INTER-RATER RELIABILITY OF THE CHEDOKE ARM AND HAND ACTIVITY INVENTORY IN AN ACQUIRED BRAIN INURY POPULATION

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Lay Abstract

It is important to measure change using reliable assessment tools. Outcome measures are designed for specific populations. If used in a different population, the reliability may be impacted. The Chedoke Arm and Hand Activity Inventory (CAHAI) is a measure of upper limb function that has been developed for use in the stroke population. It was unknown if the measure would still be reliable in the acquired brain injury (ABI) population. The goal of this thesis was to determine if the CAHAI is also reliable in ABI. Our results suggest that the CAHAI is highly reliable in this population.

Abstract

Background:
Motor impairments are common sequelae of Acquired Brain Injuries (ABI). An estimated 55-75% of ABI survivors have on-going limitations in UL function. Objective measures of UL function that have established validity and reliability in the ABI population are not readily available in the literature. The Chedoke Arm and Hand Inventory (CAHAI) is an assessment used with the stroke population. There are 4 versions of this assessment; a 13 item version and 3 shortened ones. The main purpose is to assess how much the affected UL contributes to a bilateral task. The CAHAI has strong reliability and validity in this population; however, it is unknown whether this measure can be used with other clinical populations such as ABI.

Purpose:
The purpose of this study was to estimate the inter-rater reliability of the Chedoke Arm and Hand Activity Inventory (CAHAI) when used with persons with ABI including 3 shortened versions of the measure.

Methods:
This is an observational parameter estimation study. Participants were recruited from an in-patient ABI rehabilitation program. The administration of the CAHAI was video recorded for 6 persons with ABI. The videos were assessed by 6 clinicians to estimate inter-rater reliability. A Latin square design was used to balance the order raters evaluated the videos.

Analysis:
A repeated measures ANOVA was performed and the variance components were used to calculate an intra-class correlation coefficient (ICC) and standard error of measurement (SEM) with 95% confidence intervals (CI).

Results:
Inter-rater reliability was high for all versions: CAHAI-7 ICC= 0.96 (95% CL: 0.89-0.99, SEM 2.65); CAHAI-8 ICC= 0.96 (95% CL: 0.90-0.99, SEM 2.72); CAHAI-9 ICC= 0.95 (95% CL: 0.85-0.99, SEM 3.49); CAHAI -13 ICC=0.96 (95%CL: 0.88-0.99, SEM 3.35).

Conclusions:
These results suggest the CAHAI is highly reliability in the ABI population. The shortened versions may be particularly useful when time constraints or patient tolerance are an issue.

Dedication

I would like to dedicate this thesis to my family who have supported me in various ways throughout my masters degree: my husband Frazer for his love and patience, for doing more than his fair share of the household tasks so that I could spend time at school and for just listening when I needed an ear; my children, Adam and Noah for supporting and encouraging me every day, helping out around the house when I was busy writing and for being quiet when I needed quiet to write; my parents for always being there to love, support and encourage me in everything I do; and my in-laws for treating me like a daughter. I love each and every one of you more than words can say. I never could have completed this thesis without you. Thank you.

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Table of Contents

Lay Abstract……………………………………………………………………………………..iv

Abstract……………………………………………………………………………………………v

Dedication……………………………………………………………………………………..vi

Acknowledgements……………………………………………………………………………vii

Table of contents……………………………………………………………………………….ix

List of Tables……………………………………………………………………………………xi

List of Figures…………………………………………………………………………………xii

List of Appendices……………………………………………………………………………xiii

List of Abbreviations…………………………………………………………………………xiv

Declaration of Academic Achievement………………………………………………………xv

Chapter 1: Introduction…………………………………………………………………………1

Overview…………………………………………………………………………………..1

Background……………………………………………………………………………....2

The Economic Burden of Illness……………………………………………………………4

Clinical Outcome Post ABI…………………………………………………………………5

Physical Impairments……………………………………………………………………..7

Cognitive Impairments……………………………………………………………………..8

Psycho-social Impairments…………………………………………………………………9

Rationale for Outcome Measurement in ABI……………………………………………...10

Principles of Reliability and Outcome Measurement………………………………………12

The ICF model and its relation to upper limb function post ABI………………….15

Measures of Upper Limb Function in ABI…………………………………………………16

The Chedoke Arm and Hand Activity Inventory....19
Summary....23
Purpose....24
Outline of Thesis....24
References....25
Chapter 2: Inter-Rater Reliability of the Chedoke Arm and Hand Activity Inventory in an Acquired Brain Injury Population....36
Abstract....38
Introduction....39
Methods....41
Results....46
Discussion....48
References....55
Chapter 3: Inter-Rater Reliability of Three versions of the Chedoke Arm and Hand Activity Inventory in an Acquired Brain Injury Population....65
Abstract....67
Introduction....68
Methods....71
Results....76
Discussion....77
References....82
Chapter 4: Discussion and Conclusion....90
Summary....91

Strengths and weaknesses……………………………………………………………………92

Implications and future directions…………………………………………………...94

Key Messages…………………………………………………………………………………95

References……………………………………………………………………………... ….97

List of Tables

Table 1: Participant Demographics……………………………………………………………99

Table 2: CAHAI-13 Total scores……………………………………………………………….100

Table 3: Rater Comments……………………………………………………………………..101

Table 4: Summary of scores for the CAHAI-7, CAHAI-8, and CAHAI-9………...102

Table 5: Reliability Coefficients and Standard Error of Measurement………...103

List of Figures

Figure1: CAHAI score form……………………………………………………………………..104

List of Appendices

Appendix 1: Retrospective CAHAI Variability Data……………………………….....105

Appendix 2: Retrospective CAHAI analysis…………………………………………….106

Appendix 3: Participant consent form…………………………………………………….107

List of Abbreviations

ABI	Acquired brain injury
ANOVA	Analysis of variance
CAHAI	Chedoke arm and hand activity inventory
ICC	Intra class correlation coefficient
ROC	Receiver operating curve
SEM	Standard error of measurement
UL	Upper limb
WHO	World Health Organization

Declaration of Academic Achievement

The following is a declaration that the content of the research in this document has been completed by Denise Johnson and recognizes the contributions of Dr Jocelyn Harris, Professor Paul Stratford and Dr. Julie Richardson in both the research process and the completion of the thesis. Denise Johnson contributed to the study design, completed and submitted the ethics application, was responsible for data collection, data analysis and writing of the manuscripts. Denise Johnson is first author on both manuscripts included in this thesis. Dr. Jocelyn Harris contributed to the study design, and assisted with manuscript review and editing. Professor Paul Stratford contributed to the study design, assisted with data analysis and provided manuscript review. Dr Julie Richardson provided manuscript review.

Chapter One: Introduction

Background and overview of thesis:

The objective of this thesis is to investigate a measure of upper limb function in the Acquired brain injury (ABI) population and to contribute to the body of knowledge on psychometric properties of a measure for this population. ABI is an important public health concern that is a leading cause of death and disability with significant health, social and economic impacts.[1–3] Motor impairments are a common sequel of Acquired Brain Injuries (ABI). Severe motor impairment in the upper limb (UL) results in a poor prognosis for motor recovery. An estimated 55-75% of ABI survivors have on-going limitations in UL function.[4,5] Limitations in UL function result in difficulties performing activities of daily living.[6] As a result many ABI survivors require extensive rehabilitation to maximize their recovery. In order to measure the progress, quantify the impairment and make informed treatment decisions reliable assessments tools are required. Outcome measures of UL function that have established validity and reliability in the ABI population are not readily available in the literature. The psychometric properties of outcome measures are population specific. The Chedoke Arm and Hand Inventory (CAHAI) is an assessment of UL function used with the stroke population.[7] There are 4 versions of this assessment; the original 13-item version and 3 shortened ones.[8] The main purpose of the measure is to assess how much the affected UL contributes to a bilateral task. It is unknown whether the measure would be reliable in other populations such as ABI despite clinical experience suggesting that it is routinely used in this population. The subsequent sections in this chapter will expand on these ideas and present a rationale for the thesis including why ABI is an important population to study, the significance of upper limb impairment, how the sequelae of ABI can impact testing and why the CAHAI was chosen as the measure to study. The findings will offer valuable psychometric data that will enhance the use of upper limb measurement in ABI.

Background and overview of ABI

It is important to understand the epidemiology of ABI in order to justify the scope and importance of the problem. An ABI encompasses both traumatic brain injury (TBI), and non-traumatic causes such as tumours, encephalitis and anoxic injuries.[1,2] The incidence of ABI ranges from 47 to 790 out of every 100000 people per year.[9,10] It is estimated that 1-2% of the United States population is living with a TBI related disability.[1,11,12] The variability is a result of differing inclusion criteria and definitions of what constitutes an ABI/TBI.[13] ABI is often associated with comorbidities with estimates indicating up to 70% of individuals sustaining concomitant injuries.[3,10] Regardless of whether an ABI is caused by traumatic or non-traumatic events, the clinical course is similar.[14] The extend of damage to the brain and resulting clinical presentation however, vary greatly from person to person depending on the severity and location of the insult.

The most common mechanisms of TBI are falls and motor vehicle accidents.[10,11,15] According to the World Health Organization (WHO) TBI results from the application of external forces to the skull that can lead to neurological damage,[12] with acceleration and deceleration forces disrupting the nervous tissue and blood vessels of the brain.[16] Injury can range from mild to severe and include oedema as well as haematomas. An anoxic injury can be caused by a number of different aetiologies including cardiac events, or any injury that causes an interruption in the cardio respiratory system that perfuses the brain. Tumours can be varying sizes and can be localized in the brain or spread through the body. On the ABI specialized in-patient tertiary care unit where our sample for this thesis was collected from, approximately 1/3 of the injuries are traumatic, 1/3 anoxic, ¼ are haemorrhagic, and the remainder are severe occlusive strokes. It is unknown whether this is representative of other rehab units as this information is not available in the literature that was reviewed.

An ABI often requires long-term care and therefore high costs to health care systems are incured.[11] Depending on the study the incidence of ABI has been reported to range anywhere from 47-790 cases per 100,000 in developed countries.[10] This variation in incidence may be attributed to differences in how ABI is reported and classified by various researchers in various countries. The incident rates translate to an estimated 1.7-2% of the population living with an ABI.[1,11] There is a higher incidence of ABI in males than females, and in adolescents and older adults more so than other age groups.[2,10,15,17] This is even more pronounced in the TBI group.[14,18] Additionally, there is documented evidence that incidence and prevalence are not equal amongst ethnic groups.[10–12] For example in a population based study in New Zealand, the Maori people had a greater incidence of TBI compared with people of European origin and those from rural communities had a greater incidence than those from urban centers. [11,19] It is important to do studies specifically in the ABI population due to the high incidence and prevalence.

Following an ABI, 33% to 85% of people will suffer impairment in upper limb function.[4,5] Spasticity, range of motion limitations, coordination difficulties, decreased strength and impaired central motor recruitment are common sequelae affecting upper limb function.[5] This can have a significant impact on the person's ability to complete activities of daily living, work or leisure.[6] Since the arm and hand move as a coordinated unit, upper limb tasks are complex and include reaching, grasping, manipulating, and stabilizing. Depending on the task, various degrees of upper limb strength, dexterity, range of motion and coordination are required.[20] Although many tasks can be completed unilaterally, bimanual use allows optimal completion of tasks.[7] Restoration of arm and hand function following brain injury tends to follow a predictable path of recovery. Initially there is flaccidity, followed by increasing spasticity, gradual return of volitional motor movement first within tone patterns and then independent movement.[21] Depending on the severity of the brain injury, an individual may progress through all of these levels, or none of them. Time post injury has a significant effect on the ability to change upper limb function.[22] Hence it is critical to accurately quantify function of the arm so interventions can be planned accordingly and progress monitored.

The economic burden of illness in ABI

Brain injury is the leading cause of death and disability in developed countries and accounts for a significant portion of health spending.[12] Due to on-going advancement in medical science, more people are surviving and being directed to rehabilitation centres to augment their recovery.[1,12] In Ontario, patients with ABI who require rehabilitation had higher costs of care than those discharged to other environments such as home or alternate level of care facilities without rehabilitation.[1] The cost of care for a person with ABI is highest in the first year post injury but can continue to have an economic burden on the health care system for 3 years or more.[23,24] ABI patients have longer hospital stays than other diagnostic groups, remain in the health care system longer and have a higher cost of care, particularly those with severe functional impairments.[1,24] A recent epidemiological study, reported that although the majority of ABI patients improved in terms of medical issues, 81% had persistent disability at discharge from hospital.[2] Measuring and quantifying disability and function are important to assist in determining if the patient is progressing, if the treatment is effective and in prioritizing resources for these patients.

