability of the Child SCAT5 and it is recommended that the two scales be redeveloped using proper test development methodologies to improve the reliability and validity of the tool.

This study provides a new tool to assist clinicians in the management of concussion and can assist with determining when a patient has a true change in health status. As the nature of the pathology requires the subjective disclosure of symptoms by the patient, the MCID estimate allows clinicians to better interpret the symptom scores and strengthens the return to work, play and learn decisions.

One of the limitations of this study was the reliance on a dichotomous clinical outcome as the basis of determining a meaningful change in health status. As most patients who have suffered a sport related concussion see their return to sport as the desired change in health status this limitation is acceptable, but these results do not reflect smaller changes in health status or any change other than the clearance to return to sport. Additionally, chapter 3 describes the serious problems with the psychometric and measurement properties of the Child-SCAT5 the MCID results should not be relied upon

and if corrected the MCID for the two scales that comprise the Child SCAT5 should be re-calculated.

5.6 References

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Chapter 6

6 Investigating Patient's Interpretation of the Underlying Meaning of the Symptoms from the Adult Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation using a Qualitative Survey

6.1 Introduction

The Sport Concussion Assessment Tool (SCAT) was originally developed during the Second Consensus Conference on Concussion in Sport in 2004 and has been revised three times since.[1,2] Although the most current version of the SCAT, the SCAT5, was revised during the Fifth Consensus Conference, the symptom evaluation section has not been materially changed since it was originally developed.[1,3] The SCAT was intended to be a standardized tool used during the assessment of a sports concussion as well as an educational tool.[2] The SCAT was not developed using accepted psychometric techniques, but rather it was developed by a group of experts by combining 8 existing tools: Sideline evaluation of concussion, Management of concussion sports palm card, Standardized assessment of concussion, Sideline concussion check, McGill abbreviated concussion evaluation, National Hockey League physician evaluation form, UK Jockey Club assessment of concession and the Maddocks questions.[1,3]

Next to a clinical examination, symptom evaluations are the most commonly used tool by clinicians when assessing or managing a concussion.[1,6] The SCAT5 is comprised of 22 symptoms on a 7-point Likert-scale, from 0 to 7.[2] 2 The symptoms that comprise the SCAT5 are: headache, pressure in head, neck pain, nausea or vomiting, dizziness, blurred vision, balance problems, sensitivity to light, sensitivity to noise, feeling slowed down, feeling like in a fog, don't feel right, difficulty concentrating, difficulty remembering, fatigue or low energy, confusion, drowsiness, more emotional, irritability, sadness, nervous or anxious and trouble falling asleep.[3]

The methodology for developing clinical instruments is well established as to ensure content validity of the items that comprise the instrument.[4] This process typically follows a systematic process that includes defining the concepts to be measured, making

decisions regarding the level of specificity of items, generating an item pool, having content experts provide feedback, field test the draft instrument and conduct reliability and validity studies on the resulting tool.[5] As the SCAT symptom evaluation was not developed using an established methodology and relied only on content experts there is a fundamental need to evaluate the content validity of the tool, specifically the underlying meaning of the 22 symptoms that comprise the SCAT5 symptom evaluation. The purpose of this pseudo-qualitative study was to deepen the understanding of the SCAT5 symptom evaluation items and to explore the potential meanings individuals may ascribe to each item using an open-ended survey and thematic analysis. Through this, the common thematic responses will be identified to determine if the original wording requires modification to better align with individual's interpretation of them.

6.2 Methods

A total of 80 individuals participated in the study (40 submitted complete surveys and 40 submitted partial surveys with only some of the symptoms having responses to). Participants were recruited using a convenience snowball sampling technique using the Qualtrics survey platform and ethical approval was received from Western University's Office of Research Ethics prior to collecting responses. Adults over the age of 18 were eligible to be included in the study without any other exclusion criteria. After providing their consent digitally participants were asked how they would describe each of the 22 items from the SCAT5 symptom evaluation and were provided with free text responses boxes for each symptom. Based on a recommendation by Fugard and Potts, a minimum of 30 responses was required to achieve a sufficient sample of responses to achieve saturation.[7] Responses were reviewed, and each response was coded with a theme (each response was allowed to have multiple tags). Themes were developed by reviewing all the responses first and identifying common responses. Once the responses were coded, code frequencies were tabulated, and common theme(s) were identified.

6.3 Results

The symptoms, associated tags and frequency of the tags and the resulting overall theme are displayed in Table 6-1.

Table 6-1: Symptoms, response tags and frequencies and resulting common themes.

	Response Tag	Tag Frequency	Common Theme
Headache	Pain in the head Duration Throbbing Pounding Aching Temple Pulsating	28 8 7 4 2 2 1	Pain in the head
Pressure in head	Pushing in Pushing out Pressure Tight Heavy Full Headache Like Pounding	15 8 6 5 3 2 2 1	Pressure Pushing In/Out
Neck Pain	Aching/Sore/Hurts/Pain Neck Pain Muscle Discomfort Tight Feeling Trap Pain Reduced Range of Motion Whiplash Pressure Stiffness	29 28 6 5 5 2 2 2 1 1	Aching/Sore/Hurts/Pain Neck Pain
Nausea or Vomiting	Throwing up/Being sick Feeling like throwing up Upset Stomach Unwell	22 21 9 3	Throwing up/Being sick Feeling like throwing up
Dizziness	Balance Issues Spinning Visual disturbance Light headed Disorienting	23 19 9 2 1	Balance Issues Spinning

