

**WHEELCHAIR RUGBY CLASSIFICATION: A RETROSPECTIVE COHORT STUDY
ANALYSIS OF THE TRICEPS MANUAL MUSCLE TEST – COMPARING ASSESSED
MANUAL MUSCLE TESTING SCORES TO STANDARDIZED VALUES**

MARNIE McROBERTS

A THESIS SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

GRADUATE PROGRAM IN KINESIOLOGY AND HEALTH SCIENCE
YORK UNIVERSITY
TORONTO, ONTARIO

August 2025

© MARNIE McROBERTS, 2025

ii. ABSTRACT

This retrospective cohort study evaluated the consistency of triceps manual muscle test (MMT) scores with standardized expectations across low and mid-point wheelchair rugby classifications (0.5–2.5), using data from 492 assessments of 283 Canadian athletes between 1992 and 2019. Athletes were stratified by sport class, and triceps MMT scores were analyzed to determine alignment with standardized ranges. While 0.5 and 2.0 classes showed general alignment, 1.0 and especially 1.5 classes exhibited significant inconsistencies; over 75% of 1.5-class assessments fell outside the expected range. These discrepancies raise concerns about the objectivity, reliability, and application of the modified triceps test within the classification process. The study highlights the influence of contextual factors and subjective judgment in current protocols and underscores the need for greater standardization, improved training, and empirical validation of assessment tools. Refining these elements is essential to ensure fairness, preserve competitive integrity, and uphold the athlete-centered principles of functional classification.

iii. ACKNOWLEDGEMENTS

First and foremost, I would like to extend my deepest thanks to my supervisor, Dr. Loriann Hynes. Your encouragement to pursue graduate studies as a mature student and your unwavering belief in my ability to complete this degree while managing a demanding professional life have meant the world to me. I am truly grateful to have you as a supervisor, mentor, colleague, and friend. Thank you for recognizing my potential and for dedicating so much time and energy into understanding and supporting my chosen area of research. This journey would not have been possible without your guidance.

To Dr. Joseph Baker, thank you for your insightful guidance and genuine enthusiasm throughout this process. I sincerely appreciate your expertise and thoughtful contributions, which have greatly strengthened my confidence and capacity to conduct research in a field we are both passionate about.

To Dr. Alison Macpherson, thank you for your invaluable guidance and support throughout this journey. I am especially grateful for your help in navigating the degree process and for deepening my understanding of statistical analyses.

To my incredible current and former lab mates at the WHIPR Lab—Christina Amaral, Michael Modica, Ravneet Kalkat, Davin Mahal, and Benjamin Migotto—thank you for your patience, kindness, and unwavering support. Your willingness to offer help whenever it was needed made a significant difference, and I am truly grateful for each of you.

To Wheelchair Rugby Canada, thank you very much for supporting my research efforts in the area of classification. I would especially like to acknowledge Paul Easton, Head of Classification, for your invaluable guidance and encouragement in helping me narrow my focus and refine my research topic. And to Patrick Côté, thank you for helping me better understand the mechanics of the game, and for diving into classification along with me.

To my friends and family—thank you for your enduring support, patience, and understanding throughout this journey. Your encouragement has been, and continues to be, deeply appreciated.

Finally, I would like to dedicate my thesis to the inventor of the sport – Duncan Campbell, thank you for developing this crazy sport, and for welcoming me into the community. And to Garrett Hickling, one of the best to ever play the game – your knowledge of the game and desire to get people involved will be greatly missed.

iv. TABLE OF CONTENTS

Abstract	ii
Acknowledgments	iii
Table of Contents	iv
List of Tables	vi
List of Figures	vii
Terminology	viii
Chapter One: Introduction	1
Introduction to Parasport	1
Introduction to Classification	3
Introduction to Wheelchair Rugby	6
Classification in Wheelchair Rugby	8
Literature Review on Manual Muscle Testing	14
Triceps Manual Muscle Test	20
Triceps Muscle Function in Wheelchair Rugby	23
Chapter Two: Purpose and Rationale	29
Purpose and Rationale	29
Positionality Statement	31
Hypothesis	31
Chapter Three: Methods	34
Participants	34
Inclusion / Exclusion Criteria	35
Statistical Analysis	36
Chapter Four: Data Analysis	37
Demographic Characteristics	37
Results	39
Chapter Five: Discussion	46
MMT Results and Impact on Final Class Outcomes	46
Sport Class Math	46
Standardized Values and Assessment Accuracy	48
Overall Impact of Results of MMT Scores for Triceps	50
Importance of Technical Assessment and On-Court Observations	52
Impact of Classification Results on Wheelchair Rugby Programs	54
Impact on the Team	54
Impact on the Athlete	56
Impact on the Sport	57
Critical Gaps in Valid and Reliable Classification Measures	57
Objectivity in Functional Sport-Specific Classification Systems	57
Classifier Training and Technical Expertise	58
Timing of Classification Assessments	60
Testing Conditions	61
Efficacy of Modified Triceps Test	63
Research Implication	64
Chapter Six: Limitations, Future Directions, and Conclusions	65

Study Limitations	65
Future Directions	65
Conclusions	67
References	69
Appendices	73
Appendix A: Eligibility Test for Classification in Wheelchair Rugby	73
Appendix B: Sample Wheelchair Rugby Classification Form	74
Appendix C: Standardized Manual Muscle Testing Scores	75
Appendix D: Characteristics of Sport Classes	76
Appendix E: Eligible Impairment Types in the Paralympic Movement	77

vi. LIST OF TABLES

Table 1.1: Athlete Database Characteristics 38

vii. LIST OF FIGURES

Figure 1a: Breakdown of MMT Triceps Scores for the 0.5 Class..... 40

Figure 2a: Breakdown of MMT Triceps Scores for the 1.0 Class..... 41

Figure 3a: Breakdown of MMT Triceps Scores for the 1.5 Class..... 42

Figure 4a: Breakdown of MMT Triceps Scores for the 2.0 Class..... 43

Figure 5a: Breakdown of MMT Triceps Scores for the 2.5 Class..... 44

Figure 6a: Summary of MMT Triceps Scores..... 45

viii. TERMINOLOGY

AB – Able-bodied

ALS – Amotrophic Lateral Sclerosis

C – Confirmed

CMT – Charcot-Marie Tooth

CP – Cerebral Palsy

DTT – Deltoid-to-Triceps Transfer

FA – Fredrich’s Ataxia

IPC – International Paralympic Committee

IWRF – International Wheelchair Rugby Federation

MD – Muscular Dystrophy

MIC – Minimum Impairment Criteria

MMT – Manual Muscle Testing

MRC – Medical Research Council

MS – Multiple Sclerosis

NE – Not Eligible

OA – Observation Assessment

ROM – Range of Motion

SCI – Spinal Cord Injury

TBI – Traumatic Brain Injury

WHO – World Health Organization

WWR – World Wheelchair Rugby

Chapter 1: Introduction

Introduction to Parasport

The Paralympic Games, which run parallel to the Olympic Games, have experienced immense growth since their inception over a half century ago.^{1,2} To better understand the current state of the Paralympic Movement, however, it is important to first explore its origins. The first international sporting event for athletes with a disability can be traced back to the Deaflympics in 1924 and the origins of the Paralympic Games can be linked to a wheelchair competition for injured servicemen in England in 1948 called the Stoke Mandeville Games.¹⁻³ In 1944, a German neurosurgeon by the name of Ludwig Guttmann established the Stoke Mandeville Spinal Injuries Unit, where he began to encourage the use of sport for recreation and rehabilitation among his patients with disabilities. Rehabilitation for persons with a spinal cord injury was previously unstructured and coupled with a feeling of hopelessness, but Guttmann believed that movement was central to patient recovery and felt that sport could be a popular avenue to aid in rehabilitation.³ He discovered that sport could also be used to help build camaraderie within the unit, and empower patients to motivate and help each other with their recovery. Over time, he recognized the advantages of grouping individuals with similar injuries and saw sport as a powerful tool to motivate patients in reaching their rehabilitation goals. Although this progressive approach was initially met with skepticism from practitioners, its benefits soon became clear. Guttmann's vision ultimately laid the foundation for the creation of the Stoke Mandeville Games.³