Clinical outcome post ABI

Injuries post ABI may be focal or diffuse and the associated impairments vary depending on the pathophysiology. A focal injury causes damages to specific brain areas due to direct or indirect contact. The resulting contusions in the brain contribute to neuronal destruction and ischemia. This leads to focal impairments related to the functioning of that specific part of the brain.[25] A diffuse injury results in scattered axonal change throughout the sub-cortex, corpus callosum and brain stem. The consequence of this is swelling of the axon and interruption of the connections as well as downstream denervation.[25] Patients with diffuse axonal injury have more heterogeneous impairments compared to those with focal lesions involving unilateral motor pathways.[22,25] Subsequently, recovery of motor impairments following a diffuse injury has a better prognosis but longer recovery time than those with focal impairments.[25]

The magnitude of the ABI is frequently described in the literature as mild, moderate or severe; however, no standard classification is used in studies. The most common classification method is the Glasgow Coma Scale (GCS) which is well documented in the literature.[2] The GCS consists of three subscales: eye-opening which is indicative of brain stem arousal; verbal which is indicative of the cortex and brainstem working together; and the motor response which is indicative of the integrity of the cortex and spinal cord.[26] Typically a GCS of 13-15 is considered a mild injury, 9-12 is moderate, and 8 or less is severe. The GCS can be used to predict morbidity and mortality in more severe injuries.[10,27] ABI severity can also be classified by: duration of posttraumatic amnesia; duration of coma; or loss of consciousness. Regardless of classification system, there exists a general consensus in the literature that mild TBI is most prevalent and under reported.[17]

Injury severity can impact the number and extent of impairments post ABI. Frequency and number of impairments increases with ABI severity.[28] Persons with a mild brain injury such as a concussion may recover in hours to days, however, those with severe injuries may take months to years to recover and in many cases may never fully recover leaving the individual with life-long impairments and disability.[28] The duration of recovery and severity of consequences are directly related to injury severity and location of brain damage.[3]

Impairments may be categorized in to several broad areas such as physical, cognitive, and psychosocial. However, every brain injury is different and no two patients will have exactly the same presentation. Depending on the type of brain injury and what part of the brain is injured the presentation of deficits will vary greatly. For example an injury to the motor cortex will result in greater motor impairments such as the ability to move ones limbs or walk, while and injury in the frontal lobes may impact executive functioning and emotional regulation.[25,29]

The focus of this thesis is the measurement of UL function. However UL function is impacted by a variety of cognitive and psycho-social factors. As such an over view of these potential impairments will be provided in the subsequent sections.

Physical Impairments

There is a broad spectrum of physical impairments resulting from ABI. However, the number and severity of physical impairments is difficult to locate in the literature because most epidemiological studies only report gross impairments such as ability to walk or presence and absence of spasticity. It is more difficult to locate the function, coordination or severity of motor dysfunction. In a review of physical mobility outcome measures used in TBI, only 175 studies reported physical outcomes.[30] The most common outcome measure was the Functional Independence measure (FIM).[4,30] There were no studies that used impairment measures.[30] Due to this lack of measuring and reporting physical impairments post ABI, it is difficult to ascertain exact epidemiological information about strength and range of motion for example. It is generally accepted in the published literature that severe motor impairment can be a sequelae of ABI but there is no clear consensus on how to quantify, measure or track it. Following an ABI there is a general pattern of motor recovery that slows after 6 months; however, more than one third of individuals will have motor impairment at 2 years post injury.[4] Motor impairment following brain injury is often related to abnormal muscle tone or spasticity. Spasticity is present in 66.7% of patients with ABI.[31] Vestibular impairments, ataxia or tremors can also contribute to motor function.[22] Physical impairments include balance, vestibular or postural control impairment and neuromuscular movement impairment. Balance deficit has been reported in up to 34% of TBI patients.[32] A longitudinal multicentre study post severe TBI found that impaired gait was the most common physical impairment post ABI.[4] In their study, 43.5% of their sample had impaired gait. It was also reported that 32.7% had impaired arm strength and 47.8% had impaired finger to nose test (a measure of coordination).[4] Additionally, motor impairment can affect the production of speech and ability to swallow. Dysphagia has been reported in 27-61% of patients.[31] Consequences of physical impairment can lead to difficulties in performance in ADL, returning to work or engaging in social activities. Establishing a reliable upper limb measure in ABI has the potential to impact the collection of data related to physical impairments. Having a reliable measure of UL function will allow researchers to collect more detailed data on physical impairments related to the UL. This could potentially add a richness and depth of upper limb data to future epidemiological studies.

Cognitive Impairment

Cognitive impairment can impact the use and reliability of outcome measures. Cognitive impairment following a brain injury can include slowed processing; decrease insight, judgement and executive functioning. As with physical impairments, cognitive sequelae of brain injury are dependent on a number of variables including severity and extent of injury. Up to 65% of moderate to severe patients with TBI report cognitive problems.[33] One of the most prevalent cognitive impairments is memory.[34] Attention, processing and executive functioning are also commonly affected in mild brain injury.[33] Moderate to severe cases present with similar impairments and frequently have the additional challenges of communication, visual-spatial processing, insight and awareness of deficits and intellectual abilities.[33] Long lasting disability and reduced quality of life has been documented for those with severe impairments.[28] The presence of significant cognitive deficits can limit a persons' ability to perform activities of daily living, work, drive, or manage money.[33] Many studies exclude participants with cognitive impairments. Our study did not exclude them. It would be difficult to obtain a representative sample of ABI if cognitive impairments were excluded due to the high prevalence of these type of impairments as outlined above. Clinical experience suggests that patients with cognitive impairment perform best on functional tasks. For example, a patient may be unable to follow the command to bend the elbow and bring the hand to the ear, however if hands a telephone, will automatically bend the elbow to bring the phone to the ear. When cognitive impairments exist, context can take on increased importance in aiding understanding. Thus it is important that any measure of upper limb function in ABI be functional and intuitive to the individual.

Psychosocial Impairment

Psychosocial sequelae of brain injury can include behaviour or emotional issues. Deficits in auto-regulation, insight and judgement and impulsivity are common and can impact the ability to make or maintain social relationships.[35] Mood disorders and family dysfunction are commonly seen problems post injury.[35] In a cross sectional study on moderate to severe TBI, they found 55% of care-givers reported high levels of strain and burden.[36] ABI can result in an increased risk of depression and binge drinking.[37] There is a 1.5x greater risk of depression in patients with TBI compared to the healthy population.[37] There are also frequent sleep issues, and anxiety. [28] Headaches and pain have been reported in 47% of people with moderate to severe TBI.[36] Headaches and pain resulting from impairments of both the physical and psychosocial domains can be debilitating.[28] Both cognitive and psychosocial deficits are more persistent years after an ABI than physical impairments.[36] These deficits, although not directly related to upper limb function, can impact participation, motivation and understanding by the patient to use the upper limb and hence can impact any formalized testing. Selection of appropriate outcome measures must consider the impact of these impairments.

Rationale for Outcome measurement in ABI

There is significant pressure on clinicians to include standardized outcome measures in their practice. Using reliable outcome measures is critical in order to identify deficits, monitor progress and evaluate treatment effectiveness. Over the past twenty years there has been an increased focus on using outcome measures in rehabilitation. This is in part due to funding accountabilities and the need to justify resources and money expended on patient populations/or treatments.[38] While clinicians can verbalize why outcome measures are important, many acknowledge inconsistent use.[39,40] In order to advance the practice skills and body of knowledge in a given field or discipline treatment outcomes must be tested using reliable measures.

Outcome measures are frequently developed for specific populations. In order to ensure the selected measure represents both the population and construct of interest, reliability and validity in that population must be established. Reliability and validity are context specific.[41] However, many outcome measures designed for use in one population are used in other similar ones when a suitable measure is not available. Much of the research on neurological outcome measures is done on the stroke population because of the large prevalence, homogeneity of the manifestations and standard approach to care and management.[3] By contrast, other neurological populations such as ABI, Multiple Sclerosis or Parkinson's Disease have lower incidence rates, and/or are heterogeneous, or lack a consistent or commonly accepted approach.[3] In these populations no condition specific measures of upper limb function exist and clinicians are faced with the choice of either not using an outcome measure or of using one from another population. For example, two studies used the Chedoke Arm and Hand Activity Inventory CAHAI (a measure of upper limb function post stroke) in other populations without establishing reliability and validity: the CAHAI has been used as a secondary outcome measure to capture improvements in manual dexterity following a home based intervention in a sample of individuals with Multiple Sclerosis (MS)[42] and also as a measure of bimanual hand function post spinal cord injury.[43]

Common data elements for ABI research were developed in 2010 and revised in 2013.[44] One such element is the inclusion of reliable outcome measurement scales. Outcome measures are used to assess and quantify change. Outcome measurement is essential in order to justify resources, monitor patient progress and quantify and describe clinical presentations. [39,40] In clinical practice, assessments are typically completed at regular intervals, frequently coinciding with admission or discharge from a program or plan of care.[45,46] This thesis will contribute valuable information regarding the population specific psychometric properties of the CAHAI and will provide clinicians with a viable option to consider when assessing people with ABI's.

Principles of reliability and outcome measurement

Wade[47] defines outcome measurement as "the expected or looked for change in some measure or state." This pertains to a patient characteristic such as range of motion, activities of daily living, quality of life, care-giver burden or motor function, which may change over the course of rehabilitation or a study period. Typically an outcome measure is used to assign scores to certain variables using ratio, interval, ordinal or nominal descriptors. Classical test theory partitions a measured value or score in to a true score and error value. The type of scale often influences the interpretation and amount of error associated with that measure.[48] Hence reporting the context specific reliability of a measure should include a point estimate of relative and absolute reliability coefficients as well as their confidence intervals.[47] A common statistic used to assess inter-rater reliability studies on interval or ratio data is the intra class correlation coefficient (ICC).[49] The ICC can take on values from 0 to 1, with higher values representing a greater degree of relative reliability. It is calculated by dividing the true score variance by the observed score variance.

Interpretation of what is considered an acceptable ICC varies. Cicchetti[50] suggests under 0.4 is poor, 0.4 to 0.59 is fair, 0.59 to 0.74 good and 0.75 to 1 is excellent. However, the interpretation of the ICC should also consider comparison with other comparable measures.

Additionally the standard error of measure (SEM) is valuable because it is reported in the actual units of the measure.[48] The SEM is an indicator of consistency and is necessary in order to determine the amount of error associated with a particular score.[48]. It is calculated from the square root of the error variance. The ICC is unit-less allowing it to be used to compare measures and decide which one may have greater reliability. The SEM cannot be used to compare different measures because it is in the actual units of measurement that the tool uses. ICC is considered to be a relative reliability coefficient while SEM is considered an absolute reliability coefficient.[48] For measures to be clinically useful, they must display a sufficiently high ICC and sufficiently low SEM in the context of interest.[41]

Intra-rater reliability is calculated within the same rater whereas inter-rater reliability is calculated between multiple raters.[38] For a measure to be considered reliable, one should be able to obtain similar scores across between individual raters as well as similar scores if repeat assessments are completed by the same rater.

However with measurement there is a component of error. Error may be introduced by: the patients biology or motivation; disruptions in the environment (e.g. poor lighting); examiner instructions or expectations; as well as the calibration or scale of the measuring instrument.[48] The error may be systematic meaning the score is consistently either lower or higher than the true value or random meaning that the error is randomly distributed above and below the true value. In order to base a clinical decision on a measure, one should consider the magnitude of error and the consistency or repeatability of the measure.

In order to maximize reliability it is important that no true change occurs in the patient or state that is being studied between ratings. Strategies to ensure there is no true change when designing reliability studies are to have raters assess the patients 1) at the same time, 2) at a time point very close to one another, or 3) use a video so that all raters view the exact same thing.[49] There are advantages and disadvantages to each method. Having multiple raters assessing the same person at the same time may create a bias if they see one another's scores or reactions to the assessment; having them assess each person separately can create a participant burden, and using a video is not typically how an assessment would be completed clinically but can reduce demand on the person.

A strategy to partition an order effect from a rater effect is to use a latin square design.[51] A latin square design balances the order in which raters view and score participants. An additional consideration in studies that apply a rating system or measure to a new population is the variance in ratings. Care must be taken to ensure that ratings are distributed across the scale. If a subsequent study on a new population has ratings that are distributed in a narrow range at some point on the scale it can lower the estimate of reliability. [52] To determine the estimate of reliability in a population, variance of the scores needs to be considered. Using a sample with low variance in their scores may result in inflated reliability coefficients. In order to ensure that our study included substantial variance, we examined retrospective data from the patient population (Appendix). We then chose the point of assessment for our study to be 6 weeks as that point in time there was a good range of scores which would give us the most accurate estimate of reliability in our sample.