Blurred Vision	Unfocused Not seeing normally Hazy Double vision	23 21 2 1	Unfocused Not seeing normally
Balance Problems	Issues with standing Issues with walking Unstable/Not Sturdy Balance Issues Feeling like you will fall Coordination issues	28 18 6 6 5 2	Issues with standing Issues with walking
Sensitivity to light	Light hurts eyes Light causes other symptoms Brighter than normal Inability to open eyes/Squinting Inability to focus	22 18 16 7 1	Light hurts eyes Light causes other symptoms Brighter than normal
Sensitivity to noise	Noise causes other symptoms Noise is louder than normal Noise causes pain Inability to cope with sound	19 18 14 11	Noise causes other symptoms Noise is louder than normal Noise causes pain
Feeling slowed down	Low energy/Fatigue/Lethargic Slower than normal Unproductive Sluggish Behind/unable to keep up Lag Unmotivated	13 10 8 4 3 2 1	Low energy/Fatigue/Lethargic Slower than normal
Feeling like in a fog	Lack of focus Unclear/Blurry Difficulty to concentrate Slow Cognitive issues/brain fog Day dreaming Foggy/hazy Sleeping/sleepy Surreal feeling Forgetful Not feeling normal Air is thick Under water feeling	12 11 11 6 4 3 3 2 2 2 2 1 1	Lack of focus Unclear/Blurry Difficulty to concentrate

Don't feel right	Different than normal Something is wrong Off Emotional change Tired Pain Malaise	19 14 7 6 5 2 1	Different than normal Something is wrong
Difficulty concentrating	Lack of focus Trouble thinking Day dreaming/distracted Cannot complete tasks In a daze Concentration issues Lack of attention	23 7 6 5 1 1 1	Lack of focus
Difficulty remembering	Unable to remember/recall Forgetful Gap/space in memory	22 7 1	Unable to remember/recall
Fatigue or low energy	Tired/exhausted Sluggish/slow Feel like sleeping No motivation Lethargic Weak	23 6 5 4 2 2	Tired/exhausted
Confusion	Unable to understand Lack of awareness/clarity Disoriented Lost Memory loss	19 15 6 4 2	Unable to understand Lack of awareness/clarity
Drowsiness	Difficulty staying awake/sleepy Tired/fatigue Slow Sluggish	22 16 3 2	Difficulty staying awake/sleepy Tired/fatigue
More emotional	Stronger emotional response Reduced emotional control Crying/upset Irritable/angry Sensitive Negative Empathy/sympathy Happy	23 20 12 4 3 2 1 1	Stronger emotional response Reduced emotional control
Irritability	Easily angry Annoyed Cranky	24 9 2	Easily angry

	Impatient Short On edge Bitchy Frustrated	2 2 2 1 1	
Sadness	Sad Depressed Unhappy Emotional Upset Negative Feelings Crying Feeling Down Somber Melancholy	7 7 5 4 3 2 2 2 1 1	Sad Depressed Unhappy
Nervous or Anxious	Worrying On edge/feeling of unease Unsettled Nervous Fear Stressed Anxious Can't sit still Uncomfortable Inattention	10 8 6 4 4 4 3 3 2 1	Worrying On edge/feeling of unease
Trouble falling asleep	Insomnia Mind racing/ Overstimulated Cannot relax Cannot calm down Tossing and Turning Restless	22 5 5 3 3 1	Insomnia

6.4 Discussion

Out of the 22 symptoms, 14 were determined to have common themes that were comparable to the original symptom and do not warrant modification: headache (pain in the head), pressure in the head (pushing in, pushing out), neck pain (neck ache/sore/hurt/pain), nausea or vomiting (throwing up/being sick, feeling like throwing up), sensitivity to light (light hurts the eyes, light causes other symptoms, light is brighter than normal), sensitivity to noise (noise causes other symptoms, noise is louder than

normal and noise causes pain), difficulty concentrating (lack of focus), difficulty remembering (unable to remember/recall), fatigue or low energy (tired/exhausted), drowsiness (difficulty staying awake/sleepy, tired/fatigue), irritability (easily angry), sadness (sad, depressed, unhappy), nervous or anxious (worrying, on edge/feeling of unease) and trouble falling asleep (insomnia).

6.4.1 Dizziness

The most common themes identified for dizziness were balance issues and spinning. Describing dizziness as having issues with balance or feeling like you are spinning are interesting as they identify a physical consequence of being dizzy (balance issues) as well as a alternative description of dizziness. Interestingly, the first edition of the SCAT combined dizziness and balance problems into one item.[8] The SCAT symptom evaluation currently includes balance problems thus no modification is required but the items should be evaluated via traditional psychometric methods to ensure that these two items are independent of one another and do not suffer from a response linked bias.[4,9]

6.4.2 Blurred Vision

There were two themes that were identified within the responses relating to blurred vision. Describing blurry vision as unable to focus is consistent with blurred vision. However, almost an equal number of responses described the general feeling of not being able to see normally. This item should be changed back to the wording used in the first edition of the SCAT "Vision Problems" and provide examples of this including blurred vision and the inability to focus.[8]

6.4.3 Balance Problems

The two themes identified within the balance problems responses relate to static and dynamic balance, issues with standing and issues with walking. Both of these themes are consistent with balance however, it may be prudent to separate this item into two distinct items "Balance problems when standing" and "Balance problems when walking". Since balance may be interpreted differently by individuals and marked differences in

static and dynamic balance may be present it may be beneficial to have individuals evaluate these separately.

6.4.4 Feeling Slowed Down

This symptom also resulted in two common themes within the responses, low every/fatigue/lethargic and feeling slower than normal. The latter of the two themes is consistent with the original symptom however, the addition of feeling low energy/fatigue/lethargic differs from this. There is already a symptom addressing fatigue or low energy thus no modification is required. However, the items should be identified via traditional psychometric methods to ensure that these two items are independent of one another and do not suffer from a response linked bias.[4,9]

6.4.5 Feeling Like in a Fog

The most diversity in responses for the 22 symptoms was "Feeling like in a fog" eliciting 13 distinct themes. The three most common themes, lack of focus, unclear/blurry and difficulty with concentration are all distinct and overlap with other items (blurred vision and difficulty concentrating). This indicates the need to evaluate the items via traditional psychometric methods to ensure that these three items are independent of one another and do not suffer from a response linked bias. The intention of this item may have been to measure "brain fog" which has been systematically described as being forgetful, cloudy and having difficulty focusing, thinking and communicating.[10] As the current wording of the item is interpreted differently, it may be beneficial to change this item to "Brain fog" and provide the systematically derived examples outlined above.