The first Stoke Mandeville Games took place coincidentally alongside the opening day of the 1948 Olympic Games in London. Initially featuring only one sport – archery - the event quickly expanded in following years to include adapted versions of several popular sports. In

1952, the Games gained international status when a team from the Netherlands joined the competition, and from there, the Stoke Mandeville Games rapidly evolved into a global phenomenon.³ The first International Stoke Mandeville Games that was held in deliberate connection with the Olympic Games took place in Rome in 1960, marking the first time they were scheduled to coincide with an Olympic year. From that point forward, a permanent sporting event for athletes with disabilities would be held every four years alongside the Olympic Games, officially known as the Paralympic Games. While the Stoke Mandeville Games continued as an annual tradition, the Paralympics emerged as the premier international competition for athletes with disabilities.³

Athlete participation in the Paralympics has increased significantly over the years, from 400 athletes participating in the first Games in Rome in 1960, to 4,328 athletes participating in the 2016 Summer Paralympic Games in Rio, 4,393 athletes participating in the 2020 Summer Paralympic Games in Tokyo, and 4,463 athletes competing in the Summer Paralympic Games in Paris.^{4,5} Media attention has also grown over the years, with 2.15 million spectators tuning in to watch the Paralympic Games in Rio.⁵ This number increased significantly in Tokyo and Paris, with the most recent Games providing broadcasting coverage for the first time in history of all of the Paralympic sports, with global partnerships providing coverage to engage audiences in a wide variety of new and meaningful ways.^{1,5,6} This increase in participation and attention has been reflected in scientific research as well; however in comparison to able-bodied (AB) sports, research in para sport is still very limited and further research is needed, especially in those areas that are unique to para sport, such as classification.

The International Paralympic Committee (IPC) was founded in 1989 as the international non-profit organization that would be responsible as the governing body of the Paralympic

Movement. The IPC not only oversees the delivery of the Paralympic Games, it works with over 200 plus member organizations to enable athletes with a disability to achieve sporting excellence.⁷ One of the core strategic goals of the IPC is to effectively support its members in advancing the Paralympic Movement. A key objective in achieving this goal is the ongoing management, review, and development of the IPC Classification Code.⁸

Introduction to Classification

Classification refers to the system used to determine what athletes are eligible to compete in a given para sport, where athletes are grouped together based on their degree of activity limitation resulting from their impairment.⁶ Classification is unique to para sport, but would be similar to grouping athletes in able bodied sport by age, gender or weight. Classification systems are not only important for providing competitive structure in elite sport, but it is also important for promoting equal participation for athletes at all levels of para sport. If classification systems did not exist, competition outcomes would be predictable, where the least impaired athlete or teams with the least impaired athletes would always win.⁶ Classification systems are therefore carefully designed to ensure that athletes can succeed in Paralympic sport because they have the most favourable combination of attributes (anthropometric, physiological, and psychological), and have been able to develop those attributes to the best effect through training.⁹

Classification in sport for persons with disabilities has existed since the 1940s, but it has transitioned from a medical classification system based on diagnosis and disability type, to a more functional or sport-specific classification system based not only on an athlete's health condition (disorder or diagnosis), but also on the athlete's functional abilities to perform within a sport. This shift promotes participation in sport by minimizing the impact of impairment on the

outcome of competition and allows athletes with varying degrees of impairment to compete together.¹⁰ Generally speaking, classification provides structure and ensures that an athlete's impairment is relative to sport performance.¹¹

In order to be classified to participate in a para sport competition, an athlete must first demonstrate that they have an underlying health condition that has led to a permanent eligible impairment. The IPC, governing body of the Paralympic Movement, adopted a list of ten eligible impairment groups from the World Health Organization (WHO) which are often categorized into three general impairment types: 1) physical impairments which comprise of the eight impairment types that cause activity limitation that are biomechanical in nature – impaired muscle power, impaired range of movement, limb deficiency, leg length difference, hypertonia, ataxia, athetosis, and short stature, 2) visual impairments, and 3) intellectual impairments.^{6,12,13} See Appendix E for a full description of the eligible impairment types. The International Federations overseeing each individual Paralympic sport is however able to define which of these eligible impairment types fit within their own individual sports. Some Paralympic sports may provide opportunities for athletes in all categories, while other sports may only be inclusive of one eligible impairment type.^{6,14}

Once this determination is made, it becomes essential for all sports to adopt appropriate and effective methods for assessing impairment.¹⁴ There are currently 28 Paralympic sports including 22 summer sports and six winter sports, where each sport has its own unique sport-specific classification system created by their International Sport Federation. Classification systems must be sport specific in order to minimize the impact of impairment on sport specific performance.^{6,9}

Once it has been determined that an athlete has an eligible impairment type for a given sport, the next step in the classification process is to determine if that athlete has met the Minimum Impairment Criteria (MIC) for the sport. This means that not only does an athlete have to have an eligible impairment type, but they also must demonstrate a minimum level of disability to be considered a participant – the eligible impairment type alone does not guarantee you are going to be eligible to participate. This minimum impairment criteria is also established by each International Sport Federation.⁶

The third and final step of the classification process is also the most complex: determining an athlete's individual sport class. While the specifics may vary across different sports, this step always involves a thorough evaluation of the athlete's functional abilities and the impact of their impairment within the context of the sport. Athletes are then grouped with others who have similar levels of limitation to ensure fair and meaningful competition.⁶

The development of evidence-based classification systems is essential to ensuring fair competition in Paralympic sport. According to the IPC, such systems must have a clearly defined purpose—to minimize the impact of eligible impairments on sport outcomes—and classification systems must use scientifically supported methods in assigning classes.^{12,14} This includes using objective, reliable, and sport-specific impairment measures that are resistant to the effects of training.¹⁴

Currently, many Paralympic sports rely on clinical assessments such as manual muscle testing (MMT), which lacks the reliability and objectivity needed for evidence-based classification.¹⁴ This is particularly problematic in team sports like wheelchair rugby, where athletes with different impairments compete together on court. If classification does not

accurately reflect how impairments affect performance, it can compromise fairness, discourage participation, and damage the credibility of the sport.^{13,15}

Despite clear IPC guidelines and a strong research framework, no Paralympic sport has yet achieved a fully evidence-based classification system.¹⁵ To move forward, sports must develop valid tests and demonstrate clear links between impairment and performance.^{14,16} Continued collaboration between researchers and sport organizations is critical to achieving systems that are fair, transparent, and grounded in science.

Introduction to Wheelchair Rugby

Of the 28 Paralympic sports, this study will focus on the sport of wheelchair rugby. Wheelchair rugby is a Canadian heritage sport, invented in Winnipeg, Manitoba in 1977.¹⁷ Canada is considered a leader in the Paralympic Movement, in large part due to the early efforts of Toronto orthopedic surgeon Dr. Robert Jackson who helped make Canada's participation in its first Paralympic Games in 1968 in Tel Aviv, Israel possible.² In 1993, wheelchair rugby was recognized internationally as an official sport for athletes with a disability, and the International Wheelchair Rugby Federation (IWRF), now World Wheelchair Rugby (WWR) was established. In 1994, the sport was officially recognized by the IPC as a Paralympic sport. It was a demonstration sport in the 1996 Summer Paralympics in Atlanta, and was then recognized as a full medal sport for the first time at the 2000 Summer Paralympic Games in Sydney. Currently, this sport attracts more than forty countries who participate in the sport internationally, or who are developing programs within their nation.²

Wheelchair rugby is a competitive, full contact, co-ed team sport that was developed for athletes with tetraplegia (quadriplegia), meaning that athletes have an impairment in at least three limbs.¹⁸ Impairment examples may include spinal cord trauma, amputations, cerebral palsy,

muscular dystrophy, polio, and other neurological conditions which result in full or partial impairment in the legs and arms.¹⁹ The game consists of four 8 minute quarters, and is played on a regulation basketball court with a ball identical in size and shape to a regulation volleyball. The sport blends elements of basketball, handball, and ice hockey, and contact between chairs is not only allowed but encouraged, which makes it one of the most popular Paralympic sports. The objective of the game is to carry the ball across the opponent's try line while maintaining control, requiring at least two wheels to cross the line for the score to count. Players can pass, bat, roll, dribble, or carry the ball in any direction, but must adhere to rules of the sport that promote continuous play and tactical movement. Teams have 40 seconds per possession to attempt a score, 8 seconds to inbound the ball, and 12 seconds to advance it past midcourt. They must also bounce or pass the ball every 8 seconds.^{17,20,21}