The ICF model and its relation to upper limb function post ABI

The World Health Organization (WHO) International classification of Function (ICF) model suggests that a person can be evaluated at the level of body structures and function, activity and participation. This is a model in which the determinants are non-linear but instead are interactive and exert influence on one another. Additionally, the contextual factors of environment and person can affect function at any level. Body structure and functions are anatomical or physiological components. Examples include range of motion, strength, and pain. Activity by contrast is an action or performance of a function. Examples of activity include walking, reaching and dressing. Participation refers to a person's role such as being a mother, working or doing a hobby. When someone sustains an ABI, their function may be affected at any or all of these levels. It should be noted that having impairment at the body structure and function level may or may not result in limitations at the activities or participation level and vice versa. Following severe ABI up to 80% of people may have lifelong impairments.[9] It is therefore critical to focus on activities and participation because impairments may be longstanding. Selecting outcome measures that target each of these levels will help ensure that the focus of rehab is not just impairment based but aims to restore some ability to participate in meaningful activity. An ABI can impact body structures and functions, activity limitations, or participation. This would suggest that the best outcome measure for upper extremity function in ABI would be one that measures functional activities. Some tools exist to measure impairments in ABI but not function. Range and spasticity can be measured with goniometry and the modified ashworth or tardieu spasticity scales.[26] Measures of activity and function are needed for ABI. For a measure to be useful in ABI it should include a variety of functional activity tasks, which could be completed, by participants at various levels of impairment. The CAHAI is a tool that assesses a person at the level of activities.

Measures of Upper Limb Function in ABI

An ABI can impact body structures and functions, activity, or participation. Individuals with ABI and their therapists frequently cite remediation of impairments and restoration of functional use of the upper limb as a goal.[53] This suggests outcome measures for upper limb function need to include functional activities/tasks that can be completed by people at various levels of impairment.[4] Measures of upper limb function in the ICF activity domain are needed for the ABI population.

At present, there is only one upper limb function measure with established psychometric properties in the ABI population, the Test Evaluant la performance des membres superieurs des personnes agees (TEMPA).[54] It is a measure initially developed for use in the elderly population and then subsequently researched for use in individuals with stroke, ABI and multiple sclerosis in separate studies. Although the authors conclude the measure is highly reliable in the ABI population

(ICC 0.89 to 1.00), they fail to report the standard error of measurement. There are also methodological issues. Guidelines for reporting reliability studies[41] suggest key items for inclusion in a report of reliability. The guidelines recommend including detailed information on how sample size was calculated; however, Mosely[54] et al does not include this information in the study. The author also does not specify if the raters viewed the videos independently. This could potentially introduce bias in the results. Additionally, examination of the task analysis, which is a sub-component of the measure, were not completed because previous studies had shown the ICC values to be in the poor range. Further, the TEMPA has received little attention in the literature, and is not mentioned in Stroke or ABI best practice guidelines.[54,55]

There was one other study which included 5 ABI participants out of 58 total participants in their study of the reliability of the AARAT, BBT and Fugl-Meyer however this number was not sufficient to determine psychometric properties specifically for ABI.[56]

The use of outcome measures is a standard of practice for both physiotherapists[57] and occupational therapists[58]. They are used to: describe impairment and disability; set measurable goals; document progress towards goals; and measure response to interventions. Despite the use of outcome measures being considered standard practice in ABI rehabilitation, there is inconsistent use of standardized outcome measures by clinicians.[59] Therapist, environmental and patient factors are cited reasons for this inconsistency. In ABI rehabilitation an additional factor is the dearth of appropriate measures that are valid and reliable in this population.

ABI clinical practice guidelines use a set of inclusion criteria that include methodological rigor for psychometric properties.[46] Ashford et al[60] identified 20 measures of upper extremity function in neurological populations which included ABI. Recent reviews of outcome measures used in ABI by Salter et al[46] and Tate et al[61] indicated there are over 700 measures related to function following an ABI. While Tate[61] listed the measures without consideration of the quality, Salter et al[46] critically appraised each measure. Salter et al[46] found only 20 of those measures had sufficient research to warrant inclusion in their review. Of the 20 measures reviewed none focused on upper limb function[46] and as a result they did not recommend the use of any despite upper limb function being identified as a common problem following an ABI.[53,60,62] It is critical that reliable measures of UL function in ABI be identified in order to meet the standards of practice. This thesis attempts to remediate the problem by investigating inter-rater reliability of a measure of UL function.

To date ABI best practice guidelines have not recommended upper limb function outcome measures. However; common measures of upper extremity function are recommended in the neurological literature including the Canadian Stroke Best Practice Guidelines[55] and include: Action Research Arm Test (ARAT), The Wolfe Motor Function Test (WMFT), the Box and Block Test (BBT); the Nine Hole peg test (NHPT) and the Chedoke Arm and Hand Inventory (CAHAI).[60,63,64] In deciding which measure to investigate for ABI, considerations were made. The measure needs to be function based so that tasks would be meaningful even to those with cognitive impairment. Both the NHPT and BBT are tasks that are not function based. This ruled out both the NHPT and BBT. Secondly, the measure needed to be able to quantify a wide range of impairments. As outlined in the section on clinical outcome post ABI, there can be a wide range of impairments depending on the severity and location of the ABI. The ARAT has been shown to have a floor and ceiling effect;[65,66] The BBT requires significant hand function to complete and may not be suitable for more involved patients;[56,67] and the WMFT has a floor effect in people with severe impairments.[68,69] Additionally, the measure needed to be user friendly, affordable, easy to access and easy to administer. The NHPT has been shown to have a practice effect and requires the purchase of specialized equipment.[70]The BBT, WMFT and ARAT all require special equipment as well. As a result the CAHAI was chosen as a measure that had the best fit with the needs of the ABI population as a measure worth investigating further psychometric properties.

The Chedoke Arm and Hand Activity Inventory

The CAHAI is a measure of interest to both researchers and clinicians that are seeking upper limb outcome measures.[55] Some upper limb measures consider only unilateral tasks such as turning a key, stacking blocks or sorting items;[56,68,71] however, optimal function is achieved when both upper limbs work together. The CAHAI consists of items requiring bilateral movement. This makes it an appealing tool for this study in ABI due to the prevalence of bilateral impairments in this population. The CAHAI was developed for use in the stroke population following a rigorous process. Barreca et al[7] used five theoretical constructs to guide their development of the CAHAI: (1) definition of upper limb function, (2) key aspects of normative upper limb movements, (3) potential for functional change, (4) meaningful for survivors of stroke whose upper limb vary in the degree of motor recovery, and (5) a measure of the contribution of the paretic upper limb in functional bilateral tasks.[7] They defined upper limb function as “The main purpose of the arm and hand is to move as an integrated unit in various directions so as to stabilize, reach, grasp, and manipulate objects of various sizes and weights repeatedly in order to perform basic life skills such as feeding, dressing, personal care, domestic chores, mobility, and communication. Functional use of both arms allows the client optimal completion of various activities of living, work, and leisure.” In order to capture the full range of normative upper limb movements they chose items that highlighted different characteristics of upper limb strength, dexterity, ranges, and grips. By choosing familiar everyday items that offer different sensory input their theory was that they may facilitate upper limb function. The developers felt that the CAHAI should consist of those activities that were meaningful to patients; such that, they could see small but meaningful change that could then motivate them to persist in attempting to use the affected limb. Furthermore, it was decided that the intent of the CAHAI was to measure the degree to which the paretic upper limb participated in tasks. The items on the CAHAI would allow the rater to indicate whether the paretic upper limb was used in a stabilization or manipulation role. They then completed a review of the literature, looking for potential functional upper limb tasks used in other measures. This method identified 177 items. Secondly, individuals with stroke were surveyed and asked about the performance of their affected arm and hand in daily life and what activities they would want to do if improvement of their upper limb occurred. This information was used to generate a list of 574 items meaningful to stroke participants. Clinicians experienced in stroke care were then consulted. The 751 generated items were categorized into personal hygiene; dressing; eating; domestic chores; mobility; and communication. Items with potential gender bias were eliminated, as were items that were not bilateral, reducing the list to 26 items. These items were piloted with stroke survivors and items were added or removed based on safety issues or level of difficulty and the pilot testing was repeated. From this iterative process, 13 items were identified by eliminating ones with poor frequency endorsement, were difficult to standardize or showed a redundancy with other items.[7]

The CAHAI uses every day bilateral, gender-neutral tasks. The specific tasks and score sheet are outlined in Figure 1. The tasks are rated on a 7-point scale, similar to the Functional independence measure (FIM). Scores are assigned to the affected limb only. Scoring is done following observation of the task performance. A detailed scoring manual outlining the task components and a scoring key are available. A score of 7 indicates complete independence for the task; 6 modified independence (including excessive time, use of assistive devices or safety concerns); 5 supervision (including cueing); 4 minimal assist; 3 moderate assist (includes using table for support); 2 maximal assist; and 1 total assist (includes using only one hand to complete the task, or if it is unsafe to attempt the task). The total score is obtained by adding the score for each individual item and can range from 13 (severe impairment) to 91 (normal UL function). The average administration time of the full version is approximately 30 minutes

Once the CAHAI items were finalized a reliability and validity study was undertaken in the stroke population.[72] Barreca et al took a sample of 39 stroke participants divided in to 2 cohorts to stratify for severity and chronicity and assessed them using the CAHAI, ARAT and CMSA. Test-retest reliability was excellent at 0.98 (95% CI 0.96-0.99) and SEM was 2.8 (95% CI 2.3-3.7). Construct validity of the CAHAI and the ARAT were correlated at 0.93 (95% CI 0.87-0.96). Sensitivity to change, established using a receiver operating curve (ROC), was superior for the CAHAI compared to the ARAT or CMSA at 0.95 (95% CI 0.87-1.0).[72] The strength of these psychometric properties positions the CAHAI as a useful and appealing measure of upper limb function in stroke. Despite these strengths, authors have questioned the cultural validity of the CAHAI.[68,69]

Historically, tests have been condensed to reduce the administration time. Some examples of this are the FIM and Alpha FIM, and the Carroll test of upper limb function, which was reduced to create the ARAT. In order to increase the clinical utility and enhance uptake of the CAHAI, Barreca et al[73] examined 3 shortened versions of the CAHAI (CAHAI-9, CAHAI-8, CAHAI-7). Completing a factor analysis and having experienced clinicians' rank the items reduced the items. Each version was then evaluated to determine test-retest reliability, cross-sectional and longitudinal validity. The ICC estimates of reliability were as follows for each of the shortened versions: CAHAI-9 ICC=0.97, CAHAI-8 ICC=0.97, CAHAI-7 ICC=0.96. The cross sectional validity calculated using a Pearson correlation coefficient of the CAHAI with the Action Research Arm Test (ARAT) was: CAHAI-9=0.94, CAHAI-8=0.95, CAHAI-7=0.95 and the longitudinal validity calculated using ROC's was

CAHAI-9=0.94, CAHAI-8=0.93, CAHAI-7=0.97. They conclude that all three versions are highly valid and reliable for use in the stroke population and are better at detecting clinically important change than the ARAT.[73,74] Because of these strong psychometric properties, functional components and ease of access, the CAHAI was chosen to evaluate in the ABI population for this study.

Summary

ABI is an important public heath concern. The sequelae of ABI can include UL dysfunction. Quantifying UL impairment is important to aid in the allocation of resources and to measure treatment effectiveness. The importance of rehabilitation is consistently underestimated and is consequently more difficult to fund.[12] It therefore becomes critical to use psychometrically tested outcome measures to demonstrate the value of a given intervention. For an ABI survivor rehabilitation is important for the regaining of function.[12] One method to demonstrate the value of rehabilitation is to demonstrate change through outcome measures. However, the specific population being studied may impact psychometric properties of a measure. The CAHAI is a measure with established psychometric properties in the stroke population. There are no UL measures with established psychometric properties in the ABI population. The CAHAI may be suitable for use in the ABI population. The use of reliable outcome measures can contribute to clinical decision-making. It helps determine treatment effectiveness, patient progress and subsequently recovery, making the choice of measure important. Therefore it is important to study the reliability of the CAHAI in an ABI population.

Purpose

The purpose of this thesis is as follows:

1. To estimate the inter-rater reliability of the Chedoke Arm and Hand Activity Inventory in individuals with ABI.

2. To estimate the inter-rater reliability of three shortened versions of the Chedoke Arm and Hand Activity Inventory in individuals with ABI.