6.4.6 Don’t Feel Right

This item has two distinct themes arise from the responses which are consistent with the original item but may be beneficial to in addition to it. Respondents described "Don’t feel right" as feeling different than normal or feeling like something is wrong. The item may function in a more appropriate manner if it was changed to reflect all three: Don’t Feel Right/Feeling different than normal/Feeling like something is wrong. The two additional items would clarify what is being asked and provide more accurate results.

6.4.7 Confusion

The two most common themes resulting from the responses for confusion were unable to understand and lack of awareness/clarity. While not distinctly unique to the original item but again but provide a distinct enough difference to warrant a modification. In order to provide more clarity to individuals it is recommended that this item be changed to reflect "Confusion (lack of awareness, lack of clarity or the inability to understand things as you normally would)".

6.4.8 More Emotional

The item "more emotional" elicited two types of responses, examples of emotions or general descriptions of changes to emotions. The two most common themes centered around describing emotions rather than providing examples of emotions; stronger emotional response and reduced emotional control. These two items both look at how an individual response emotionally and it would be beneficial to provide individuals more content for this item. Therefore, it is recommended that this item be modified to be more neutral and reflect the two themes "Change in normal emotional control or response".

6.5 Conclusion

Out of the 22 items that comprise the SCAT5's symptom evaluation, the underlying meaning of the 14 of the items were in general agreement with the responses obtained from the participants. Of the remaining 8 items 2 were identified as overlapping other symptoms and 6 were identified as being interpreted by the participants in a manor inconsistent with the original wording of the item. The results of this study support a recommendation to modify the 6 items in order to better convey the underlying meaning, prevent misinterpretation by patients and clinicians, and to ensure consistency. The remaining 2 items should be re-evaluated using traditional psychometric methods to ensure that they are testing independent constructs and do not suffer from a response linked bias. As individual persons may interpret the meaning of these items differently and respond accordingly, the potential for miscommunication between patients and clinicians is significant. If a patient responds based on their own interpretation and a clinician interpret the item different from the patient this could result in a clinical error,

delaying or preventing appropriate care from being provided. Additionally, The recommendations for modifying the 6 items is as follows: "Blurred Vision" should be modified to reflect "Not being able to see normally", "Balance Problems" should be split into two distinct items Balance problems when standing" and "Balance problems when walking", "Feeling like in a fog" should be modified to reflect "Brain fog (for example being forgetful, cloudy and having difficulty focusing, thinking and communicating)", "Don't feel right" should be modified to "Don't Feel Right/Feeling different than normal/Feeling like something is wrong", Confusion should be modified to provide examples "Confusion (lack of awareness, lack of clarity or the inability to understand things as you normally would)" and "More emotional" should be modified to reflect "Change in normal emotional control or response".

As this study took a quasi-qualitative approach it did not permit for follow-up questions from the researchers to the participants. The time and resources required to conduct a true qualitative interview were a major limitation to the study however the results do form a strong foundation for future research on the redevelopment of the problematic items.

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7 General Discussion

The identification, assessment and diagnosis of concussions is a complex multifaceted process and clinicians often rely on symptom checklists to aid in this process. The adult and child versions of the 5th Sport Concussion Assessment Tool's symptom evaluation are widely used but the lack of a systematic test development methodology they are malfunctioning and may not provide valid or reliable results. While it is understood that the SCAT5 symptom evaluation should not be used in isolation, the identified psychometric issues need to be addressed.

Understanding the psychometric and measurement properties of a clinical tool is important in order to implement it in clinical practice. The Rasch model provides a comprehensive, robust approach for the evaluation of the psychometric properties of the polytomous Likert-scale used by the SCAT5 and Child SCAT5. Additionally, understanding the responsiveness and clinical utility of a clinical tool's scale using an anchor-based approach to estimating the minimal clinically important difference for items provides a general guideline for the interpretation of longitudinal changes and identifying meaningful changes in patient's health status.

7.1 Psychometric and Measurement Properties of the SCAT5

In chapter 2 the SCAT5 symptom evaluation was evaluated against the Rasch model in order to understand the psychometric and measurement properties of the tool. The SCAT5 was poorly fitting to the Rasch model suggesting that there are psychometric issues with the scale bringing into question it's reliability and validity. The SCAT5 was found to be multidimensional, had poorly fitting items and had 10 items that were identified to have sex linked biases. The SCAT5 was found to possess good reliability and was determined to be capable of differentiating between different levels of patients but does have redundancy within the items. There were 15 pairs of items that were identified to have response linked dependencies that shared overlapping clinical profiles which is a manifestation of the item redundancy as identified by the strong PSI and Cronbach's alpha.

In order to understand how individuals interpret the meaning of the 22 items that comprise the SCAT5 symptom evaluation a qualitative survey was conducted (chapter 6). Participants were asked to describe their interpretation of each of the symptoms using their own words. The responses for each item were then coded and most frequent codes were used to identify the most common themes which were then compared to the original wording of the items. Out of the 22 items, 14 were in general agreement with the most frequent themes obtained from the survey, 2 items were identified to have overlapping interpretations with other items and 6 were interpreted in a manor inconsistent with the original wording of the items. The identified inconsistencies are problematic as individuals and clinicals may interpret the meaning of symptoms differently which could result in clinical errors, inappropriate treatments being prescribed or a delay in care. Chapter 6 provides the recommended changes to the items in order to provide better targeted items with homogeneous interpretations.