Wheelchair rugby is played in manual sport wheelchairs that are specifically designed to meet the physical demands of the sport. There are two main types of chairs: offensive chairs, that are built for speed and agility, which feature rounded bumpers to avoid getting picked and are typically used by players with greater physical function; and defensive chairs that are designed to block and trap opponents, with hooked bumpers that are more suited to players with lower levels of function.¹⁷

In wheelchair rugby, athletes are allocated one of seven sport classes which range from 0.5 to 3.5 (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5), meaning that each athlete after completing the process of classification will play on court with a specific assigned class number. Low point athletes include the 0.5, 1.0 and 1.5 classes, representing athletes with the least amount of function on court or highest amount of dysfunction. These athletes play a defensive role on court, acting more as a blocker and setting picks rather than being a major ball handler.¹⁸ Mid point athletes

include the 2.0 and 2.5 classes, representing athletes with increased levels of function, who therefore have increasing roles on the court as ball handlers and have both defensive and offensive roles. High point athletes include the 3.0 and 3.5 classes, representing the athletes who have the highest amount of function on court. These athletes are offensive players, who are very good ball handlers and fast playmakers. They most often also have some trunk function, allowing them to have increased functional skill levels on court. Athletes exceeding the 3.5 maximum class value would not meet the minimum impairment criteria, and are therefore not eligible to compete in the sport.¹⁸ Please see Appendix D for a detailed list of class characteristics.

Games are played four on four, where teams must field athletes with a mix of classification values.¹⁹ The total amount of points permitted on the court at any given time referred to as the total class value on the court, cannot exceed 8.0. This means that teams can put on the court any combination of four athletes that does not exceed 8.0. An example of a four athlete line-up would therefore be: $3.5 + 3.0 + 1.0 + 0.5$, which therefore allows for athletes of all levels of ability to have equal opportunities to perform on court, and prevents athletes with the highest amount of function from consuming all of the playing time.¹⁸ The variety of potential line-up combinations adds to the complexity of the game and team strategy, and highlights the impact that classification results can have on team outcomes.^{18,19}

Classification in Wheelchair Rugby

The classification system in wheelchair rugby has evolved significantly since the sport's early years. Initially, classification followed a medical model, introduced with three sport classes based largely on medical diagnosis and the level of spinal cord injury. However, as the

sport developed and the athlete population grew more diverse, this system was no longer sufficient. In 1991, a sport-specific classification approach was introduced. This model was better suited to reflect the functional abilities of a wider range of athletes, allowing for a more equitable playing field.¹⁹

Today, the WWR classification system adheres to the IPC's requirement for evidence-based classification. It is informed by sport-specific research and is updated as new evidence emerges. The system aims to ensure that athletes compete in categories that reflect the impact of their impairment on performance in wheelchair rugby.¹⁹

The classification process in wheelchair rugby is a structured, step-by-step system designed to ensure fair and equitable competition. It begins with confirming that an athlete has an eligible impairment resulting from a health condition, as outlined by the IPC's Classification Code. This must be confirmed through medical documentation prior to the start of a classification assessment.¹⁹ In wheelchair rugby, the eligible impairment types that were determined appropriate for the sport include: impaired muscle power, impaired passive range of motion, limb deficiency, hypertonia, ataxia, and athetosis.²² Although athletes with disability types found within these impairment categories were already participating in the sport prior to this newly defined list, the inclusion of the formal list of eligible impairment types from the IPC Classification Code in 2015 were not implemented into the classification process in wheelchair rugby until changes were made to a newer version of the classification manual in 2021. Prior to the formalization of the eligible impairment list, athletes with coordination impairments such as hypertonia, ataxia, and athetosis were eligible to participate, however since objective and reliable tests for measuring those impairments were limited, it should be noted that sport class decisions

were primarily based on the technical and observation assessments rather than manual muscle testing.¹⁸

To be classified in the sport of wheelchair rugby, athletes must first pass an Eligibility Test (see Appendix A) to ensure that the severity of impairment and sport specific activity limitation meets the minimum eligibility requirement as determined by the International Federation. The eligibility test measures impairments in muscle strength in upper extremities, trunk, and lower extremities and/or limb length as required.^{18,19} If an athlete does not meet the sport's Minimum Impairment Criteria (MIC), they are designated 'Not Eligible' (NE) and cannot compete in sanctioned events. Those who meet the MIC proceed to further classification stages, where they are assigned a sport class based on the extent of their functional ability within the sport.^{18,19}

Classification in wheelchair rugby includes three components. The first component includes a physical assessment known as the bench test to evaluate trunk and limb function through manual muscle testing. Please refer to Appendix B – Sample Wheelchair Rugby Classification Form, for a full list of muscles that are assessed by classifiers using manual muscle testing.¹⁸ Entry sport class is calculated by adding up the value for both arms in terms of where scores fit within the standardized values within the manual for each class, then dividing by two getting the average score for right and left upper extremities, and finally adding in a trunk score if and where applicable for athletes who have trunk function.¹⁸ Athletes within each sport class can represent a wide range of impairment types, and therefore a variety of impairment scores may be seen within one class. For example, an athlete's impairment may result in asymmetrical function, meaning an athlete could have function in one hand for instance that exceeds the function of other scores or standardized scores within a given class. Overall, however, that

athlete's level of function does not match with the next/higher class, so overall an athlete may be determined to 'best fit' into one class over another.¹⁸ See Appendix C – Standardized Manual Muscle Testing Scores for a comparison of the standardized MMT scores outlined for each class.¹⁸

Next, a technical assessment is conducted, which includes a range of sport-specific tests (such as wheelchair and ball activities) and novel non-sport tests depending on disability type, in a non-competitive setting. This stage is intended to help assess how the impairment impacts the performance of sport-specific movements. Once these steps have been completed, an athlete will receive a temporary class and be assigned a tracking code OA (Observation Assessment) to identify they are participating in the third and final component – the observation assessment, in order to allow classifiers to see them on court. During this final step, athletes are observed on court during competition to further assess their sport-specific function, and help validate earlier findings at game speed.^{18,19} Once all steps have been completed, the athlete will then be assigned a final sport class based on the results of all components of the classification process.

It must be noted that all classification assessments take place during competition at sanctioned events. The bench test and technical assessments will take place prior to the start of competition so that the observation assessment can take place during an athlete's first appearance on court. On court classification assessments take place during preliminary rounds and must be completed by the end of pool play of a competition. Classification panels work to make decisions as quickly and efficiently as possible, but they must have the opportunity to adequately observe the athlete during competition, so teams must have the athletes on court for a significant portion of the games.¹⁹

In cases where, after the bench test and technical assessment, an athlete's abilities appear to straddle two sport classes, they are temporarily placed in the higher (less impaired) class for competition, and their status is re-evaluated during game play. In situations where a classification panel make on court observations that conflict with their assessment findings, components of the bench test and technical assessment may be repeated for clarification.¹⁹ Once receiving a final sport class at a competition, athletes will continue to participate at that class until their next classification assessment. Athletes must undergo this classification process at a minimum of three competitions spaced at least 11 months apart in order to receive a 'confirmed' sport class status (C). Confirmed status is granted when classifiers are confident that the athlete's impairment and performance capacity are consistent and not expected to change, therefore athletes must receive the same final class result in three consecutive classification evaluations.^{18,19}

Classifiers are highly trained individuals with a variety of formal medical and/or health-related educational backgrounds with training in neuromuscular evaluation and testing.¹⁸ Classifiers work as members of a classification panel, where during a competition a three person panel will collectively make classification assessments. There are four certification levels for becoming a classifier, ranging from National to International levels, increasing in formal advanced training and experience as you progress from level to level. Methods of certification are delivered through workshops and seminars, as well as application of knowledge and practical experiences collected through hands-on training and mentorship with classifiers. Classifiers must maintain certification through annual evaluations and regular participation in classification events.¹⁸