3. To describe the ease, use and clinical utility of the Chedoke Arm and Hand Activity Inventory in the ABI population.

Outline of Thesis:

The structure of this thesis is a sandwich style thesis. The preceding chapter is an overview of the current knowledge regarding upper limb outcome measures in Acquired Brain Injury (ABI) and their significance. The potential sequelae of ABI and their consequences are presented. The chapter provides rationales for why the study's contained in this thesis are important. An overview of the literature related to the Chedoke Arm and Hand Inventory's psychometric properties is also provided. Finally, reliability is reviewed and the purpose of the thesis is presented. Chapter two contains the manuscript *Inter-rater Reliability of the Chedoke Arm and Hand Activity Inventory (CAHAI) in an Acquired Brain Injury Population*. It is a reliability study to determine if a measure developed for use in the stroke population might also be reliable for use in the ABI population. Chapter 3 contains the manuscript *Inter-rater Relaibiltiy of Three versions of the Chedoke Arm and Hand Activity Inventory.* It is a reliability study, which builds on the previous chapter to determine if 3 shortened versions of the measure are also reliable. The final chapter 4 will summarize the findings from the two manuscripts. Implications for clinical practice will be discussed and areas for future research will be suggested.

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Chapter 2: Study #1

Inter-rater reliability of the Chedoke arm and hand activity inventory in an acquired brain injury population

The following paper has been formatted according to the style requirements for the Journal of Neurological Rehabilitation and was submitted for peer review June 2016.

Title: **Inter-rater reliability of the Chedoke Arm and Hand Activity Inventory**

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Key words: Upper Limb, outcome measures, brain injury, reliability, assessment.

Abstract

Background:

The Chedoke Arm and Hand Activity Inventory (CAHAI) is an assessment of upper limb function designed for use in the stroke population. The CAHAI has strong reliability and validity in this population; however, it is unknown whether this measure can be used with other clinical populations such as acquired brain injury (ABI).

Purpose:

The purpose of this study was to estimate the inter-rater reliability of the CAHAI when used with persons with ABI.

Methods:

The research design was an observational parameter estimation study. Participants were recruited from an in-patient ABI rehabilitation program. The administration of the CAHAI was video taped for 6 persons with ABI. To estimate inter-rater reliability each video was assessed independently by 6 clinicians yielding a total of 36 assessments. A Latin square design was used to balance the order raters evaluated the videos. Shrout and Fleiss Type 2,1 intra class correlation coefficients (ICC) and standard error of measurement (SEM) were calculated to estimate inter-rater reliability of the CAHAI.

Results:

Inter-rater reliability was high ICC=0.96 (95%CL: 0.88, 0.99) and the SEM was 3.35 (95%CL: 2.63, 4.63) CAHAI points.

Conclusions:

These results suggest that the CAHAI, although designed for use in the stroke population, can be used reliably in the ABI population.

Introduction:

Acquired Brain Injury (ABI) is one of the leading causes of disability world wide[1] affecting over ten million people annually.[1–4] Over 40% of persons affected have long term disability[4] which can result in motor, cognitive, behavioural or emotional impairments. These sequelae often result in difficulty completing and participating in daily, social, vocational and recreational activities.[2] This can result in long-term resource intensive treatment goals. Subsequently, valid and reliable assessment methods are a vital aspect of the rehabilitation process in order to determine treatment focus, patient progress, and treatment effectiveness. .

Evidence-based practice guidelines[5,6] state the importance of considering psychometric properties in choice of assessment tool. Using measures with satisfactory reliability and validity can aid clinical decision making and support establishing realistic rehabilitation goals. In rehabilitation insufficient testing of measures is common[7,8] leaving clinicians to use tools inter-changeably among populations, assuming accurate information is being collected. However, Kottner et al[9] postulates that measures are designed with a specific population in mind which affects the interpretation of reliability as resulting coefficients are population specific. Hence, reliability and validity established in one population cannot be assumed suitable for use when sample diagnosis or demographics differ. This highlights the importance of establishing psychometric properties within each population.

It is challenging to find outcome measures with established psychometric properties for the acquired brain injury population.[6] In a systematic review of assessment tools for adults with ABI, 728 instruments were identified, of those, 23 assessed neuromuscular and movement related functions with only 6 focused on the upper limb.[8] All 6 measures focused exclusively on impairment rather than disability and yet the focus of rehabilitation is often restoration of function.

Additionally, an evidence based review of outcome measures for persons with moderate to severe brain injury[6] stated that evaluation and measurement of upper limb impairment and function is a component of best practice. Though critical appraisal of measures was completed, no valid or reliable measures of upper limb function were found.[6] As a result, no clear recommendations were made regarding which assessment tools are best to use. When an appropriate measure is not available for a patient group, a frequent strategy is to select a tool that is valid and reliable in a similar population; stroke literature has identified many upper limb measures with sound psychometric properties.[10,11]

Although stroke and ABI share similar residual effects, differences in mechanism of injury can result in diffuse brain damage.[12,13] As such the neuro-motor deficits in stroke are frequently unilateral compared to bilateral in ABI, thus typically resulting in greater impact on function.[14] Upper limb deficits are common following ABI[15–17] with reports of between 12.9-27.7% having impaired strength,[16] which is considered a correlate of upper limb function in stroke patients.[18] Many assessment tools developed for use in the stroke population focus on measuring motor impairments resulting from hemiplegia and thus may not capture the complex nature of bilateral motor deficits. When differences such as this exist, we cannot assume a tool developed for stroke will also be reliable in ABI. As a result further study is needed.

Common measures of upper extremity function in the neurological literature including the Canadian stroke best practice guidelines[28] are: Action Research Arm Test (ARAT), The Wolfe Motor Function Test (WMFT), the Box and Block Test (BBT); the Nine Hole peg test (NHPT) and the Chedoke Arm and Hand Inventory (CAHAI).[24,29,30]

The ARAT has been shown to have a floor and ceiling effect;[31] The BBT requires significant hand function to complete and may not be suitable for more involved patients;[32] the NHPT has been shown to have a practice effect and requires the purchase of specialized equipment;[24] and the WMFT has a floor effect in people with severe impairments.[33,34] The CAHAI has good psychometric properties, is free, uses common everyday items, uses functional tasks and is reflective of the ICF domains of activities and participation.

The purpose of this study was to estimate the inter-rater reliability of the Chedoke Arm and Hand Activity Inventory (CAHAI) in the ABI population. A secondary objective was to describe the clinician rater's perceived utility of this measure.

Methods

Prior to starting the study approval was received from the hospital and university research ethics boards.

Study design

A cross sectional, observational parameter estimation study design in which 6 raters reviewed 6 participant videos, was used to estimate the inter-rater reliability of the CAHAI. To minimize systematic differences owing to the order ratings were obtained, a Latin square design was applied. The sample size of 6 raters and 6 participants (36 individual data points) was based on the expectation of obtaining an inter-rater reliability of 0.90 with a lower one-tail 95% confidence limit (CL) of 0.7.[19] A latin square design is an array with each variable occurring exactly once in each row and each column. It balances for order effect. This design allows a variable (participant CAHAI scores) to be evaluated multiple times (by using multiple raters). Using this technique, a sample size of 36 can be achieved with a reduced number of participants because the participants are assessed multiple times by multiple raters.

Measures

Chedoke Arm and Hand Activity Inventory

The purpose of the CAHAI (Figure 1) is to evaluate the contribution of the impaired upper limb when performing a bi-lateral task. It specifically measures the motor skills necessary to complete the task (e.g. fine or gross motor, stabilization or manipulation). The CAHAI is a standardized measure with a detailed instruction and scoring manual.[20–22] The CAHAI was developed following a literature review and consultation with clinicians and individuals with stroke. This process led to an exhaustive list of functional upper Limb tasks that were analysed and refined to the current 13 items. An advantage of the CAHAI is that it uses inexpensive everyday materials, which are accessible to clinicians. The CAHAI is scored on a seven-point scale, similar to the Functional Independent Measure.[23] For each item the score can range from 1 (i.e. the affected limb performs less than 25% of the task) to 7 (i.e. the affected limb completes all required components), with mid-scale scores representing different percentages of contribution of the affected limb and or help with the task using light touch assistance. The result is a total possible score ranging from 13 to 91.[21,22]

The CAHAI has good psychometric properties.[20,21,24] Studies have shown high inter-rater reliability (ICC 0.98, 95%CI: 0.96-0.99), low SEM (SEM 2.8, 95%CI: 2.3-3.7)[20], internal consistency of 0.98[21], and a minimal detectable change (MDC90) of 6.3 points, meaning that 90% of participants will have random variation in their performance of 6.3 points or less.[20] The CAHAI has cross sectional validity (ICC 0.93, 95%CI: 0.87-0.96) with the Action Research Arm Test,[20] and sensitivity to change (ICC 0.95, 95%CI: 0.87-1.00).[20] However, some authors have questioned the clinical utility of this measure[25,26,27] including the impact of non motor deficits on scoring (i.e. cognitive, perceptual or communication impairments); the potential ceiling and floor effects in very high or very low functioning participants; and therapists low confidence in their own ability to accurately score the measure.[25] Although therapists report struggles with limiting scoring to only motor performance of a task when rich information about other aspects of the participant was evident,[26] the majority of therapist supported the use of the CAHAI due to its inclusion of functional every day tasks.[25]

Chedoke McMaster Stroke Assessment (CMSA)

The CMSA was used to determine study inclusion. The CMSA[28] is a measure developed for use in the adult stroke population and is comprised of motor impairment scales (hand, arm, foot, and leg) and a disability inventory. For this study, the arm and hand impairment scales were used. Individuals are asked to do a series of movements and are graded on a 7-point scale. The impairment scale classifies the affected arm and hand on a 7 point scale where 1 is severe impairment such as flaccid paralysis and 7 is typical movement. For the arm scale an example movement is touching your hand from your knee to your chin; for the hand scale an example movement is touching your thumb to each of your fingers. The CMSA has excellent test retest (ICC=0.98), intra rater (0.98) and inter rater (0.99) reliability as well as construct and concurrent validity in the stroke population.[28]

Participant recruitment

Both the raters and participants for this study were recruited from an ABI in-patient rehabilitation unit at a regional tertiary care hospital. A convenience sample of individuals with upper limb impairment as a result of an ABI (confirmed by radiological evidence), aged 16 to 65 years, and with a CMSA arm and hand score between 2 and 6 respectively was recruited. Exclusion criteria consisted of behaviours that would prevent safe participation or the inability to follow a one-step command. Consecutive individuals that met eligibility criteria were video recorded during administration of the CAHAI at 6 weeks post admission. Participants received standard care throughout the study for the upper Limb. This included, the graded repetitive arm supplementary program (GRASP)[29] daily, individual motor recovery exercises; functional task specific training; arm ergometer; and range of motion exercises 3-5 days per week. Usual length of stay for people in the ABI in-patient program ranges from 2 weeks to 3 months.

Raters of the video recordings were recruited from the inpatient ABI program and consisted of 3 physiotherapists (PT's) and 3 occupational therapists (OT's). All raters had experience using the CAHAI in the ABI population and were trained on the administration and scoring of the CAHAI in a half-day workshop.

Procedure

Treating therapists identified consecutive admissions to the in-patient ABI rehabilitation unit and completed the CMSA bilaterally in order to determine severity of motor impairment and study eligibility. Demographic (e.g. age and hand dominance) and injury characteristics (e.g. mechanism of injury and time since injury) were collected for each participant. Demographic data was collected for each clinician rater (e.g. year of practice, years of ABI experience).

The administration of the CAHAI was videoed in a single session for each participant. All participants were administered the CAHAI at approximately 6 weeks post admission to capture the majority of patients prior to discharge. Raters independently viewed and scored the most involved upper limb using the videos and were blinded to the other raters' scores. Raters were also asked to complete a form soliciting suggestions, feedback and comments regarding using the CAHAI in the ABI population.

Statistical analysis

Descriptive statistics were used to summarize patients' and raters' characteristics. The mean and standard deviation were calculated for each CAHAI item and the total score. The primary analysis was a 3-way analysis of variance (ANOVA) with CAHAI scores as the dependent variable. Factors were patients (6-levels), raters (6-levels), and order (6-levels). In the absence of an order effect, the 3-way model was reduced to a 2-way ANOVA containing the factors patients and raters.

Variance components were estimated and used to calculate a Shrout and Fleiss Type 2,1 intra class correlation coefficients (ICC) and standard error of measurement (SEM). These results were reviewed to check for outliers and a separate analysis repeating the above ANOVA's was done to determine if extreme scores created excess influence on the ICC. Data was analysed using STATA 12.1.