In isolation, chapters 2 and 6 provide a comprehensive review of the SCAT5's psychometric and measurement properties and a combined review of the results identified the common items that are malfunctioning. The 6 items identified in chapter 6's qualitative survey with interpretations inconsistent with the original wording of the items were also identified in chapter 2 as exhibiting sex-linked differential item functioning and having a response linked dependence (Blurred vision, Balance problems, Feeling like in a fog, Don't feel right, Confusion and More emotional). This would suggest that these 6 items have the most problematic psychometric properties and are the most malfunctioning of the items and require refinement in order to be clinically useful. As there is strong evidence of psychometric issues within these 6 items it may be prudent to discontinue their use in clinical practice as they may be providing inaccurate information to clinicians due to malalignment in interpretation of a symptom's meaning, inappropriate interventions due to a belief of the presence of a certain condition based on this malalignment or a prolonging in symptoms based on the same reason.

7.2 Psychometric and Measurement Properties of the Child SCAT5

In chapter 3 the child and adult (parent/guardian) sections of Child SCAT5 symptom evaluation were evaluated against the Rasch model independently of one another. Both sections of the Child SCAT5 were found to be poorly fitting to the Rasch model due to the multidimensionality of the scales and redundancy within the items. Both sections were found to possess good reliability and be able to differentiate between different levels of patients. The strong PSI and Cronbach's alpha for both sections indicated item redundancy which manifested in 26 pairs of items in the child section and 28 pairs of items in the adult (parent/guardian) section with response linked dependencies. While most pairs of items exhibiting a response linked dependence did also have an overlapping clinical profile there were 12 pairs of items in the child section and 13 pairs of items in the adult (parent/guardian) section that lacked one. The lack of an overlapping clinical profile however, suggests that these items are not evaluating the same underlying construct and poses unknown and problematic response dependencies. The Child SCAT5 symptom evaluation is a reliable scale but is not a valid measure of concussion due to the poor fit to the Rasch model. Again, the underlying cause of these issues can again be traced back to the lack of a systematic test development methodology when the scale was being developed.

7.3 Responsiveness and Minimal Clinically Important Difference Estimates for the SCAT5 and Child SCAT5

In chapters 4 and 5 the responsiveness and minimal clinically important difference estimates for the items, total number of symptoms endorsed and total symptom score were analyzed. The use of a clinician-based anchor to establish the MCID estimates was preferred in this case as it ensured that other clinical factors were taken into account outside of those captured by the scales.

Chapter 4 provides an overview of the MCID estimates for the SCAT5 and found that all the 22 symptoms, the total symptom score and total number of symptoms had MCID estimates with 95% confidence intervals greater than 1 ensuring that the results have

clinical utility. Additionally, all of the 22 symptoms, the total symptom score and total number of symptoms endorsed had MCID estimates greater than the MDC estimates indicating that the results represented a true clinical change and are not caused by measurement error or chance.

In contrast, chapter 5 focused on the Child SCAT5 and had problematic results. Only 15 symptoms from the child section and 12 from the adult (parent/guardian) sections had MCID estimates greater than the MDC estimates. This indicates that only these items had results that represented a true clinical change not caused by measurement error or chance. The Likert-scale used by the Child SCAT5 was identified as being a potential source for this error given the range of possible responses may be insufficient to permit individuals to discriminate amongst different levels of the construct.

The results from both chapter 4 and 5 are not meant to be used in isolation to make clinical decisions but may provide clinicians with a new tool to aid in the management of concussion by providing general guidelines for interpretation the self-reported symptom scores and aiding in identifying true changes in health status. The individual item estimates could be used for this purpose but a simplified approach using the average MCID estimate for all symptoms may be more clinically useful as it does not require as much time to apply.

7.4 Overall Conclusion

The results of the 3 chapters that focused on the adult SCAT5 symptom evaluation and the 2 chapters that focused on the Child SCAT5 symptom evaluation provide a comprehensive overview of the psychometric and measurement properties of the tools and identify the problematic areas.

The adult version of the SCAT5 is a reliable scale but has validity issues. The SCAT5 was found to be multidimensional, had poorly fitting items and were found to have a sex-linked response bias within some of the items. Additionally, 15 pairs of items were found to be linked through a response dependency suggesting that there is a redundancy within the items which was confirmed through an evaluation of the underlying clinical profiles.

The estimation of the MCIDs for the items, total symptom score and total number of items endorsed for the adult SCAT5 symptom evaluation yielded valid results that are significant and clinically relevant. Lastly, the quasi-qualitative study on the underlying interpretation of the symptoms that comprise the scale yielded results that correlated with the results of the Rasch analysis. This combined analysis can then be used as the basis for the redevelopment of the items in order to improve the psychometric and measurement properties of the tool.

The Child-SCAT5 symptom evaluation was also found to be a reliable scale but had more serious validity issues. The scale was found to be multidimensional and had a significant number of response dependent items without overlapping clinical profiles suggesting a linkage with an unknown underlying construct. This presents a significant psychometric issue and require further research in order to better understand why these items are functioning in this manner before any work can be conducted on revising the scale. The estimation of the MCIDs for the Child-SCAT5 were not as positive as the results for the adult version. Only 15 items from the child section and 12 symptoms from the adult (parent/guardian) section were found to be valid and clinically relevant. While the same issues regarding the development of the Child-SCAT5 symptom evaluation as the adult version the additional problems with the Child-SCAT5 are likely a result of the limited number of response categories used which limits the range of possible responses and is not sufficient to permit discrimination amongst different levels of the underlying construct.

The results of the 3 chapters that focused on the adult SCAT5 and the 2 chapters that focused on the Child SCAT5 provide a comprehensive overview of the psychometric and measurement properties of the tools and identify the problematic areas. Additionally, establishing the MCID estimates provide new approaches for clinicians to use the tools in their practice. Overall, both the SCAT5 and Child SCAT5 are reliable but are poorly functioning tools and suffer from psychometric issues.