Classification can have a significant impact on competition results and on an athlete's ability to be successful.²³ In team sports, this impact does not just impact a single athlete but can expand to impact the entire team. Teams are permitted to bring a maximum of twelve athletes to a competition, so the variety of potential line-up combinations will depend on the number and what class of athletes you have ready to perform at a given level of competition. The variety of potential line-up combinations can certainly add to the complexity of the game and team strategy, and highlights the impact that classification results can have on team outcomes.²⁴ Coaches have a lot to consider when selecting line-ups, whether or not you match the opposition's line-up, and/or possibly take disability type into consideration. Each athlete's classification results have the ability to impact the entire structure of a line-up. Within each class, an athlete's overall level of function may be closer to the lower end of scores for a particular class or could be closer to the higher end of scores for that class. It is more advantageous and would be considered a competitive advantage to have athletes who fall within the higher end of scores for a given class, meaning that they have the highest amount of function possible. With that said, if the goal is to have athletes at the highest amount of function possible within the class, it is likely that they are on the border of staying within that class or perhaps being assessed as qualifying for the higher class which would then be a significant disadvantage to the team and drastically change line-up options in a game. This can impact tournament outcomes if the final class is different than what a team may be expecting for their athlete. It should also be highlighted that final class decisions may not come until the end of pool play, so an athlete may be playing at a different class in the tournament initially and that class could change after the observation component which can impact results positively or negatively.

Manual Muscle Testing

Manual muscle testing (MMT) is a widely used clinical tool for evaluating muscular strength by determining a muscle or muscle group's ability to resist manual resistance applied by a trained examiner. It has become a foundational assessment method in rehabilitation, neuromuscular diagnosis, and parasport classification. MMT is especially valued for its practicality as it does not require specialized equipment, can be administered in virtually any environment, and is relatively quick to perform.^{25,26} This cost-effective means of evaluating impairment allows for several assessments to be performed within a short period of time. These characteristics have made it the most common method used in classification for many Paralympic sports, including wheelchair rugby.^{18,27}

The principles of manual muscle testing follow the basic rules of muscle length-tension relationships, as well as those of joint mechanics, where external force in the form of resistance is applied at the end of range or slightly off from the end of range in the opposite direction of that of the contracting muscle.²⁵ The accuracy of the manual muscle test is highly dependent on the location of the applied resistance, and the consistency of application. Hand placement is typically near the distal end of the body segment to which the muscle attaches. The application of resistance should be steady and build over 2 to 3 seconds to achieve the maximum tolerable intensity.²⁵

The defining feature of MMT is the break test, in which the athlete is instructed to hold a limb in a test position while the examiner applies manual resistance, attempting to 'break' the position. This procedure evaluates isometric muscle contraction—an important distinction because isometric strength, as opposed to isokinetic or isotonic strength, is relatively resistant to performance enhancement through high-velocity training.^{14,16,25,26} This resistance to training

effects makes MMT particularly suitable for classification, where the primary objective is to assess underlying impairment rather than acquired athletic ability.^{12,26} In line with the IPC position stand, impairment assessments must be precise, reliable, and generate quantitative, ratio-scaled data on maximal muscle force.¹⁶ Isometric tests fulfill these criteria better than dynamic measures because maximum force generation typically occurs at low velocities and is less responsive to training.¹⁶ This is particularly relevant for athletes with conditions such as spinal cord injury, cerebral palsy, or muscular dystrophy, where strength impairments significantly impact function and sport performance.²⁸ MMT provides a practical method for identifying these deficits; however, its clinical utility can be challenged by subjectivity, particularly when raters are required to discern between subtle gradations of partial muscle strength.^{25,27}

The use of MMT in classification is not without limitations. A major concern is its reliance on an ordinal grading scale, which lacks the precision and ratio-level measurement needed for evidence-based classification systems.^{26,29} This prevents meaningful quantification of strength differences across muscle groups and limits the ability to aggregate scores in a way that reflects true activity limitation.

In wheelchair rugby, MMT is a critical component of the first part of the classification assessment, the physical assessment or ‘bench test’. Muscle strength is assessed by a trained classifier, and graded on a five-point ordinal scale which is defined within the classification manual as follows:²⁵

0 = Complete lack of voluntary muscle contraction. The examiner is unable to feel or see any muscle contraction.

- 1 = Faint or 'flicker' muscle contraction without any movement of the limb. The examiner can see or palpate some contractile activity of the muscle(s) or may be able to see or feel the tendon 'pop up' or tense as the athlete tries to perform the movement.
- 2 = Very weak muscle contraction with movement through complete range of motion in a position that eliminates or minimalizes the force of gravity. This position is often described as the horizontal plane of motion.
- 3 = Muscle can complete a full range of motion against only the resistance of gravity.
- 4 = Able to complete the full range of motion against gravity and can tolerate strong resistance without breaking the test position. The Grade 4 muscle clearly breaks with maximal resistance.
- 5 = Able to complete the full range of motion and maintain end point range position against maximal resistance. The examiner cannot break the athlete's hold position.

When muscle strength falls between the above defined numerical grades, classifiers will use a plus (+) or minus (-) to represent that difference accordingly where:²⁵

- Grades 0&1 = Represent absence or minimal muscle contractile activity, so plus (+) and minus (-) should not be used.
- Grade 2- = Gravity eliminated movement that is less than full range of motion.
- Grade 2+ = In gravity minimized position, completes full available range and takes maximal resistance; or against gravity, up to half of full range of motion.
- Grade 3- = Against gravity, more than half but less than full range of motion.

Grade 3+ = Completes full range of motion against gravity, and hold end position against mild resistance.

MMT involves a combination of subjective and objective components, including the examiner's impression of resistance tolerated, and the athlete's ability to hold a position. For this reason, results can vary widely between examiners, especially for mid-range grades or where an athlete is presenting with partial paresis.^{25,27,28} Factors such as the examiner's anatomical knowledge, consistency in test positioning and stabilization, and interpretation of muscle substitution patterns all influence the outcome.^{25,27} While training and experience can improve reliability, studies consistently show that even trained clinicians may diverge in their application of MMT, especially in complex cases or when grading partial muscle activity.^{25,27,29}

Wheelchair rugby is one of the few Paralympic sports that explicitly mandates the use of the Daniels and Worthingham's method as a reference for all MMT.^{14,18} This method is preferred over the Medical Research Council (MRC) scale because it includes functional movement descriptions, considers the effect of gravity, and utilizes the break test.^{25,27,29} In contrast, the MRC method evaluates isolated muscles, lacks defined testing procedures, and may not be sensitive enough to detect small changes in strength.³⁰ It is for these reasons that the wheelchair rugby classification manual specifies Daniels and Worthingham's method, distinguishing it from other scales.^{25,27} In wheelchair rugby, classifiers come from a wide variety of professional and educational backgrounds, so standardization is essential to reduce inconsistency.²⁷ Having all classifiers reference the same manual for conducting all tests certainly improves consistency, yet inter-rater reliability still remains a concern and requires classifiers to undergo formal training in anatomy, neurology, and correct technique.^{25,27,31}

In a study evaluating the intra and inter-rater reliability of MMT in the new hand classification of wheelchair rugby, researchers found that despite having this central resource, classifiers were still uncertain about hand placement and the correct interpretation of test results, particularly due to the shift from assessing individual muscles to evaluating joint-based movements.²⁷ The Daniels and Worthingham method tests functional movements for some muscle groups rather than isolating smaller muscles, which although more sport-specific can cause confusion. The use of mixed terminology (i.e. listing both joint movements and individual muscles on classification forms) further confuses application and may contribute to inter-rater variability.²⁷ Classifiers have reported confusion during international competitions, especially when uncertain about hand placement, resistance direction, or interpretation of movement quality. These inconsistencies suggest that current levels of reliability are suboptimal and that additional training and refinement of testing protocols are needed.²⁷ These issues can lead to classification errors, affecting athlete eligibility and class assignment, which in turn impact team fairness and athlete development opportunities.^{26,27,29}

An additional point of interest is that classifiers often incorporate plus (+) and minus (-) distinctions when assigning muscle grades. Daniels and Worthingham advise against the use of plus and minus signs in MMT, as these modifiers introduce subjectivity and reduce the reliability of the grading system, especially for grades 3 and above.²⁵ Sticking to whole number grades promote greater consistency and clinical clarity. They note, however, that a minus may be appropriate in the context of Grade 2, where a meaningful difference exists between a muscle that can complete the full range of motion in a gravity-eliminated position and one that can only perform part of the movement. In this case, they recommend assigning a 2- grade to help reflect subtle but important changes in function.²⁵ Regardless of numerical grade, practitioners should

be encouraged to document qualitative observations about the movement to provide a complete picture of the performance.²⁵ The regular use of plus and minus in MMT in wheelchair rugby classification, though common in practice, deviates from the referenced guidelines and adds to the complexity of maintaining consistency.