Results

Demographic findings are reported in Table 2. A total of 6 male participants with ABI were included in the study with a mean (SD) age of 55.33 (4.84) years (min., max.: 50, 64). The participants mean (SD) months from injury to admission to the program were 10.72 (5.41) (min., max.: 4.2, 19.53). Using the CMSA scores, 4 of the participants had bilateral UL impairments, of those with bilateral impairments, 2 had the right side as most impaired. Both of the participants with unilateral impairment were most impaired on the right side. The severity of motor impairment for the weakest upper limb varied from 2-6 for both the arm and hand scales. A total of 6 female raters were recruited (3 PT and 3 OT). The mean (SD) years in practice were 18.92 (11.88)(min., max.: 1.5, 32) with 11.83 (8.84) (minimum, maximum: 1, 22) years of ABI experience. Raters experience using the CAHAI varied from 5 to 20+ times.

A total of 36 assessments were analysed (Table 2). The mean (SD) total score for the CAHAI was 42.14 (20.27) (min., max.: 16, 85). Descriptive statistics analyzed by rater and by order were used to look for extreme scores; none were identified.

Inter-rater reliability

The 3-way ANOVA (participant, rater and order) revealed no significant order effect; as a result a 2-way ANOVA considering the subject and rater is reported. The inter-rater reliability estimate was ICC=0.96 (95%CL: 0.88, 0.99) and the SEM was 3.35 (95%CL: 2.63, 4.63) CAHAI points. The ICC analysis was repeated excluding the participants with the highest and lowest scores to determine if either had excess influence on the ICC. No statistically significant influence was found.

Clinical utility of the CAHAI in the ABI population

Although a formal qualitative inquiry was not followed, raters were asked to provide feedback regarding the use of the CAHAI (Table 3). In summary the main issues presented by the therapists' concerned administration and scoring. Administering the CAHAI to participants presented challenges. It was common for therapists' to report the need to repeat instructions and provide multiple physical and verbal demonstrations for the items. The instructions for each item are standardized and therefore extra cueing and repetition of instructions results in a lowed score (possible maximum score of 5 out of 7). An example of participant difficulty with instructions is item nine, Cutting Medium Resistance Putty. One therapist stated:

‘*It required me to change the instructions from cut 5 small separate pieces using both of your hands to put the fork in one hand and the knife in the other, now cut the putty as if it was a piece of meat, cut 5 pieces*’.

In this example the scoring would be a maximum of 5 even if the participant completed the task perfectly. This could potentially create a false ceiling in the score, particularly if cueing was required on multiple tasks.

Discussion

This is the first study to establish reliability of the CAHAI for use with the ABI population. The inter-rater reliability was excellent[30] (ICC=0.96). The SEM, which is representative of the consistency of the CAHAI scores, was low (3.35).[31] The SEM is reported in the actual units of the CAHAI, which is important in order for clinicians to know how much of the score could be attributed to error, and how much is true change. Our findings suggest the CAHAI is reliable in the ABI population.   This is salient because brain injuries are one of the leading causes of disability worldwide. Having a reliable measure specific to ABI will assist clinicians to monitor progress and prioritize therapist time and treatment focus related to UL function.

Our results demonstrate a wide range of scores. There were no floor or ceiling effects noted. A floor effect is can occur if collected data is clustered at the bottom end of the scale. When a floor effect occurs, a measure may not be able to distinguish between participants at the bottom of the scale. A ceiling affect is a similar issue which occurs if data is clustered at the top end of a scale. This is an important consideration in choosing an appropriate measure. Several other measures of upper limb function have been shown to have significant floor and ceiling effects in other populations (The ARAT has been shown to have a floor and ceiling effect;[31] and the WMFT has a floor effect in people with severe impairments.[33,34]) The CAHAI on the other hand appears to be able to differentiate participants at either end of the scale.

The results of our study are encouraging for the use of the CAHAI in the ABI population as our sample, though small, was heterogeneous. It included people with various etiologies, levels of motor impairment and a mixture of right or left sided weakness. The clinician raters representated both PT and OT, which is consistent with discipline collaboration when working in an inpatient setting. [21] The raters also represented a range of experience both in treating ABI and using the CAHAI suggesting that the CAHAI can be used reliably by a variety of therapists. While our study did not include participants from acute or community settings, we used multiple raters. This represents standard of care across the continuum where individuals may be administered the same assessment by many therapists.[32] Having strong inter-rater reliability determined by using multiple raters lends support for its use across the continuum when many different therapists may be involved in the persons care.

Comparison to previous research

In the stroke reliability research on the CAHAI by Barreca et al[20], the inter-rater reliability was ICC=0.98 (95%CL: 0.96-0.99) which is similar to our findings of ICC=0.96 (95%CL: 0.88-0.99). Having similar results not only advances the body of evidence and knowledge translation of the CAHAI but also confirms that the CAHAI, designed for use with the stroke population, can be used reliably in the ABI population. Even though the impairments may have a different presentation in the two populations, the functional implications appear to have some overlap and can be measured by the same tool. Irrespective of similar functional implications, reliability coefficients are population specific. Thus it is important to consider the original reliability work and equally important to complete studies in additional populations in order to advance the use of reliable instruments. [32,33] This ensures accurate information is being collected for the population of interest.

Past studies have highlighted the challenges in finding outcome measures for use in ABI, particularly for the upper limb.[6,8] ABI survivors consistently rate upper limb function as a therapy goal,[17] consequently valid measures in this population are needed in order to evaluate UL function accurately. Measures of UL function designed for the stroke population have reliability coefficients similar to those found in our study. Baker et al[11], in a review of stroke upper limb measures, reported only 3 measures meet the psychometric standards specified by the Scientific Advisory committee of medical outcome trust (MOT), the CAHAI; the stroke rehabilitation assessment of movement (STREAM) upper limb subscale; and the ABILHAND.[11] The STREAM upper limb subscale reports an ICC=0.96.[34,35] The ABILHAND reports an ICC of 0.90.[36,37] These ICC's are consistent with the results of our study suggesting the CAHAI is a viable option to assess UL in the ABI population. Those involved in the development of ABI best practice guidelines and reviews of outcome measures are encouraged to consider recommending the CAHAI as a reliable measure of upper limb function.

Clinician perceived utility

Raters had mixed reviews regarding the clinical utility of the CAHAI in the ABI population. They expressed concern that due to difficulty with instruction comprehension, the ability to follow directions and not necessarily hand function was being measured. Raters stated that scoring both limbs would be meaningful because many of the participants had bilateral involvement. Additionally, raters had difficulty limiting their focus to assessment of only the upper limb when information about cognitive and perceptual status was observed. An explanation for this may be the prevalence of cognitive, behavioral and perceptual deficits in individuals with ABI.[38] Qualitative studies on the clinical utility of the CAHAI with stroke survivors, support these findings as clinicians sought to document non motor findings such as perception, sensory and cognitive deficits[25,26]. By providing space on the score sheet to record additional comments the CAHAI may be used to capture valuable information regarding the impact cognitive-perceptual deficits may have on motor performance.

There were also positive comments regarding the CAHAI. The participants in this study included people with receptive aphasia and neglect. Many motor assessment tools are not appropriate to use when these deficits are present. Raters stated that by using a functionally based measure participants were better able to attempt each test item. This may be a consequence of functional tasks being more familiar and intuitive than abstract movement patterns often performed in impairment-based assessments. Another possible contributor to participants ease and willingness to attempt tasks is the administration guidelines. The guidelines require both demonstration of each item along with verbal instructions. The combined visual and verbal cues may enhance comprehension of task demands by participants with difficulty participating in assessments with exclusively verbal directions. Further study to refine and revise the instructions to allow for extra explanation without being penalized may result in improved scores and may impact reliability.

Limitations

Participants in this study were chosen from a sample of individuals with ABI and may not be representative of all people with ABI. While our study used multiple raters, we did not recruit participants from across the continuum. The literature suggests that although males are twice as likely as females to sustain an ABI, both sexes are affected.[2] From our sample, we can only conclude that the CAHAI is reliable with in-patient males with an ABI. Participants with ABI often have a reduced tolerance for activity.[40] It would not be feasible due to the associated burden experienced by the participant to be administered multiple assessments by different raters. Therefore, videotaping was used to gather the data. This approach allowed the use of multiple raters with no additional demand on the participants, however in clinical practice the raters would be administering the test. When a rater administers the test there are added sources of error; the raters may all administer slightly differently and the participants may perform slightly differently on different occasions. This may impact the rater's ability to score the items. As a result, the use of the video design may have reduced some of the error variability in our sample and may have increased our ICC. Future studies may wish to use an alternate design to confirm these findings.

Future directions

Further the use of the CAHAI in the ABI population, will require validity studies as well as using a sample with more females, a wider age distribution and using various practice settings is required. Many people with ABI have bilateral impairment however the CAHAI scores only the most affected upper limb. Determining if the CAHAI can be used reliably to score bilateral impairment would further its clinical utility. In the stroke population several shortened versions of the CAHAI have established reliability. Future work to estimate reliability with these versions in the ABI population would be beneficial.

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The authors report no conflict of interest. The authors alone are responsible for the content of this paper.

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Table 1: Participant Demographics (N=6)

Sex	M=6,
Age, yrs. (mean ± SD)	55.33 ± 4.84 (min., max. 50, 64)
Type of injury	2 traumatic, 2 anoxic, 2 aneurysms
Hand dominance	R=4, L=2
Most impaired side	R=4, L=2
CMSA left arm/7 (min, max)	5.83 (3,7)
CMSA right arm	4.5 (2, 7)
CMSA left hand	5.5 (3,7)
CMSA right hand	4.8 (2,7)
Months post injury	10.72 (min., max. 4.2, 19.53)

Table 2: CAHAI 13 total scores

Participant	Mean(SD)	Minimum, maximum
A	45.67(6.09)	38, 53
B	37.17(6.08)	28, 46
C	19.00(2.00)	16, 22
D	79.67(3.50)	77, 85
E	46.67(2.88)	43, 51
F	24.67(3.27)	20, 28

Table 3: Rater comments

Rater	Comments
R1	• Space to score participation of both upper extremities • Area to comment on cognitive deficits, which may impact participation score regardless of motor function.
R2	• Doesn't capture cognition difficulties and is difficult to score this when the limitation is not due to physical reasons. • Item 13 (carrying a bag up stairs) doesn't capture both sides. • I find that I always want to score both arms and so perhaps adjusting the items and wording to properly capture their true scores would be helpful.
R3	• I do not feel that the CAHAI is suitable for anyone with bimanual involvement. • Due to cognitive impairments there was huge variation between even 2 trials of the same task making the question: "is it their hand function or ability to follow instructions?" that we are measuring.
R4	• Often bilateral involvement in ABI, it is nice to see how the hands work together in a functional task and score each hand. (dexterity, coordination) • Issue of quality of performance is not addressed in scoring (cognitive component, apraxia or coordination).
R5	• Able to get people with aphasia and neglect to complete functional task easier than abstract tasks.
R6	• I like the combination of verbal and visual demonstration of the tasks but would like a formal method to score both limbs.

Figure 1: CAHAI score form

Chedoke Arm and Hand Activity Inventory: Score Form

CAHAI-13 Version

Name: **Date:**

Activity Scale			
1. total assist (weak U/L < 25%) 2. maximal assist (weak U/L = 25-49%) 3. moderate assist (weak U/L = 50-74%) 4. minimal assist (weak U/L > 75%)	5. supervision 6. modified independence (device) 7. complete independence (timely, safely)		
	Affected Limb:		Score
1. Open jar of coffee	☐ holds jar	☐ holds lid	☐
2. Call 911	☐ holds receiver	☐ dials phone	☐
3. Draw a line with a ruler	☐ holds ruler	☐ holds pen	☐
4. Pour a glass of water	☐ holds glass	☐ holds pitcher	☐
5. Wring out washcloth			☐
6. Do up five buttons			☐
7. Dry back with towel	☐ reachs for towel	☐ Grasps towel end	☐
8. Put toothpaste on toothbrush	☐ holds toothpaste	☐ holds brush	☐
9. Cut medium resistance putty	☐ holds knife	☐ holds fork	☐
10. Zip up the zipper	☐ holds zipper	☐ holds zipper pull	☐
11. Clean a pair of eyeglasses	☐ holds glasses	☐ wipes lenses	☐
12. Place container on table			☐
13. Carry bag up the stairs			☐
Total Score			☐ **/91**
Comments			

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Chapter 3: Study #2

Inter-rater reliability of three versions of the Chedoke arm and hand activity inventory in an acquired brain injury population

The following paper has been formatted according to the style requirements for the Archives of Physical Medicine and Rehabilitation and was submitted for peer review July 2016.

Title: **Inter-rater Reliability of Three Versions of the Chedoke Arm and Hand Activity Inventory**

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Key words: **Upper Limb, Outcome Measures, brain injury, reliability, assessment.**

Abstract

Purpose:

The purpose of this study was to estimate the inter-rater reliability of three shortened versions of the Chedoke Arm and Hand Activity Inventory (CAHAI)-13 (CAHAI-9, CAHAI-8, CAHAI-7) when used with persons with acquired brain injury (ABI).