7.5 Future Directions

This thesis provides a comprehensive analysis of the psychometric and measurement properties of the adult and child version of the 5th Sport Concussion Assessment Tool. The identified issues with each of the tools can be used as a foundation for future studies to correct for and aid in the redevelopment of concussion symptom checklists with strong psychometric and measurement properties. The redevelopment of the SCAT5 and Child SCAT5 symptom checklist must follow a systematic test development methodology to ensure that the psychometric issues are resolved.

Appendices

Appendix A: Ethics Approval – Concussion Electronic Data Capture System

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Kevin Asem
Department & Institution: Family Medicine, Western University

Review Type: Delegated
HSREB File Number: 109738
Study Title: Concussion electronic data capture system

HSREB Initial Approval Date: January 30, 2018
HSREB Expiry Date: January 30, 2019

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol		2018/01/18
Letter of Information		2018/01/19
Recruitment Items	Video Script	2017/10/10
Instruments	REDCap patient history	2017/09/22
Instruments	REDCap intake form	2017/09/22
Instruments	REDCap clinical assessment form	2017/09/22
Instruments	REDCap self-report of symptoms	2017/09/22
Instruments	REDCap SCAT5 form	2017/09/22
Instruments	REDCap disposition form	2017/09/22
Data Collection Form/Case Report Form	Data collection form	2017/09/25

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

Appendix B: Ethics Approval – SCAT Concussion Symptom Survey

Western Research

Date: 7 August 2018

To: Dr. Joy MacDermid

Project ID: 110767

Study Title: SCAT Concussion Symptom Study

Application Type: HSREB Amendment Form

Review Type: Delegated

Full Board Reporting Date: August 21, 2018

Date Approval Issued: 07/Aug/2018

REB Approval Expiry Date: 21/Mar/2019

Dear Dr. Joy MacDermid ,

The Western University Health Sciences Research Ethics Board (HSREB) has reviewed and approved the WREM application form for the amendment, as of the date noted above.

Documents Approved:

Document Name	Document Type	Document Date
CONSENT	Consent Form	13/Jul/2018
Protocol	Other	Received July 23, 2018
survey	Online Survey	19/Jun/2018

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix C: Interview Script for SCAT Concussion Symptom Survey

Participants will be interviewed and asked questions directly relating to the SCAT5 symptom evaluation scale inventory. Interviews will be a minimum of 15 minutes and a maximum of 30 minutes.

Participants will be asked – "how would you describe each of these scale items?"

Headache
Pressure in head
Neck Pain
Nausea or vomiting
Dizziness
Blurred vision
Balance problems
Sensitivity to light
Sensitivity to noise
Feeling slowed down
Feeling like "in a fog"
"Don't feel right"
Difficulty concentrating
Difficulty remembering
Fatigue or low energy
Confusion
Drowsiness
More emotional
Irritability
Sadness
Nervousness or Anxiousness
Trouble falling asleep

Appendix D: Sport Concussion Assessment Tool 5th Edition

BJSM Online First, published on April 26, 2017 as 10.1136/bjsports-2017-097506SCAT5
To download a clean version of the SCAT tools please visit the journal online (http://dx.doi.org/10.1136/bjsports-2017-097506SCAT5)

SCAT5©

SPORT CONCUSSION ASSESSMENT TOOL – 5TH EDITION
DEVELOPED BY THE CONCUSSION IN SPORT GROUP
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

Patient details

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date of Injury: _____ Time: _____

WHAT IS THE SCAT5?

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

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

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

Recognise and Remove

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

Key points

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

Remember:

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

1

IMMEDIATE OR ON-FIELD ASSESSMENT

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

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

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

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

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

STEP 1: RED FLAGS

RED FLAGS:

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

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

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

STEP 3: MEMORY ASSESSMENT MADDOCKS QUESTIONS[2]

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

Mark Y for correct answer / N for incorrect

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

Note: Appropriate sport-specific questions may be substituted.

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

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

CERVICAL SPINE ASSESSMENT

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

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

Davis GA, *et al. Br J Sports Med* 2017;0:1–8. doi:10.1136/bjsports-2017-097506SCAT5

OFFICE OR OFF-FIELD ASSESSMENT

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

STEP 1: ATHLETE BACKGROUND

Sport / team / school: _____

Date / time of injury: _____

Years of education completed: _____

Age: _____

Gender: M / F / Other

Dominant hand: left / neither / right

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

When was the most recent concussion?: _____

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

Has the athlete ever been:

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

Current medications? If yes, please list:

_____

_____

_____

_____

_____

_____

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

2

STEP 2: SYMPTOM EVALUATION

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

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

Please hand the form to the athlete

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

If not 100%, why?

_____

_____

_____

Please hand form back to examiner

3

STEP 3: COGNITIVE SCREENING

Standardised Assessment of Concussion (SAC)[4]

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

ORIENTATION

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

IMMEDIATE MEMORY

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

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

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

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

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

CONCENTRATION

DIGITS BACKWARDS

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

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

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

MONTHS IN REVERSE ORDER

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

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

Davis GA, *et al. Br J Sports Med* 2017;0:1–8. doi:10.1136/bjsports-2017-097506SCAT5

4

STEP 4: NEUROLOGICAL SCREEN

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

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

BALANCE EXAMINATION

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

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

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

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

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

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

5

STEP 5: DELAYED RECALL:

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

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

Time Started

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

_____

_____

_____

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

6

STEP 6: DECISION

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

Date and time of injury: _____

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

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

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

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

Signature: _____

Name: _____

Title: _____

Registration number (if applicable): _____

Date: _____

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

Davis GA, *et al. Br J Sports Med* 2017;0:1–8. doi:10.1136/bjsports-2017-097506SCAT5

Appendix E: Child Sport Concussion Assessment Tool

BJSM Online First, published on April 28, 2017 as 10.1136/bjsports-2017-097492childscat5

Child SCAT5©

SPORT CONCUSSION ASSESSMENT TOOL
FOR CHILDREN AGES 5 TO 12 YEARS
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

FIFA

Patient details

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date of Injury: _____ Time: _____

WHAT IS THE CHILD SCAT5?