To enhance the reliability and utility of MMT in classification, several improvements have been recommended. These include standardizing test positions and techniques; training classifiers in precise anatomical knowledge and resistance application; reducing subjectivity by avoiding use of plus/minus modifiers; and ensuring that tested movements are functionally relevant to the sport.^{21,25,27} For example, in wheelchair rugby, the use of joint-based movement terminology such as finger abduction rather than specific muscle names like *interossei*, aligns better with Daniels and Worthingham's system and reduces misinterpretation.²⁵ Additional measures such as providing clear, consistent instructions to the athlete; conducting tests in quiet, distraction-free environments; and recording descriptive observations alongside the grade can further improve the validity of results.^{25,27}

In addition, the correlation between MMT grade and functional ability is often weak. For instance, two athletes may both receive a Grade 2 for elbow extension despite differing vastly in their active range of motion, which would have significant implications in tasks such as passing or reaching.²⁶ The ordinal nature of MMT also restricts its utility in measuring small improvements in strength over time, limiting its sensitivity in both classification and rehabilitation contexts.^{27,30}

Ultimately, the widespread use of MMT in Paralympic sport classification reflects its many strengths—practicality, familiarity, and efficiency. However, these benefits must be balanced against its known weaknesses. The variability introduced by subjective grading, the

limitations of ordinal scales, and the inconsistent interpretation of testing techniques pose substantial challenges to achieving fair and reliable classification outcomes. Since classification can influence everything from athlete confidence and competitive success to funding and representation, inconsistencies in MMT application can have far-reaching effects.^{12,26,27} Ensuring that manual muscle testing is applied with diligence, standardization, and context-specific knowledge is essential if it is to continue serving as a valid and equitable foundation for parasport classification.

Triceps Manual Muscle Test

This study focuses on a section of the physical assessment or bench test, which includes the assessment of muscle strength using manual muscle testing (MMT). More specifically, this particular study focuses on one of the manual muscle tests—the triceps test. The triceps brachii work collectively to extend the elbow. The lateral head is used for movements involving occasional high-intensity force, whereas the medial head enables more precise and low-force movements.²⁵ The traditional manual muscle test for the triceps brachii involves resisted isometric testing of the muscle group, however, in wheelchair rugby, this particular test has been modified from the Daniels and Worthingham method to accommodate an added component of muscular endurance.

In the Daniels and Worthingham method, to assess triceps strength, MMT is performed using specific positions and grading criteria. For Grades 5, 4, and 3, the patient is prone on a table with the shoulder abducted to 90 degrees and the elbow flexed at 90 degrees, allowing the forearm to hang vertically. The examiner instructs the patient to straighten the elbow. If the patient achieves full range of motion (Grade 3), resistance is then applied.²⁵ One hand supports

the arm just above the elbow, while the other applies downward resistance to the forearm just proximal to the wrist. The elbow is slightly flexed to prevent joint locking, which is particularly important in patients with hyperextension. The grading criteria are as follows: Grade 5 indicates the patient maintains full extension against maximal resistance; Grade 4 is similar but with a noticeable 'give' at the end range; and Grade 3 reflects full motion without resistance.²⁵

For Grades 2, 1, and 0, testing is done with the patient in short sitting (ie sitting in their chair with knees bent at 90°). The arm is supported in a horizontal position with the shoulder abducted and the elbow flexed at approximately 45 degrees to minimize gravitational effects. The therapist supports the elbow for Grade 2 testing and the forearm for Grade 1 and 0 testing while palpating the triceps near the olecranon.²⁵ The patient is asked to try to straighten the elbow. Grade 2 is assigned if the patient completes the movement in the gravity-minimized plane. Grade 1 is given if contractile activity is felt in the muscle or tendon without joint movement, while Grade 0 indicates a complete absence of palpable contraction.²⁵

Daniels and Worthingham note that substitutions during testing can falsely suggest triceps activity. In patients with absent triceps strength (Grade 0), elbow extension can occur through external shoulder rotation. This causes the arm to drop below the forearm, allowing gravity to passively extend the elbow. To prevent this, the arm should be supported by a table or board.²⁵ Another substitution involves horizontal adduction of the shoulder, a maneuver sometimes used by patients with cervical spinal cord injuries. If the wrist is stabilized, horizontal adduction can create a thrust that passively extends the elbow. To avoid this during testing, the therapist should support the arm at the elbow rather than the wrist.²⁵

Daniels and Worthingham also note several testing nuances that help improve the accuracy of MMT for the triceps. For example, during resistance testing for Grades 4 and 5, the

elbow should remain slightly flexed to avoid stabilization by hyperextension. Because the triceps crosses two joints, testing in the prone position with the shoulder abducted may disadvantage the muscle mechanically, potentially leading to underestimation of strength.²⁵ An alternative test position for Grades 3 and higher involves having the patient seated while the therapist supports the abducted arm from behind.²⁵

A new test for the triceps muscle was introduced in the wheelchair rugby classification manual, in order to accommodate a component of muscular endurance. The decision to modify this particular test was due to the importance of sustaining triceps strength in sport-specific activities in wheelchair rugby. It is the only muscle test used in wheelchair rugby that has been modified with this endurance component.²⁵ In the modified version of the test, the athlete's arm is placed in an anti-gravity position and athletes are asked to complete ten repetitions of full range of motion of the elbow. They are then asked to maintain end point range position and hold it against maximal resistance. The classifier attempts to break the athlete's hold position, and a score is then graded accordingly based on the following scoring criteria.^{18,22}

The scoring has been adjusted for this modified test as follows:^{18,22}

- 3- = 5-9 repetitions
- 3 = 10 repetitions
- 3+ = 10 repetitions then minimal resistance
- 4- = 10 repetitions then moderate resistance
- 4 = After 10 repetitions moderate resistance throughout active ROM
- 5 = Able to complete 10 repetitions through full range of motion and maintain end point range position against maximal resistance. The examiner cannot break the athlete's hold position.

The modified triceps test was introduced to reflect the important role of the triceps in wheelchair rugby-specific movements; however, its implementation is grounded in theoretical assumptions and lacks empirical validation. Further research is needed to clarify the extent to which triceps function influences performance in the sport.

Triceps Muscle Function in Wheelchair Rugby

In wheelchair rugby, the triceps brachii is heavily involved in a variety of passing techniques and plays a vital role in supporting an athlete's overhead game. The four most common passes used in the game are a chest pass, overarm throw, side-arm throw, and a one handed pass. To be effective, athletes must rely on a coordinated effort from multiple muscle groups, which most commonly include the trapezius, deltoids, pectoralis major, biceps, and triceps.^{32,33} The triceps muscle is particularly important in elbow extension for generating power and maintaining the control needed to execute these throwing actions. This is especially important when throwing with force, where elbow extension drives much of the velocity and trajectory of the ball.³²

In wheelchair rugby classification, low point athletes (0.5, 1.0, and 1.5 classes) typically lack sufficient shoulder, triceps, and wrist stability, which can limit their ability to handle the ball or perform rapid directional changes in the chair.^{26,34} These athletes therefore mostly assume defensive roles on court where fine motor coordination is less critical. Conversely, high point athletes (3.0 and 3.5 classes) will exhibit stronger shoulder and elbow control, with increased triceps function which enables longer, more controlled contact with the push rim, assists with wheelchair acceleration, and allows the athlete to be more dynamic in offensive tasks.^{18,34}

Strong triceps function also supports wrist extension during propulsion, contributing to more efficient and stable pushing techniques.²⁶