Relevance:

The CAHAI is an assessment of upper limb function with high reliability in the stroke and ABI populations. In the stroke population, three shortened versions of the measure have established reliability. Clinicians state time constraints as a barrier to use of standardized assessment. Establishing reliability of the shortened versions in the ABI population may increase use of this measure.

Methods:

This is an observational parameter estimation study. Participants were recruited from an in-patient ABI rehabilitation program. The administration of the CAHAI was video recorded for 6 persons with ABI. The videos were assessed by 6 clinicians to estimate inter-rater reliability. A Latin square design was used to balance the order raters evaluated the videos.

Analysis:

A repeated measures ANOVA was performed and the variance components were used to calculate an intra-class correlation coefficient (ICC) and standard error of measurement (SEM) with 95% confidence intervals (CI) for each of the shortened versions.

Results:

Inter-rater reliability was high for all 3 versions: CAHAI-7 ICC= 0.96 (95% CL: 0.89-0.99, SEM 2.65); CAHAI-8 ICC= 0.96 (95% CL: 0.90-0.99, SEM 2.72); CAHAI-9 ICC= 0.95 (95% CL: 0.85-0.99, SEM 3.49).

Conclusions:

These results suggest the three shortened versions of the CAHAI demonstrate high reliability in the ABI population. These versions may be particularly useful when time constraints or patient tolerance are an issue.

Introduction:

World-wide the incidence of acquired brain injury (ABI) is over ten million people.[1–5] Of those approximately one quarter will have impaired upper limb (UL) function.[2–5] UL function is an important aspect of performance in activities of daily living such as self-care, feeding and dressing and can contribute to quality of life.[6,7] Good quality, reliable outcome measures are critical in evaluating and quantifying UL function in order to determine patient progress and treatment effectiveness; however, several studies have identified inconsistent use of outcome measures by clinicians.[8–10] Factors impacting use of outcome measures include environmental, patient, and clinician factors with lack of time and resources as one of the most commonly identified.[9,10] Time efficiency has been cited as a major reason for the development of shortened versions of assessment tool's[11,12].

Environmental factors affecting use of outcome measures include: availability of the measure, space to administer it, and social norms in the clinical setting. Availability is linked to cost and need for specialized equipment or training,[9] which can significantly reduce the use of standardized assessments in routine practice. Further, outcome measures that require considerable space or special modifications to the environment are not feasible in some practice settings.[10] However, encouraging the use of standardized assessment use through benchmarks, audits, and best practice guidelines[8]; or social pressure from colleagues can shape the clinical environment in favour of using outcome measures.[9] With cost and specialized equipment being a barrier, measures that are readily available, low cost, and use items easily obtainable will have greater uptake within practice settings.[10]

Patients themselves can influence the ease with which standardized measures are completed. A commonly identified factor is patient tolerance for lengthy assessments. Some patients, particularly in the more acute phases of recovery have significant drowsiness or fatigue and decreased physical endurance, which impacts clinician efficiency in using and completing assessments.[10] Multiple sessions may be required or the patient may require frequent rest breaks, both of which increase the clinician time to complete an assessment. Additionally patients with communication, behavioural or sensory perceptual issues may require modifications or increased time to complete an outcome measure. Individuals with these deficits may perform better on assessments that use everyday tasks that are more intuitive and rely less on high level cognitive or communication skills to measure function.[13] Measures, which are concise, easy to use, and meaningful to the patient, are more likely to be completed by time-constrained clinicians.[8,9]

Clinician knowledge regarding assessment availability and corresponding psychometric properties can influence the selection of an appropriate measure.[8–10] In addition to clinician knowledge, skilful ability to administer the test is critical in order for a measure to be adopted as part of routine practice. [8] Role modelling and mentoring may play a part as clinicians that have colleagues with skill and experience are more likely to use the assessment themselves[9]. This suggests that peer social support; training and education can impact the practice of routine use of outcome measures.

Clinicians of all disciplines consistently rate time to administer and re-administer outcome measure as one of the barriers to use[8]. The current health care system demands high workload ratio of patient to clinician[10]. Staffing shortages, high patient caseloads and non-patient care demands put pressure on resources. Clinicians report that the time spent using outcome measures is often at the expense of other types of patient care including treatment[8]. Using objective standardized assessments for each patient on admission, discharge and/or at reassessment of progress can be time intensive.[8,10] Despite time being a barrier across the continuum of care, clinicians also report they would find the time to complete an outcome measure, if it was indicated by a clear need or benefit, by prioritizing or deferring other tasks.[10] Investigating psychometric properties of outcome measures that are brief or have shortened versions can help remediate some of these clinician barriers.

An evidence based review of moderate to severe brain injury[14] suggested that evaluation and measurement of upper limb impairment and function is a component of best practice; however no valid or reliable measures of upper limb function specific to ABI were identified. When an outcome is not available for a patient group, a frequent strategy is to select a tool that is valid and reliable in a similar population; stroke literature has identified many upper limb measures with sound psychometric properties.[15,16] One such measure is the Chedoke Arm and Hand Activity Inventory (CAHAI ICC=0.98, 95%CL: 0.96-0.99). Additionally there are three shortened versions which demonstrated high inter-reliability in the stroke population (CAHAI-7 ICC=0.96; CAHAI-8 ICC=0.97; CAHAI-9 ICC= 0.97).[12]

The main purpose of the CAHAI is to measure how much the affected arm and hand contributes to a bilateral task. The development of the CAHAI is described in detail elsewhere in the literature.[13,17] The full 13-item version takes approximately 30 minutes to complete. In a recent study the inter-rater reliability for the CAHAI-13 was established in the ABI population (ICC= 0.96, 95% CL: 0.87-0.99) (ref 1st paper). In the stroke population the shortened versions can be completed in 10-15 minutes depending on upper limb severity.[12,18] This reduction in administration time may be appealing to clinicians. Given the issues with clinician time and patient fatigue in the ABI population, establishing psychometric properties of the shortened versions of the CAHAI in the ABI population would be beneficial. The purpose of this study is to estimate the inter-rater reliability of three shortened versions of the CAHAI in the ABI population.

METHODS

Prior to starting the study ethics approval was received from the hospital and university research ethics boards.

Study design

A cross sectional, observational parameter estimation study design in which 6 raters reviewed 6 participant videos, was used to estimate the inter-rater reliability of the CAHAI. To minimize systematic differences owing to the order ratings were obtained, a Latin square design was applied. The sample size of 6 raters and 6 participants (36 individual data points) was based on the expectation of obtaining an inter-rater reliability of 0.90 with a lower one-tail 95% confidence limit (CL) of 0.7. [19]

Measures

Chedoke Arm and Hand Activity Inventory

The purpose of the CAHAI (Figure 1) is to evaluate the contribution of the impaired upper limb when performing a bi-lateral task. It specifically measures the motor skills necessary to complete the task (e.g. fine or gross motor, stabilization or manipulation). The CAHAI is a standardized measure with a detailed instruction and scoring manual.[13,17,18] The CAHAI was developed following a literature review and consultation with clinicians and individuals with stroke. An advantage of the CAHAI is that it uses inexpensive everyday materials, which are accessible to clinicians. The CAHAI is scored on a seven-point scale, similar to the Functional Independent Measure.[20] For each item the score can range from 1 (i.e. the affected limb performs less than 25% of the task) to 7 (i.e. the affected limb completes all required components), with mid-scale scores representing different percentages of contribution of the affected limb and or help with the task using light touch assistance. The result is a total possible score ranging from 13 to 91.[18,19] The CAHAI has good psychometric properties.[13,17,21] Studies of the CAHAI-13 in the stroke population have shown high inter-rater reliability (ICC 0.98, 95%CI: 0.96-0.99), low SEM (SEM 2.8, 95%CI: 2.3-3.7)[17], internal consistency of 0.98[13], and a minimal detectable change (MDC90) of 6.3 points.[17] The CAHAI has cross sectional validity (ICC 0.93, 95%CI: 0.87-0.96) with the Action Research Arm Test,[17] and sensitivity to change (ICC 0.95, 95%CI: 0.87-1.00).[17] In the ABI population the CAHAI also has high inter-rater reliability (ICC= 0.96, 95% CI: 0.87-0.99).

In the stroke population the three shortened versions of the CAHAI demonstrated high inter-rater reliability (CAHAI-7 ICC=0.96; CAHAI-8 ICC=0.97; CAHAI-9 ICC= 0.97).[22] In order to identify which items should be included on a shortened version of the CAHAI, items were ranked according to difficulty, ability to demonstrate early functional change and those that were representative of greatest functional UL return[12]. The items omitted in the shortened versions include: CAHAI-9 zipping up a zipper; cleaning eye glasses; placing a container on the table; and carrying a bag up the stairs; CAHAI-8 omits all the same items as CAHAI-9 plus cutting medium resistance putty; and CAHAI-7 omits all the same items as CAHAI-8 and CAHAI-9 plus putting toothpaste on a tooth brush. Authors have questioned the last two items in particular (placing a container on the table; and carrying a bag up the stairs) as these items do not necessarily reflect upper limb function but encompass a multitude of other motor skills and cleaning glasses was not meaningful to all individuals.[13, 14] The goal of the shortened versions is time efficiency.

Chedoke McMaster Stroke Assessment (CMSA)

We used the CMSA to determine study inclusion. The CMSA[23] is a measure developed for use in the adult stroke population and is comprised of motor impairment scales (hand, arm, foot, and leg) and a disability inventory. For this study, the arm and hand impairment scales were used. Individuals are asked to do a series of movements and are graded on a 7-point scale where 1 is severe impairment such as flaccid paralysis and 7 is typical movement. The CMSA has excellent test retest (ICC=0.98), intra rater (0.98) and inter rater (0.99) reliability as well as construct and concurrent validity in the stroke population.[23]

Participant Recruitment

Both the raters and participants for this study were recruited from an ABI in-patient rehabilitation unit at a regional tertiary care hospital. A convenience sample of individuals with upper limb impairment as a result of an ABI (confirmed by radiological evidence), aged 16 to 65 years, and with a CMSA arm and hand score between 2 and 6 respectively were recruited. Exclusion criteria consisted of behaviours that would prevent safe participation or the inability to follow a one-step command. Consecutive individuals that met eligibility criteria were video recorded during administration of the CAHAI at 6 weeks post admission. Participants received standard care throughout the study for the upper limb. This included, the graded repetitive arm supplementary program (GRASP)[24] daily, individual motor recovery exercises; functional task specific training; arm ergometer; and range of motion exercises 3-5 days per week. Usual length of stay for people in the ABI in-patient program ranges from 2 weeks to 3 months.

Raters of the video recordings were recruited from the inpatient ABI program and consisted of 3 physiotherapist clinicians (PT's) and 3 occupational clinicians (OT's). All raters had experience using the CAHAI in the ABI population and were trained on the administration and scoring of the CAHAI in a half-day workshop.

Procedure

Treating clinicians identified consecutive admissions to the in-patient ABI rehabilitation unit and completed the CMSA bilaterally in order to determine severity of motor impairment and study eligibility. Demographic (e.g. age and hand dominance) and injury characteristics (e.g. mechanism of injury and time since injury) were collected for each participant. Demographic data was collected for each clinician rater (e.g. year of practice, years of ABI experience). The administration of the CAHAI was videoed in a single session for each participant. All participants were administered the CAHAI at approximately 6 weeks post admission to capture the majority of patients prior to discharge. Raters independently viewed and scored the most involved upper limb using the videos and were blinded to the other raters' scores. The scores were calculated for each of the 3 shortened versions from the total CAHAI-13 score for each participant. Given that the items on each of the shortened versions are also included in the CAHAI-13, the scores for the CAHAI-7, 8 and 9 were calculated by adding the first 7, 8 or 9 items on the score sheet.

Statistical analysis

Descriptive statistics were used to summarize patients' and raters' characteristics. The mean and standard deviation were calculated for each CAHAI item and the total score. The primary analysis was a 3-way analysis of variance (ANOVA) with CAHAI scores as the dependent variable. Factors were patients (6-levels), raters (6-levels), and order (6-levels). In the absence of an order effect, the 3-way model was reduced to a 2-way ANOVA containing the factors patients and raters.

Variance components were estimated and used to calculate a Shrout and Fleiss Type 2,1 intra class correlation coefficients (ICC) and standard error of measurement (SEM). Data was analysed using STATA 12.1.