The Child SCAT5 is a standardized tool for evaluating concussions designed for use by physicians and licensed healthcare professionals[1].

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

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

Recognise and Remove

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

Key points

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

Remember:

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

1

IMMEDIATE OR ON-FIELD ASSESSMENT

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

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

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

The GCS is important as a standard measure for all patients and can be done serially if necessary in the event of deterioration in conscious state. The cervical spine exam is a critical step of the immediate assessment, however, it does not need to be done serially.

STEP 1: RED FLAGS

RED FLAGS:

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

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

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

STEP 3: EXAMINATION

GLASGOW COMA SCALE (GCS)[2]

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

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

CERVICAL SPINE ASSESSMENT

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

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

OFFICE OR OFF-FIELD ASSESSMENT
STEP 1: ATHLETE BACKGROUND

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

Sport / team / school: _____

Date / time of injury: _____

Years of education completed: _____

Age: _____

Gender: M / F / Other

Dominant hand: left / neither / right

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

When was the most recent concussion?: _____

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

Has the athlete ever been:

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

Current medications? If yes, please list: _____

STEP 2: SYMPTOM EVALUATION

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

To be done in a resting state

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

2

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

Child Report[3]

	Not at all/ Never	A little/ Rarely	Somewhat/ Sometimes	A lot/ Often
I have headaches	0	1	2	3
I feel dizzy	0	1	2	3
I feel like the room is spinning	0	1	2	3
I feel like I'm going to faint	0	1	2	3
Things are blurry when I look at them	0	1	2	3
I see double	0	1	2	3
I feel sick to my stomach	0	1	2	3
My neck hurts	0	1	2	3
I get tired a lot	0	1	2	3
I get tired easily	0	1	2	3
I have trouble paying attention	0	1	2	3
I get distracted easily	0	1	2	3
I have a hard time concentrating	0	1	2	3
I have problems remembering what people tell me	0	1	2	3
I have problems following directions	0	1	2	3
I daydream too much	0	1	2	3
I get confused	0	1	2	3
I forget things	0	1	2	3
I have problems finishing things	0	1	2	3
I have trouble figuring things out	0	1	2	3
It's hard for me to learn new things	0	1	2	3
Total number of symptoms:				of 21
Symptom severity score:				of 63
Do the symptoms get worse with physical activity?			Y	N
Do the symptoms get worse with trying to think?			Y	N

Overall rating for child to answer:

	Very bad									Very good
On a scale of 0 to 10 (where 10 is normal), how do you feel now?	0	1	2	3	4	5	6	7	8	9 10

If not 10, in what way do you feel different?:

Parent Report

The child:

	Not at all/ Never	A little/ Rarely	Somewhat/ Sometimes	A lot/ Often
has headaches	0	1	2	3
feels dizzy	0	1	2	3
has a feeling that the room is spinning	0	1	2	3
feels faint	0	1	2	3
has blurred vision	0	1	2	3
has double vision	0	1	2	3
experiences nausea	0	1	2	3
has a sore neck	0	1	2	3
gets tired a lot	0	1	2	3
gets tired easily	0	1	2	3
has trouble sustaining attention	0	1	2	3
is easily distracted	0	1	2	3
has difficulty concentrating	0	1	2	3
has problems remembering what he/she is told	0	1	2	3
has difficulty following directions	0	1	2	3
tends to daydream	0	1	2	3
gets confused	0	1	2	3
is forgetful	0	1	2	3
has difficulty completing tasks	0	1	2	3
has poor problem solving skills	0	1	2	3
has problems learning	0	1	2	3
Total number of symptoms:				of 21
Symptom severity score:				of 63
Do the symptoms get worse with physical activity?			Y	N
Do the symptoms get worse with mental activity?			Y	N

Overall rating for parent/teacher/ coach/carer to answer

On a scale of 0 to 100% (where 100% is normal), how would you rate the child now?

If not 100%, in what way does the child seem different?

3

STEP 3: COGNITIVE SCREENING

Standardized Assessment of Concussion - Child Version (SAC-C)[4]

IMMEDIATE MEMORY

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

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

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

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

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

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

CONCENTRATION

DIGITS BACKWARDS

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

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

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

DAYS IN REVERSE ORDER

Now tell me the days of the week in reverse order. Start with the last day and go backward. So you'll say Sunday, Saturday. Go ahead.

Sunday - Saturday - Friday - Thursday - Wednesday - Tuesday - Monday	0 1
Days Score	of 1
Concentration Total Score (Digits + Days)	of 6

4

STEP 4: NEUROLOGICAL SCREEN

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

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

BALANCE EXAMINATION

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

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

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

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

Condition	Errors
Double leg stance	of 10
Single leg stance (non-dominant foot, 10-12 y/o only)	of 10
Tandem stance (non-dominant foot at back)	of 10
Total Errors	5-9 y/o of 20 / 10-12 y/o of 30

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

5

STEP 5: DELAYED RECALL:

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

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

Time Started

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

_____

_____

_____

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

6

STEP 6: DECISION

Domain	Date & time of assessment:		
Symptom number Child report (of 21) Parent report (of 21)			
Symptom severity score Child report (of 63) Parent report (of 63)			
Immediate memory	of 15 of 30	of 15 of 30	of 15 of 30
Concentration (of 6)			
Neuro exam	Normal Abnormal	Normal Abnormal	Normal Abnormal
Balance errors (5-9 y/o of 20) (10-12 y/o of 30)			
Delayed Recall	of 5 of 10	of 5 of 10	of 5 of 10