Triceps function can also impact propulsion mechanics, particularly during the acceleration phase from a stationary position. This is a critical element in wheelchair rugby, as it can allow athletes to quickly move on court to a more advantageous position ahead of an opponent. Athletes with better elbow extension and stronger triceps can generate more effective push strokes, contributing to greater speed and maneuverability.²⁹ Many experienced athletes will adopt a shorter push angle starting closer to the top centre of the wheel, which allows for forceful acceleration while minimizing shoulder strain. This is not just influenced by muscle function and control, but it is also impacted by factors such as wheelchair configuration, such as the seat angle/dump and chair width. The presence of strong triceps however remains a key factor in allowing athletes to capitalize on optimal wheelchair configurations and propulsion strategies.³⁵

It should be noted that athletes with natural triceps function demonstrate superior throwing performance compared to those without triceps innervation or those who've had a deltoid-to-triceps (DTT) surgical transfer. DTT surgeries are not uncommon in disabled populations as triceps function can be very beneficial in overall mobility.³² A study found that individuals with natural functioning triceps can generate quicker hand speed, maintain wrist flick for better accuracy and distance, and more comfortably complete all forms of passes. DTT recipients are able to extend the elbow against gravity and mimic natural triceps function, however it was discovered that throwing distance and control was poor compared to athletes with natural triceps function.³² This finding suggests that although surgical transfers restore basic extension, they do not provide the dynamic control required for high level tasks such as passing

under competitive conditions. These findings highlight an important limitation in the current classification system, which may overestimate the functional gains associated with surgical restoration of elbow extension.³²

Ultimately, the role of the triceps muscle extends beyond simple elbow extension. It is a critical muscle in throwing mechanics, wheelchair propulsion, and overall sport-specific functionality in wheelchair rugby. Classifications that fail to adequately account for the functional differences between natural triceps activity and surgical substitutes risk misrepresenting an athlete's true capabilities and limiting fair competition.³²

The impact the triceps muscle has on performance in wheelchair rugby can perhaps be better understood by looking at the individual class characteristics. We will focus on low and mid-point classes for the purpose of this study, classes in which triceps may not be full strength. Athletes in the 0.5 class are considered low point athletes, which are the athletes with the lowest amount of muscular function, or highest levels of disability. They are therefore not the primary ball handlers, and typically play a defensive role on court, setting blocks for teammates.¹⁸ They present with significant weakness in the proximal shoulder muscles, and have little to no triceps function. This often leads to a characteristic forward head bob during propulsion, which is one of the distinctive characteristics of this class. Their pushing technique relies on an unopposed biceps push, where athletes are pulling on the back of the wheel with bent elbows flared outward. Due to impaired wrist extensors and reduced hand and wrist control, they frequently depend on their forearms to manage starts, stops, and turns.¹⁸ Ball handling is also impacted by limited strength in the shoulders, arms, and wrists, resulting in balls being carried on the lap, or tapped for short passes. For longer throws, an underhand volleyball serve motion is often used, and short passes may involve a two handed toss from the side. Typical muscle impairments include

the triceps muscle graded as 0-1, and weakness in the shoulder girdle, sternal and clavicular portions of the pectoralis major, latissimus dorsi, and possibly the shoulder rotators.¹⁸

Athletes in the 1.0 class are also low point athletes who are primarily used as blockers. They may assist with in-bounding, but are not relied on for primary ball handling. They will demonstrate improved proximal strength in comparison to the 0.5 class athlete, particularly in the deltoids and clavicular pecs, though they still exhibit weakness in the triceps and shoulder girdle overall.¹⁸ This will allow for a longer, more fluid push stroke that incorporates both pushing and pulling on the rear of the wheel, which enables more efficient multidirectional movement. This can be a distinguishing characteristic between a 0.5 and 1.0 class athlete, where the head bob is not present, and starts, stops, and turns are smoother without the need to pause.¹⁸ While some forearm compensation may still be observed due to triceps and wrist weakness, their increased upper body strength contributes to better chair control. In ball handling, they may catch a ball using the wrist or forearm, and are capable of executing a weak chest pass or a forearm-based throw.¹⁸

Athletes in the 1.5 class are strong and dynamic blockers who may also contribute as secondary ball handlers due to their increased functional abilities. They are still considered low point athletes, but they will start to play an increased offensive role on court making them close to being considered mid point athletes.¹⁸ With improved shoulder strength and stability over the lower classes, they demonstrate more effective pushing mechanics, which allow for faster propulsion and smoother control during starts, stops, and transitions. These physical advantages also enhance their ball handling, enabling them to hold the ball out in front of the chair and deliver chest passes with greater range and consistency. Wrist imbalances however can still impact ball control, and an athlete may have asymmetrical arm strength which may lead athletes

to favour their stronger side for both pushing and passing mechanics.¹⁸ While they are capable of performing one handed passes, these passes are typically limited in distance and accuracy, and are more commonly observed in the technical assessment or when in-bounding and less commonly observed on court. Athletes in this class often present with residual proximal weakness in the latissimus dorsi or sternal pecs, while showing stronger triceps and wrist function in comparison to a 1.0 class athlete.¹⁸

Athletes in the 2.0 class are considered mid point athletes, where they will most often play more of an active role as ball handlers due to strong and stable shoulder and chest musculature, as well as good triceps strength. These attributes allow for quick, controlled starts and stops, and allow for more efficient pushing around the court.¹⁸ Increased function allows for more effective chest passes with reasonable distance and control. These athletes however are limited in finger flexion which will limit their ability to securely grip the ball when under defensive pressure.¹⁸ Wrist positioning will help with ball stabilization, but the lack of a functional hand grip remains a constraint. A one handed overhead pass is possible, but these passes can lack in power, accuracy, and range, making it more common to observe within the technical assessment versus consistently on court during regular gameplay.¹⁸

Athletes in the 2.5 class are more typically a primary ball handler on court, as they are more agile, and stronger shoulder stability allows for a more effective pushing speed. They often possess the ability to grip on the push rim, which helps support efficient mobility. Partial trunk function may also be present, which if present may also add to the overall stability within the chair.¹⁸ In terms of ball handling, these athletes often have relatively balanced finger flexion and extension, but might lack a fully functional grasp-and-release mechanism. Instead, they rely on more of a curling and uncurling motion dictated by the finger flexors, without support from the

intrinsic hand muscles. This helps with dribbling capabilities using a forearm supination technique, and enables one handed overhead passes. These passes may be limited in range and precision however due to finger strength imbalances.¹⁸ Athletes within this class can catch passes securely using both arms, often scooping the ball into their lap, and they may be capable of performing a single-handed catch as well. In comparison to the 2.0 class athlete, their improved wrist and finger isolation offers greater ball security under pressure, although asymmetries in arm or hand function can still influence both propulsion and ball control.¹⁸

Considering the pivotal role of the triceps in fundamental wheelchair rugby movements—such as pushing, passing, and overhead actions—it is essential that any modified testing accurately reflects how triceps function translates to in-game performance. When scores for this muscle group fall outside the standardized classification ranges, it may suggest that the athlete’s assigned class does not accurately represent their functional abilities on court. For a complete list of standardized scores as outlined in the classification manual, please refer to Appendix C.^{18,22}

Chapter 2: Purpose and Rationale

Purpose & Rationale

Classification results in the Paralympic sport of wheelchair rugby are heavily influenced by the physical assessment, specifically the component of MMT. These assessments are subjective, and therefore subject to possible error. This is further complicated by the fact that wheelchair rugby is a sport specifically for quadriplegics, where athletes represent a variety of disability types and possess varying degrees of muscle function. For a test to be considered objective, it must not be dependent primarily on the judgement of the examiner.²⁵

The classifier is the gatekeeper responsible for making classification a true and fair system, but the evaluation process can be quite challenging, and inaccurate classifications can have a significant impact on competition results and on an athlete's ability to be successful.²³ The knowledge and acquired skill levels of the classifiers will determine the accuracy of a MMT, therefore consistent use of standardized methods for each test, proper positioning and stabilization techniques, and the ability to identify patterns of substitution in a given test and how they can be detected based on knowledge of other muscles is required.²⁵ In athletes that are quadriplegics, the ability to detect minimal amounts of contractile activity throughout contraction and relaxation phases is a critical component of the classification process as manual muscle testing scores often fall below a grade of 3 where range of motion is more severely limited due to neurological impairment.²⁵

In wheelchair rugby, all of the MMT evaluated as part of the physical assessment within the classification process follow testing protocols as outlined in Hislop and Montgomery, with the exception of the triceps test that has been modified from the published version of the test to add a component of muscular endurance due to the importance of sustaining triceps strength in

activities within the sport such as wheelchair tasks.¹⁸ Tasks requiring endurance could, for example, include push stroke, stops/starts, and some passing techniques. Triceps are also important in terms of overhead game in passing and defending, therefore having increased function in this particular muscle group would be considered a significant competitive advantage over athletes with less function, in terms of both offensive and defensive game. The validity and reliability of this modified test has not been previously explored in the literature, and although the intention of adding an endurance component may be appropriate, the results of the testing should be evaluated further to examine the validity and inquire if further investigations into the testing procedure may be warranted.