Results

Demographic findings are reported in Table 1. A total of 6 male participants with ABI were included in the study with a mean age of 55.33 ± 4.84 years (min., max.: 50, 64). The mean (SD) months from injury to admission to the program were 10.72 (5.41) (min., max.: 4.2, 19.53). Using the CMSA scores, 4 of the participants had bilateral UL impairments, of those with bilateral impairments, 2 had the right side as most impaired. Both of the participants with unilateral impairment were most impaired on the right side. The severity of motor impairment for the weakest arm and hand varied from 2-6 on the CMSA. A total of 6 female raters were recruited (3 PT and 3 OT). The mean (SD) years in practice were 18.92 (11.88)(min., max.: 1.5, 32) with 11.83 (8.84) (min. max.: 1, 22) years of ABI experience. There was a range of experience using the CAHAI from 5 to 20+ times.

A total of 36 assessments were analysed for each version (Table 2). The mean (SD) total score for the CAHAI-7 was 23.28 (12.21); (min., max.: 9,49); CAHAI-8 was 26.5 (13.78); (min., max.: 10,56) and CAHAI-9 was 28.97 (14.60); (min., max.: 11,59).

Inter-rater Reliability

The 3-way ANOVA (participant, rater and order) revealed no significant order effect; as a result a 2 way ANOVA considering the subject and rater is reported The inter-rater reliability estimate for the 3 versions is as follows (Table 3): CAHAI-7

ICC=0.96 (95%CL=0.89-0.99,); CAHAI-8 ICC=0.96 (95%CL=0.90-0.99,); and CAHAI-9 ICC=0.95 (95%CL=0.85-0.99,).

Discussion

The aim of this study was to estimate the inter-rater reliability of three shortened versions of the CAHAI when used with persons with ABI. The inter-rater reliability of all three versions was excellent[25] (CAHAI-7 ICC=0.96; CAHAI-8 ICC=0.96; CAHAI-9 ICC=0.95). The ICC is one of the most commonly used indicators of reliability.[26] The ICC, which is representative of the CAHAI's ability to differentiate upper limb function amongst people, was high. The SEM is reported in the actual units of the CAHAI. This is important in order for clinicians to know how much of the score could be attributed to error and how much is true change. In our study the SEM, which is representative of the consistency of the CAHAI scores, was low.[27] These findings indicate excellent reliability and suggest that the shortened versions may be clinically useful in the ABI population.

Comparison to previous research

The CAHAI-13 has an ICC=0.96 (95%CL=0.87-0.99) and SEM of 3.35 in the ABI population (ref manuscript 1). The shortened versions range from 0.95 for the CAHAI-9 to 0.96 for both the CAHAI-7 and CAHAI-8. This suggests that the shortened versions of the CAHAI may be as reliable in this population as the full version. Additionally, the inter-rater reliability of the three shortened versions of the CAHAI in the stroke population was high (CAHAI-7 ICC=0.96, CAHAI-8 ICC=0.97, CHAHI-9 ICC=0.97)[12] and similar to our findings (CAHAI-7 ICC=0.96; CAHAI-8 ICC=0.96; CAHAI-9 ICC=0.95). All versions in the stroke and ABI population support the use of the shortened versions when time constraints are an issue. Completing the full version may give clinicians greater insight in to the patients abilities and challenges with those specific items however it does not appear to impact the reliability of the measure as an assessment of upper limb function.

Clinical utility

These results are encouraging for the use of the shortened version of the CAHAI in this population. Multiple patient, environmental and clinician factors have been identified that impact use of outcome measures. It is possible that clinicians are more likely to use an assessment that is reliable but also time efficient for the clinician and the patient. When there are time constraints or patient factors such as decreased endurance or ability to attend to a task, the shortened versions of the CAHAI will be particularly useful. Additionally the CAHAI-7 may be useful as a screening tool to quickly and efficiently identify UL impairments. The clinical advantage of the shortened versions is shortened administration time, use of easily accessible items and functional tasks.

It may be challenging for some clinicians to decide which version of the CAHAI is optimal. Two items of particular challenge for patients, based on observation of participant videos and previous research (ref manuscript 1) include: 1) item nine, cutting medium resistance putty and 2) item 8, putting toothpaste on a toothbrush. These two tasks are the items that differentiate between the CAHAI-7, 8 and 9. Clinicians in a previous study[12] stated the two excluded items above were important tasks for their patients to practice. However, based on our findings, it is unlikely there is a benefit to completing the CAHAI 8 or 9 unless those two tasks of cutting or applying toothpaste are particularly meaningful for the patient. The CAHAI-7 is the most time efficient, uses the simplest tasks and is highly reliable. There does not appear to be an advantage to including item 8 and 9 when considering the inter-rater reliability.

Limitations

Participants in this study were chosen from a sample of individuals with ABI and therefore may not be representative. While our study used multiple raters, we did not recruit participants from across the continuum of care. The literature suggests that although males are twice as likely as females to sustain an ABI, both sexes are affected.[2] From our sample, we can only conclude that the CAHAI versions are reliable with in-patient males with an ABI. Participants with ABI often have a reduced tolerance for activity.[28] It would not be feasible due to the associated burden experienced by the participant to be administered multiple assessments by different raters. Therefore videotaping was used to gather the data. This approach allowed the use of multiple raters with no additional demand on the participants, however in clinical practice the raters would be administering the test. This may impact the raters' assigned scores.

Future Directions

Further studies to establish additional psychometric properties in the ABI population are necessary. The CAHAI versions score the most effected upper limb; however, there is need within the ABI population to be able to score each limb individually; future work to modify and validate bilateral scoring would be beneficial.

Conclusions

The current study indicates that the CAHAI-7, CAHAI-8 and CAHAI-9 demonstrates high reliability in the ABI population. There appears to be no added advantage of using the CAHAI-8 or CAHAI-9 over the CAHAI-7. This gives clinicians a choice of three reliable, time efficient and functional assessments of the UL. The CAHAI-7 is recommended as the most time efficient measure without compromising reliability.

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Disclosure:

The authors report no conflict of interest. The authors alone are responsible for the content of this paper.

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Table 1: Participant Demographics

Sex	M=6, F=0
Age (mean ± SD)	55.33 ± 4.84 years (min., max.: 50, 64)
Type of injury	2 traumatic, 2 anoxic, 2 haemorrhagic
Hand dominance	R=4, L=2
Most impaired side	R=4, L=2
CMSA left arm (mean ± SD)	5.83 ± 1.47
CMSA right arm (mean ± SD)	4.5 ± 1.76
CMSA left hand (mean ± SD)	5.5 ± 1.76
CMSA right hand (mean ± SD)	4.8 ± 1.60
Months post injury (mean ± SD)	10.72 ± 5.41 (min., max.: 4.20, 19.53)

Table 2: Summary Scores of the CAHAI 7, CAHAI-8, and CAHAI-9

Participant	Observations	CAHAI-7 Mean(SD)	CAHAI-8 Mean(SD)	CAHAI-9 Mean(SD)
A	6	30.00(3.52)	34.67(4.13)	37.83(5.91)
B	6	19.00(3.52)	21.83(3.87)	24.00(4.86)
C	6	10.17(0.98)	12.00(1.26)	13.00(1.26)
D	6	45.33(3.14)	51.50(2.81)	55.00(3.16)
E	6	22.50(1.76)	24.33(1.86)	26.83(2.04)
F	6	12.67(1.63)	14.67(1.63)	17.17(1.72)

Table 3: Reliability Coefficients and Standard Error of Measurement

Version	ICC 95% CL	SEM 95% CL
CAHAI-7	0.96 0.89, 0.99	2.65 2.08, 3.66
CAHAI-8	0.96 0.90, 0.99	2.72 2.13, 3.76
CAHAI-9	0.95 0.85, 0.99	3.49 2.73, 4.81

CAHAI score form

Chedoke Arm and Hand Activity Inventory: Score Form

CAHAI-13 Version

Name: **Date:**

Activity Scale			
1. total assist (weak U/L < 25%) 2. maximal assist (weak U/L = 25-49%) 3. moderate assist (weak U/L = 50-74%) 4. minimal assist (weak U/L > 75%)	5. supervision 6. modified independence (device) 7. complete independence (timely, safely)		
	Affected Limb:		Score
1. Open jar of coffee	☐ holds jar	☐ holds lid	☐
2. Call 911	☐ holds receiver	☐ dials phone	☐
3. Draw a line with a ruler	☐ holds ruler	☐ holds pen	☐
4. Pour a glass of water	☐ holds glass	☐ holds pitcher	☐
5. Wring out washcloth			☐
6. Do up five buttons			☐
7. Dry back with towel	☐ reachs for towel	☐ Grasps towel end	☐
8. Put toothpaste on toothbrush	☐ holds toothpaste	☐ holds brush	☐
9. Cut medium resistance putty	☐ holds knife	☐ holds fork	☐
10. Zip up the zipper	☐ holds zipper	☐ holds zipper pull	☐
11. Clean a pair of eyeglasses	☐ holds glasses	☐ wipes lenses	☐
12. Place container on table			☐
13. Carry bag up the stairs			☐
Total Score			☐ **/91**
Comments			

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Chapter 4: Discussion and Conclusion

Inter-rater reliability of the Chedoke arm and hand activity inventory in an acquired brain injury population

Chapter 4: Discussion & conclusions

This chapter presents an overall discussion of the thesis.

Summary

The use of outcome measures that assess upper limb motor function in the ABI population is limited. The main reason for this is the lack of assessments with demonstrated psychometric properties in this population. The two studies that comprise a portion of this thesis assist in addressing this problem by advancing the knowledge regarding the measurement properties of one measure, the Chedoke Arm and Hand Activity Inventory (CAHAI) as well as three shortened versions of this assessment.

The purpose of the first manuscript in this thesis was to estimate the inter-rater reliability of the Chedoke Arm and Hand Activity Inventory in individuals with ABI. The ICC was 0.96 (95%CL: 0.88, 0.99) and the SEM was 3.35 (95%CL: 2.63, 4.63). These results are consistent with the findings of the CAHAI and other measures of upper limb function in the stroke population. Although further investigation of psychometric properties is warranted, clinicians can consider the CAHAI when selecting a measure of upper limb function in patients with ABI. This study is the first to establish inter-rater reliability of an upper limb measure in the ABI population.

In addition to the main purpose of the first manuscript, informal rater comments were collected regarding the administration and scoring of the CAHAI that suggest some challenges with clinical utility. The main concern identified by raters was the impact of scoring bilateral limbs. The comments question whether the current scoring guidelines would still be appropriate when an individual has bilateral impairment and also expressed a desire to score both limbs simultaneously. Secondly the comments identified challenges in scoring individuals with cognitive impairment and the impact of those impairments on testing. These comments are useful to inform future research direction on the CAHAI.

The purpose of the second manuscript was to determine the inter-rater reliability of three shortened versions of the CAHAI. All three versions demonstrated excellent reliability: CAHAI-7 ICC= 0.96 (95% CL: 0.89-0.99), SEM=2.65 (95% CL: 2.08-3.66); CAHAI-8 ICC= 0.96 (95% CL: 0.90-0.99), SEM=2.72 (95% CL: 2.13-3.76); CAHAI-9 ICC= 0.95 (95% CL: 0.85-0.99), SEM=3.49 (95% CL: 2.73-4.81). The shortened versions further its clinical utility by reducing the time burden of administration while maintaining high inter-rater reliability.

Strengths and weaknesses

Strengths of the studies include the blinding of assessors to each other's scores and the use of a Latin square design to balance for order of assessment. These design features helped to minimize expectation bias and systematic error owing to the order of testing. A second advantage of the Latin square design was that it allowed for the use of six raters. Given the principal goal of the research was to estimate inter-rater reliability, increasing the number of raters enhances the confidence in the generalizability of the results. Given the relatively narrow width of the 95% confidence intervals, the sample size of six raters and six patients was appropriate. Since only six patients were required the rater burden was decreased and feasibility of patient recruitment was improved. Given patient recruitment is often a challenge; the methodology applied in this study could be used to evaluate the reliability of the CAHAI and similar measures in other neurological populations such as Multiple Sclerosis or Parkinson's disease. However, this design could also be considered a disadvantage in some regards. The use of a video eliminated several sources of error including rater variance in the administration of the test, and participant variance in performing the tasks on several different occasions. The reduction in error variance can have an positive effect on the ICC and could potentially have inflated the reliability coefficient.

Weaknesses of the study include the sample demographics, for example age and sex lacked variability. The studies included only male subjects aged 50-64. Although males are approximately twice as likely as females to sustain a TBI, the current results cannot be generalized to females.[2–4] Secondly, cognitive perceptual impairments were not measured which could directly impact the generalizability of our findings; for example raters identified the prevalence of these impairments as a complicating factor that potentially impacted scoring. All participants were in-patients in a rehabilitation program and were 4.2-19.5 months post injury. While this is a broad timeframe, it does not include those in the acute and chronic (≥ 18 months) stages nor those from other settings. It is possible that reliability coefficients would be different if participants were earlier or later post injury. For example, a more acute sample may have less variability in CAHAI scores due to greater upper limb severity and as a result this may decrease the ICC value. Consideration should be given to these limitations when designing future studies.