Date and time of injury: _____

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

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

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

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

Signature: _____

Name: _____

Title: _____

Registration number (if applicable): _____

Date: _____

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

Curriculum Vitae

I. EDUCATION

A. Educational Background

2015 – 2019 (expected)	*Western University*, London, Ontario PhD: Rehabilitation Science, Methods and Measurements Certificate: University Teaching and Learning
2015	*Ohio University*, Athens, Ohio Master of Science: Athletic Training
2013	*Sheridan College*, Brampton, Ontario BAHSc: Athletic Therapy

B. Certifications/Licenses

Board of Certification Certified Athletic Trainer (#2000015762)
Canadian Athletic Therapists Association Certified Athletic Therapist (#2-4398)
First Responder Canadian Red Cross (expiry 2020)
HCP-CPR Canadian Red Cross (expiry 2020)

C. Professional Society Memberships

National Athletic Trainers' Association (NATA)
Canadian Athletic Therapists Association (CATA)
Ontario Athletic Therapist Association (OATA)
World Rugby Science Network Member

D. Awards and Honors

2013 Canadian Athletic Therapists Association Leadership Award

II. EMPLOYMENT AND WORK EXPERIENCE

A. Employment

2019 – Present **Research Assistant, Lawson Health Research Institute**
Fowler Kennedy Sports Medicine Clinic, London, Ontario

2017 – Present **Lecturer, Health Science**
Western University, London, Ontario

2018 – Present Assistant Coach, Women's Soccer
Fanshawe College, London, Ontario

2016 – Present **Head Athletic Therapist**
London FC, London, Ontario

2017 – Present **Field Coverage Coordinator**
Wishbone Athletics, Hamilton, Ontario

2017 – Present **Chief Therapist**
Ontario Volleyball Provincial Championship, Waterloo, Ontario

2013 – Present **Athletic Therapist/Owner**
Robinson Sports Medicine, London, Ontario

2015 – Present **Teaching Assistant, Health Science**
Western University, London, Ontario

2016 – 2018 **Part-Time Faculty, Athletic Therapy**
Sheridan College, Brampton, Ontario

2016 **Athletic Therapist**
PFPC, London, Ontario

2015 **Athletic Therapist**
Oakville Crusaders RFC, Oakville, Ontario

2015 **Athletic Therapist**
Oakville Titans Football, Oakville, Ontario

2014 – 2015 **Graduate Assistant Athletic Trainer**
Parkersburg South High School, Parkersburg, WV

2010 – 2015 **Head Athletic Therapist**
Mississauga Blues RFC, Mississauga, Ontario

B. Committees/Organizations

2019 – Present Health Quality Ontario
Expert Consultant: Concussion Quality Standard Advisory Committee

2018 – Present Western University
Board Member, Board of Governors
Committee Memberships:
Property and Finance
McIntosh Gallery Committee
Executive Committee of the Alcohol Policy Review Committee

2018 – 2019 Western University
Senator, University Senate
Committee Memberships:
University Research board
Operations and Agenda
Student Review Board Academic
Senate Committee on Academic Policy and Awards
Senate Committee on University Planning
Subcommittee for Teaching Awards

2018 – Present Canadian Athletic Therapists Association
Director, Board of Directors

2014 – 2018 Canadian Athletic Therapists Association
Ethics Committee

2016 – 2018 Canadian Board of Certification for Athletic Therapy (CBoCAT)
Exam Developer

2014 – 2017 Ontario Athletic Therapist Association
Director, Membership, Member Services & Academic Liaison
Secretary, Executive Committee

III. RESEARCH

A. ORCID

0000-0002-5043-2106
https://orcid.org/0000-0002-5043-2106

B. Manuscripts (Published)

Robinson M., Mc Elhiney D. Investigating a 7-day Baseline while Establishing Healthy SCAT3 Symptom Frequency and Severity. *International Journal of Athletic Therapy and Training.* 2017

Robinson M., Johnson A., Walton D., MacDermid J. A Technical Comparison on the Polytomous Rasch Analysis Output of RUMM2030 and R(ltm/eRm/TAM/lordif). *BMC Medical Research Methodology.* 2019

C. Manuscripts (in Progress)

Henderson R., Shelley J., Holmes J. Bassi H., Robinson M., Stephenson D., Young J., Johnson A. Accidental cycling fatalities in Ontario: A six-year retrospective chart review from 2010-2015 (under review)

Robinson M., Fischer. L., Johnson A., Walton D., MacDermid J. Measurement properties of the Adult Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation using Rasch analysis (in progress)

Robinson M., Fischer. L., Johnson A., Walton D., MacDermid J. Measurement properties of the Child Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation using Rasch analysis (in progress)

Robinson M., Fischer. L., Johnson A., Walton D., MacDermid J. Establishing the Minimal Clinically Important Difference (MCID) for the Adult Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation (in progress)

Robinson M., Fischer. L., Johnson A., Walton D., MacDermid J. Establishing the Minimal Clinically Important Difference (MCID) for the Child Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation (in progress)

Robinson M., Fischer. L., Johnson A., Walton D., MacDermid J. Investigating Patient's Interpretation of the Underlying Meaning of the Symptoms from the Adult Version of the Sport Concussion Assessment Tool 5th Edition Symptom Evaluation using a Qualitative Survey (in progress)

D. Abstracts (Published)

Robinson M., Mc Elhiney D. Investigating a 7-day Baseline while Establishing Healthy SCAT3 Symptom Frequency and Severity. British Journal of Sports Medicine. 2017

E. Projects

- Fowler Kennedy Concussion Electronic Data Capture System
    - Developed, in consultation with stakeholders and end users (both clinical and research), a custom clinical data collection tool using the RedCap platform to streamline the collection of clinical and research data from Fowler Kennedy's concussion clinic. This has resulted in an increased amount of available time for clinician appointment and has eliminated the need for retrospective chart reviews as all clinical data is available in a user-friendly database format.