The purposes of this retrospective cohort study were:

- 1) *To evaluate the triceps test in wheelchair rugby by assessing how accurately the recorded MMT scores match the standardized MMT scores within low and midpoint classes of athletes for their assigned final class (specifically the 0.5 to 2.5 classes).*

See Appendix C – Standardized Manual Muscle Testing Scores for a comparison of the standardized MMT scores outlined for each class.¹⁸

- 2) *Based on the results of the first purpose of this project, determine whether further investigation into the validity and reliability of the modified triceps test would be recommended. This would be determined based on how closely the recorded MMT scores matched the standardized MMT scores for the identified mid and low point classes of athletes (0.5 to 2.5 classes).*

Positionality Statement

As the primary researcher in this study, I bring both academic interest and extensive lived experience within the sport of wheelchair rugby. From 2013 to 2025, I served as the Lead Medical Practitioner for Wheelchair Rugby Canada and acted as an athlete representative during classification assessments at both the national and international levels. This role allowed me to support provincial athletes undergoing national classification, as well as national team athletes navigating international classification processes.

These experiences have provided me with a comprehensive understanding of the classification system and its profound impact on athletes and teams. I have seen firsthand how classification outcomes can influence athlete identity, team dynamics, and competitive opportunities. My close involvement with the sport has fostered a deep commitment to advancing classification practices in parasport, with the goal of promoting fairness, transparency, and consistency.

While I recognize the complexity and challenges inherent in the role of the classifier, I also see the potential for research to support evidence-based improvements. Through this study, I aim to contribute meaningfully to the ongoing development of classification systems and hope that my findings will inform and inspire future research efforts focused on enhancing objectivity and integrity in classification.

Hypotheses

Hypotheses for this study are outlined below.

Hypothesis 1: Not all scores will fall within the standardized ranges; some will fall outside of the standardized ranges for each class being evaluated due to scores being assigned based on best fit overall versus an objective calculation.

To calculate a classification score in wheelchair rugby following the bench test, upper extremity total scores (for both right and left extremities) are assigned (not calculated) based on the collected manual muscle testing scores. Those two scores are added together and divided by two, then added to an athlete's trunk score to receive an estimated entry sport class. Final class is not assigned until after the technical and observation assessments. This leaves room for subjectivity so some amount of variation would be expected.

I expect that a significant portion of final classification scores will deviate both above and below the standardized range, with a majority of those scores landing in the classes directly above and below. I also expect some outlier scores, but predict that the majority of scores assessed out of range will only be off by one class. I also predict an increase in disability types represented within each progressing class which may account for some of these predicted results.

Hypothesis 2: The modified triceps test will show significant variability, indicating a need for further investigation into its reliability and/or validity for predicting final class. It is expected that the results will indicate a need for further research on and evaluation of the structure of the modified triceps test, but it is not yet clear whether results may yield positively or negatively.

Test structure should be formulated based on empirical evidence, therefore I predict that further investigations into the validity and reliability of this test will be required to determine

whether the triceps should be evaluated with an endurance component, and further evaluate why 10 repetitions specifically was chosen to represent the endurance component. The results may challenge whether this test is accurate enough to predict final class, and/or the need for less/additional reps or other muscle groups to be evaluated with an endurance component.

Chapter 3: Methods

Participants

This study population will include all Canadian wheelchair rugby athletes who have been classified nationally, by analyzing historical data from the Canadian Classification Database in the sport of wheelchair rugby. This database includes a total of 492 classification assessments that were completed on 283 different Canadian wheelchair rugby athletes from 1992 to 2019. All participants will have a physical impairment that has been deemed eligible by the International Federation (WWR) that results from a permanent and verifiable medical condition or disorder which causes activity limitation in the fundamental activities of the sport.¹¹ For the sport of wheelchair rugby, this is specifically restricted to athletes with quadriplegia.¹⁷

All wheelchair rugby athletes must go through the classification process to receive an initial sport class in order to be permitted to compete at any sanctioned event at any level of play, including Club, Provincial, and National Team athletes. Athletes must undergo three classification assessments and receive the same class outcome in each assessment being a minimum of 11 months apart, in order to be considered ‘confirmed’ within a class, however athletes can participate as soon as they receive their initial classification. The intention of the prolonged evaluation process is to account for any changes in impairment, especially for athletes with a newly acquired injury. An athlete’s class may also be protested during this process, so athletes may therefore have to undergo classification on multiple occasions.¹⁸ These factors account for the higher number of total assessments compared to total athletes.

This study population will include athletes who have played at all levels; however, this particular study will narrow the focus on low to mid-point participants from the 0.5 to 2.5 classes. The number of classification assessments represented within these five classes (0.5, 1.0,

1.5, 2.0 and 2.5) equals 364 assessments to be evaluated within the study. Low and mid point athletes will be selected specifically due to the impact of triceps function and strength on these classes. Athletes above a 2.5 class are likely to have full function in the triceps muscle with full strength.

Inclusion / Exclusion Criteria

This study excluded any athletes representing the United States of America or other countries found within the database. These athletes may have been initially included in the database if they were once permitted to attend Nationals to help fulfill rosters. They will therefore be removed from the study as the focus will remain specifically on the Canadian population.

This study also excluded any ‘spot check’ assessments. Spot checks are unofficial classifications which are considered incomplete assessments only used to provide teams with an estimate of a class assessment prior to classification. These spot checks do not meet the criteria for an official assessment and were removed from this study. They are traditionally only performed to give teams a better understanding of where the athlete may be before deciding to bring them to an official tournament for evaluation.

Classification assessments from athletes with final class scores from the 3.0, and 3.5 classes were also excluded. High point athletes (3.0 and 3.5 classes) have higher levels of function and, therefore, have manual muscle testing scores for the triceps test that are full or close to full and would therefore be likely to fit within the standardize range for their class and not be relevant to the study. These classification groups are also more likely to include a wider range of disability types containing athletes with higher levels of function which could also skew the results.

Finally, athletes who were assessed above a 3.5 class and who therefore are deemed ineligible to compete in wheelchair rugby were also excluded from the study.

Statistical Analysis

This study used a retrospective cohort design, whereby I conducted a stratified analysis of athletes based on their classification (0.5, 1.0, 1.5, 2.0, 2.5) to determine the number of assessments occurring inside and outside of the standardized classification scores for the triceps test. This exploratory, cross-sectional analysis was based on historical data from the Canadian Classification Database in the sport of wheelchair rugby from 1992 to 2019.

A descriptive statistical analysis was first conducted to summarize the key demographic variables within the dataset, including sex, assessment number, and disability type. Following this, a heat map was created to visually represent the distribution of triceps MMT scores across all low and mid-point classification levels (0.5, 1.0, 1.5, 2.0 and 2.5). Each score was coded to indicate whether it falls within, above, or below the standardized range for its respective class. The total number of assessments within each category were calculated for each class. These totals were then evaluated to determine if the assessed MMT scores align with the standard scores, highlighting the degree to which scores reflect class-specific functional profiles.

A final comparative analysis was then presented to summarize and contrast the proportions of within-range versus out-of-range scores across all classes to identify any emerging trends or patterns of inconsistency. All statistical analyses were performed using Microsoft Excel 365 Version (Microsoft Corp., Redmond, WA, USA).

Chapter 4: Data Analysis

Demographic Characteristics

This study population will include all Canadian wheelchair rugby athletes who have been classified nationally, by analyzing historical data from the Canadian Classification Database in the sport of wheelchair rugby. The Canadian database used in this study includes a total of 492 classification assessments that were completed on 283 different Canadian wheelchair rugby athletes from 1992 to 2019.