Implications and future directions

This thesis sets the foundation for future studies on the use of the CAHAI in the ABI population. Two particular challenges were identified with this population when administering and scoring the test: i) the presence of bilateral impairments; and ii) cognitive perceptual impairments. This study scored a single limb for participants based on their most impaired limb. Future study is required to determine the best method and instructions for scoring both impaired upper limbs simultaneously for each item of the CAHAI. Secondly, participants with cognitive perceptual impairments, particularly unilateral spatial neglect, required additional cueing and consequently score lower on the CAHAI. The development and validation of modified instructions allowing for attentional cues to be used without lowering the maximum possible score would assist in ensuring the measure is capturing true upper limb impairment.

Validity is important to establish in this population. Determining content and face validity would give insight in to which CAHAI items are most critical in the ABI population. Although establishing construct validity would be ideal, it may be challenging in the ABI population given the lack of outcome measures with established psychometric properties in which to compare. Completing studies investigating other psychometric properties, such as validity, and using a more varied sample to improve generalizability, can help strengthen the evidence for using the CAHAI.

Knowledge translation of this research is important in order to facilitate adoption of the CAHAI as part of standard practice. In order to aid this process study 1 'Inter-rater reliability of the Chedoke arm and hand activity inventory in an acquired brain injury population' was submitted to the Journal of Neuro-rehabilitation on July 5, 2016 for peer review. Once this manuscript is accepted, study 2 'Inter-rater reliability of three versions of the Chedoke arm and hand activity inventory in an acquired brain injury population' will be submitted to a relevant peer reviewed journal. An abstract titled 'Inter-rater reliability of the Chedoke arm and hand activity inventory in an acquired brain injury population' was accepted and presented (poster) at the International Brain Injury Congress in the Netherlands in March 2016. An in-service will be provided to clinicians and management of the ABI program at regional rehab center in order to disseminate and receive feedback on study findings.

Conclusion

The studies contained in this thesis examined inter-rater reliability of the CAHAI in the ABI population. This is the first study to establish some psychometric properties of the CAHAI in the ABI population. Continued research is needed to investigate the validity and clinical utility of this measure in the ABI population

Key Messages

The CAHAI is a promising assessment to use in the ABI population due to:

- Its high inter-rater reliability (high ICC and low SEM).

- Low demand on resources (clinician time and inexpensive easily accessible items).
- A choice of 4 versions of the CAHAI all with excellent inter-rater reliability: CAHAI-13, CAHAI-9, CAHAI-8, and CAHAI-7.

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Table 1: Participant Demographics (N=6)

Sex	M=6,
Age, yrs. (mean ± SD)	55.33 ± 4.84 (min., max. 50, 64)
Type of injury	2 traumatic, 2 anoxic, 2 aneurysms
Hand dominance	R=4, L=2
Most impaired side	R=4, L=2
CMSA left arm/7 (min, max)	5.83 (3,7)
CMSA right arm	4.5 (2, 7)
CMSA left hand	5.5 (3,7)
CMSA right hand	4.8 (2,7)
Months post injury	10.72 (min., max. 4.2, 19.53)

Table 2: CAHAI 13 total scores

Participant	Mean(SD)	Minimum, maximum
A	45.67(6.09)	38, 53
B	37.17(6.08)	28, 46
C	19.00(2.00)	16, 22
D	79.67(3.50)	77, 85
E	46.67(2.88)	43, 51
F	24.67(3.27)	20, 28

Table 3: Rater comments

Rater	Comments
R1	• Space to score participation of both upper extremities • Area to comment on cognitive deficits, which may impact participation score regardless of motor function.
R2	• Doesn't capture cognition difficulties and is difficult to score this when the limitation is not due to physical reasons. • Item 13 (carrying a bag up stairs) doesn't capture both sides. • I find that I always want to score both arms and so perhaps adjusting the items and wording to properly capture their true scores would be helpful.
R3	• I do not feel that the CAHAI is suitable for anyone with bimanual involvement. • Due to cognitive impairments there was huge variation between even 2 trials of the same task making the question: "is it their hand function or ability to follow instructions?" that we are measuring.
R4	• Often bilateral involvement in ABI, it is nice to see how the hands work together in a functional task and score each hand. (dexterity, coordination) • Issue of quality of performance is not addressed in scoring (cognitive component, apraxia or coordination).
R5	• Able to get people with aphasia and neglect to complete functional task easier than abstract tasks.
R6	• I like the combination of verbal and visual demonstration of the tasks but would like a formal method to score both limbs.

Table 4: Summary Scores of the CAHAI 7, CAHAI-8, and CAHAI-9

Participant	Observations	CAHAI-7 Mean(SD)	CAHAI-8 Mean(SD)	CAHAI-9 Mean(SD)
A	6	30.00(3.52)	34.67(4.13)	37.83(5.91)
B	6	19.00(3.52)	21.83(3.87)	24.00(4.86)
C	6	10.17(0.98)	12.00(1.26)	13.00(1.26)
D	6	45.33(3.14)	51.50(2.81)	55.00(3.16)
E	6	22.50(1.76)	24.33(1.86)	26.83(2.04)
F	6	12.67(1.63)	14.67(1.63)	17.17(1.72)

Table 5: Reliability Coefficients and Standard Error of Measurement

Version	ICC 95% CL	SEM 95% CL
CAHAI-7	0.96 0.89, 0.99	2.65 2.08, 3.66
CAHAI-8	0.96 0.90, 0.99	2.72 2.13, 3.76
CAHAI-9	0.95 0.85, 0.99	3.49 2.73, 4.81
CAHAI-13	0.96 0.85, 0.99	3.35 2.63, 4.81

Figure 1: CAHAI Score Form

Chedoke Arm and Hand Activity Inventory: Score Form

CAHAI-13 Version

Name: **Date:**

Activity Scale			
1. total assist (weak U/L < 25%) 2. maximal assist (weak U/L = 25-49%) 3. moderate assist (weak U/L = 50-74%) 4. minimal assist (weak U/L > 75%)	5. supervision 6. modified independence (device) 7. complete independence (timely, safely)		
	Affected Limb:		Score
1. Open jar of coffee	☐ holds jar	☐ holds lid	☐
2. Call 911	☐ holds receiver	☐ dials phone	☐
3. Draw a line with a ruler	☐ holds ruler	☐ holds pen	☐
4. Pour a glass of water	☐ holds glass	☐ holds pitcher	☐
5. Wring out washcloth			☐
6. Do up five buttons			☐
7. Dry back with towel	☐ reachs for towel	☐ Grasps towel end	☐
8. Put toothpaste on toothbrush	☐ holds toothpaste	☐ holds brush	☐
9. Cut medium resistance putty	☐ holds knife	☐ holds fork	☐
10. Zip up the zipper	☐ holds zipper	☐ holds zipper pull	☐
11. Clean a pair of eyeglasses	☐ holds glasses	☐ wipes lenses	☐
12. Place container on table			☐
13. Carry bag up the stairs			☐
Total Score			☐ /91
Comments			

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35

Appendix

Appendix 1: retrospective admission and discharge data

18 people:

Admission	Discharge
41	79
38	89
15	29
18	62
20	61
13	40
22	41
42	73
65	79
37	27
16	14
41	46
39	45
22	30
21	31
53	91
24	40
42	85

Admission range 13-65
Discharge range 14-91

Appendix 2: Analysis of Retrospective Data

admission

Percentiles		Smallest		
1%	13	13		
5%	13	15		
10%	15	16	Obs	18
25%	20	18	Sum of Wgt.	18
50%	30.5		Mean	31.61111
		Largest	Std. Dev.	14.6132
75%	41	42		
90%	53	42	Variance	213.5458
95%	65	53	Skewness	.5701328
99%	65	65	Kurtosis	2.509747

discharge

Percentiles		Smallest		
1%	14	14		
5%	14	27		
10%	27	29	Obs	18
25%	31	30	Sum of Wgt.	18
50%	45.5		Mean	53.44444
		Largest	Std. Dev.	24.30014
75%	79	79		
90%	89	85	Variance	590.4967
95%	91	89	Skewness	.188945
99%	91	91	Kurtosis	1.698187

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Appendix 3: Consent Form

Hamilton Health Sciences
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PARTICIPANT INFORMATION SHEET & CONSENT

You are being invited to participate in a research study.

Title of the Study: Reliability of the Chedoke Arm and Hand Inventory (CAHAI) for use in People with Acquired Brain Injuries with Upper Extremity Involvement

Principal Investigator:
Denise Johnson

Office Phone:
905-521-2100 x41101

Why is this study being done?

This study is being done in order to estimate the reliability of a tool that therapists use to assess the arm and hand function called the Chedoke Arm and hand Inventory (CAHAI). In order for an assessment tool to be useful we need to study it to make sure that it measures what it is supposed to measure and that it can detect changes over time. The CAHAI will assist Physiotherapists and Occupational Therapists to measure whether your arm and hand function is improving or worsening. We are interested in learning about this because this information will help us make improvements to the care our patients receive.

What is involved in the study?

Participation in this study is VOLUNTARY. You are being asked to participate in this study because you are currently receiving rehabilitation at Hamilton Health Sciences for an arm and hand impairment as a result of an ABI. We are seeking your permission to video the assessment of your arm and hand function using the CAHAI. The videos will be viewed and scored by 6 different Therapists. The results of the scoring will be used to determine if the CAHAI is reliable between therapists. Should you choose to participate in this study, there will be no change to your routine care.

What Are The Risks Of Discomfort Or Potential Harm?

We do not anticipate any discomfort or harm. The CAHAI is a low risk activity. Possible frustration or discomfort in your arm and hand may occur because the tasks are challenging. However, if at any time the assessment is too discomforting, you may stop that particular session or withdraw your consent at any time. You can withdraw from the study by informing the therapist working with you or by calling the principal investigator Denise Johnson at 905-521-2100 x41101

Are There Benefits To Taking Part In The Study?

There are no benefits to taking part in this study. The CAHAI assessment is an assessment that is normally done for all our patients with arm and hand impairment and does not offer anything extra above and beyond what your usual assessment would consist of. The benefit of the study is to advance our knowledge of the CAHAI and its use in people with ABI.

What About Confidentiality?

Your identity will be kept strictly confidential. Upon consenting to participate in this study, you will be assigned a subject number for identification purposes. Only the 6 therapists involved in the study will view the video recordings of the assessment. The videos will never be made public. At the end of the study, the data will be analysed and the findings will be shared with other health care professionals through research publications or presentations. Individual patients are never identified in these publications or presentations. Your privacy is very important to us and your personal information is always kept confidential. Patient disclosure may be made if required by law. During and after the study the videos will be stored on password protected individual memory sticks in a locked cabinet in a locked office for 10 years as required by law. They will then be destroyed.

What Are My Rights As A Participant?

This research project has been reviewed and approved by the Hamilton Integrated Research Ethics Board. Your decision, as to whether to take part in the study or not, will have no effect on the quality of your medical care or rehabilitation. Your legal rights are not affected by participating in this study.

What if you do not wish to participate in the study?

Participation in this study is VOLUNTARY. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time without prejudice to your future medical or rehabilitation care or participation in future research trials. Your standard treatment program will not be affected in any way regardless of whether you participate or not.

Whom may you contact to find out more about this study?

You will be given a copy of this information sheet. If you have questions about taking part in this study, please contact the Local Principal Investigator Denise Johnson, Registered Physiotherapist, Acquired Brain Injury Program 3rd floor at Hamilton Health Sciences, Regional Rehabilitation Centre at 905 521-2100 x41101 (e-mail: johnsden@hhsc.ca).

This study has been reviewed by the Hamilton Integrated Research Ethics Board. If you have questions about your rights as a research participant, you may contact the Office of the Chair of the Hamilton Integrated Research Ethics Board Chair at 905-521-2100, Ext. 42013

Thank you!

CONSENT STATEMENT

I have read (or someone has read to me) and understand the information provided above. I have been given an opportunity to ask questions and all of my questions have been answered to my satisfaction. I understand that I will receive a signed copy of this form.

BY SIGNING THIS FORM, I WILLINGLY AGREE TO PARTICIPATE IN THE RESEARCH IT DESCRIBES.

____
Name of Participant

____
Name of Legally Authorized Representative (if applicable)

______________________________ ____________
Signature of Participant (or Legally Authorized Representative) Date

Consent form administered and explained in person by:

____
Name and title

______________________________ ____________
Signature Date

SIGNATURE OF INVESTIGATOR:

In my judgement, the participant is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____
Name and title

______________________________ ____________
Signature of Investigator Date

NOTE: The signature must be an M.D. if the study involves a medical act.