F. Grants

- Ohio University Graduate Student Senate Peer Reviewed Research Grant (awarded)
- Ohio University College of Health Sciences and Professions Peer Reviewed Research Grant (awarded)

G. Presentations

- Ontario Brain Institute – CONNECT
    - Presentation on the Concussion Electronic Data Capture System (2018)
- Family Medicine Forum – College of Family Physicians of Canada
    - Lecture on Best Practices in Concussion Assessment and Management (2018)
- See the Line
    - Community Symposium Research Presentation (2018)
- Canadian Athletic Therapist's Association National Conference
    - Concussion Assessment and Management Tools and Protocols for Athletes (2017)
- 5th International Consensus Conference on Concussion in Sport (2016)
    - Investigating a 7-day Baseline while Establishing Healthy SCAT3 Symptom Frequency and Severity (2016)
- Canadian Sport Massage Therapist Association National Conference
    - Concussion Assessment and Management Tools and Protocols for Athletes (2016)
- Ontario's Standing Committee on Justice Policy regarding Bill 149, *Rowan's Law* (2016)
    - Athletic Therapists: Concussion Assessment and Management
- Ohio University Research Case Competition (2015)
    - Use of telemedicine to improve the quality of life of food insecure individuals in rural Appalachia.
- Ohio University College of Health Sciences & Professions Showcase (2015)

    - Investigating a 7-day Baseline while Establishing Healthy SCAT3 Symptom Frequency and Severity
- Ohio University Student Research Expo (2015)
    - Investigating a 7-day Baseline while Establishing Healthy SCAT3 Symptom Frequency and Severity

IV. TEACHING EXPERIENCE

A. Lecturer – Western University

- HS 2330A Systemic and Functional Anatomy (F2017, F2018)
- HS 3002B Health Occupations (W2018)
    - Was responsible for course development.
- RS 3360B Musculoskeletal Disorders in Rehabilitation (W2019)
    - Was responsible for course development.

B. Professor/Lecturer – Sheridan College

- SCIE 28634 Statistics for Health Science (W2017, F2017, W2018, F2018)
    - Was responsible for course development.
- SCIE 12941 Introduction to Biomechanics (F2016)

C. Teaching Assistant – Ohio University Division of Athletic Training

- AT 3300 Evidence Based Practice (2015)
- AT 2922 Practicum II (2015)
- AT 2151 Upper Extremity Exam Laboratory (2015)

D. Teaching Assistant – University of Western Ontario

- HS 4250A Population Health Interventions (2015)
- HS 2200B Health Occupations (2016)
- HS 2300 A/KIN 2222 A Systemic Approach to Functional Anatomy (2016)
- HS 2300 B/KIN 2222 B Systemic Approach to Functional Anatomy (2017)
- HS 2300 A/KIN 2222 A Systemic Approach to Functional Anatomy (2017)
- HS 2300 B/KIN 2222 B Systemic Approach to Functional Anatomy (2018)
- HS 3801B Research Methods and Analysis in the Health Sciences (2019)
- PT 9615B Advanced Professionalism (Wound Healing) (2019)

E. Teaching Awards

- 2017-2018 Western University Health Sciences Teaching Awards Committee: Teaching Excellence - Overall Instructor Effectiveness
- 2018-2019 Western University Health Sciences Teaching Awards Committee: Teaching Excellence - Overall Instructor Effectiveness

F. Teaching Feedback – Western University

			Displays enthusiasm	Well organized	Presents concepts clearly	Encourages participation	Responds to questions clearly	Encourages reflection	Provides fair evaluation	Provides helpful feedback	Good motivator	Effective as a university teacher	Course as a learning experience
2017-18	HS2330A	Mean	6.43	5.65	5.40	5.38	5.98	5.74	6.12	5.65	5.74	5.99	5.68
		Median	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
	HS3002B	Mean	6.51	6.11	6.30	6.26	6.49	6.17	6.04	5.88	6.04	5.61	6.43
		Median	7.00	6.00	6.00	6.00	7.00	6.00	6.00	6.00	6.00	7.00	7.00
2018-19	HS2330A	Mean	6.69	6.07	6.00	5.76	6.30	6.08	6.16	5.97	6.19	6.40	5.98
		Median	7.00	7.00	6.50	6.00	7.00	6.00	6.50	6.00	7.00	7.00	6.00
	RS3360B	Mean	6.43	5.77	5.40	6.14	5.97	5.77	5.94	5.91	5.77	6.26	6.00
		Median	7.00	6.00	5.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00

V. PROFESSIONAL DEVELOPMENT

- Doctoral Leadership Forum
  - Location: University of Western Ontario, London, Ontario
  - Date: January 19, 2018
- Teaching Mentoring Program
  - Location: University of Western Ontario, London, Ontario
  - Date: April 27, 2017
- Promoting the Academic Integrity of your Students Workshop
  - Location: University of Western Ontario, London, Ontario
  - Date: February 8, 2017
- From the OWL's nest: Best practices in course site design
  - Location: University of Western Ontario, London, Ontario
  - Date: April 6, 2017
- Fundamentals of Teaching and Learning
  - Location: Sheridan College, Mississauga, Ontario
  - Date: January 28, 2017
- Teaching Assistant Training Program

- Location: University of Western Ontario, London, Ontario
- Date: September 13, 2015

VI. REVIEWING EXPERIENCE

A. Textbooks

- Human Biology 9th Edition by Daniel Chiras

B. Peer Review Journals

- Personality and Individual Differences
- Musculoskeletal Science & Practice