While the database includes all athletes who have been classed Nationally, this particular study will narrow the focus specifically on low to mid-point participants from the 0.5 to 2.5 classes. The number of classification assessments represented within these five classes (0.5, 1.0, 1.5, 2.0 and 2.5) equals 364 assessments to be evaluated within the study.

Descriptive statistics for sex, classification assessment numbers, and disability type represented are presented in Table 1.1. A total of 364 classification assessments were analyzed within this study, with male athletes representing a total of 327 assessments, and female athletes representing a much smaller portion of the overall population (females = 37). The majority of the assessments represented a first time classification assessment (56.3% of all assessments), highlighting that not all athletes were assessed multiple times. Second time classification assessments represented a total of 99 assessments (27.2%), third time assessments for 41 assessments (11.3%), fourth time classification for 15 assessments (4.1%), fifth time classification assessments for three (0.82%), and one sixth time assessment (0.27%).

The athletes within this study represented ten different disabilities, including amputees, amyotrophic lateral sclerosis (ALS), cerebral palsy (CP), charcot-marie tooth (CMT), traumatic

brain injury (TBI), Fredrich’s ataxia (FA), multiple sclerosis (MS), muscular dystrophy (MD), post-polio, and spinal cord injuries (SCI). Please see Table 1.1 for the frequency of disabilities represented in each class. The majority (n=328) were athletes with a spinal cord injury (90.1% of the total population). The number of disability types represented in each class also increased with class number, which was expected with increased levels of overall muscular function.

Table 1.1. Athlete Database Characteristics

Characteristic	0.5	1	1.5	2	2.5	Total
Sex						
Assessments – Female	9	9	9	9	1	37
Assessments - Male	57	50	44	116	60	327
Assessment #						
1 st Classification	39	38	30	64	34	205
2 nd Classification	18	13	15	37	16	99
3 rd Classification	6	6	6	15	8	41
4 th Classification	3	2	2	6	2	15
5 th Classification				2	1	3
6 th Classification				1		1
Disability Type						
Amputee					2	2
Amyotrophic Lateral Sclerosis (ALS)				1		1
Cerebral Palsy (CP)		2		3	7	12
Charcot-Marie Tooth (CMT)			2	1	1	4
Traumatic Brain Injury(TBI)		2		1		3
Fredrich's Ataxia (FA)					1	1
Multiple Sclerosis (MS)	1	2	1	1		5
Muscular Dystrophy (MD)			1		3	4
Post-Polio			1	2	1	4
Spinal Cord Injury (SCI)	65	53	48	116	46	328

Results

An athlete with a final class score of 0.5 will have assessed MMT scores that best fit into the classification characteristics for a low level athlete (Appendix C). The MMT score for the triceps should be assessed between a 0 – 1, meaning that the muscle cannot contract voluntarily, or there may be a faint contraction of part of the muscle which may be seen or palpated, without any movement of the limb.¹⁸ This would mean that the muscle is not functional, and therefore actions on court would be more limited. There was a total of 66 athletes assessed who were assigned a final class score of 0.5. This accounted for a total of 132 MMT assessments of the triceps muscle, taking into consideration both right and left arms of each athlete. From these 132 assessments, 110 were found to be scored within the standardized range for a 0.5 class athlete (83.3%), while 18 (13.6%) scored above this range, indicating greater triceps muscle function than what is indicated for the 0.5 class. Four assessment scores were missing – not recorded on the classification forms, so those values are not accounted for in the results. Figure 1a. represents the summary analysis of the assessed MMT results for the triceps muscle for the 0.5 class.

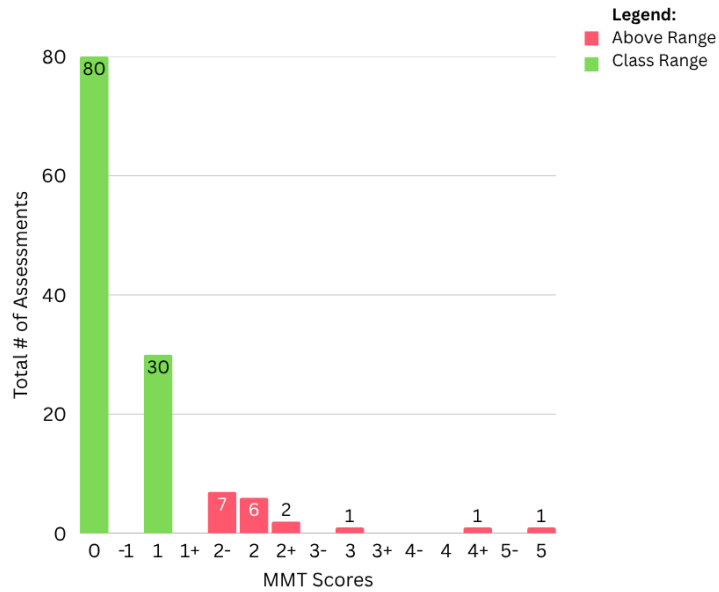


Figure 1a. Breakdown of MMT Triceps Scores for the 0.5 Class:

In the 1.0 class, the athlete’s MMT score for the triceps should be assessed between a 0 – 3, meaning there are a few levels of function that fit within this class for the triceps. For instance, the muscle may not contract voluntarily, or there may be a faint contraction of part of the muscle which may be seen or palpated, without any movement of the limb. However, the muscle might also move through the full range of motion in either a gravity eliminated position, or against gravity. In this classification, the athlete may be capable of completing 5-9 repetitions of elbow extension against gravity, or a full 10 reps against gravity.¹⁸ As a result, muscle function for this class could range from non existent or as much as being able to move against gravity for several repetitions, but the athlete is not able to move against any resistance.¹⁸ This would give the athlete more range of motion on court, but due to the inability to meet any resistance, capabilities on court will be more limited. There was a total of 59 athletes assessed who were assigned a final class score of 1.0. This accounts for a total of 118 MMT assessments of the triceps muscle,

accounting for both right and left arms of each athlete. From these 118 assessments, 90 (76.3%) were within the standardized range for a 1.0 class athlete, while 28 (23.7%) scored above the standard range, showing triceps muscle function greater than what is indicated for the 1.0 class. No assessment scores were missing from this class. Figure 2a. represents the summary analysis of the assessed MMT results for the triceps muscle for the 1.0 class.

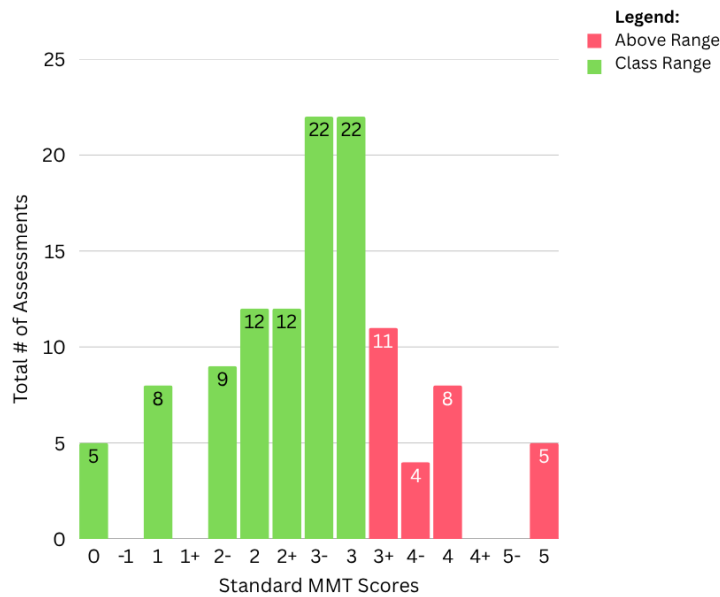


Figure 2a. Breakdown of MMT Triceps Scores for the 1.0 Class:

An athlete with a final class score of 1.5 will have assessed MMT scores for the triceps between a 3+ and 4-, meaning that the athlete can either complete the full 10 repetitions then resist manual force minimally, or moderately.¹⁸ This would mean that the muscle can now not only complete the repetitions, but it can also meet some resistance, which further increases the functional capabilities on court. There were 53 athletes assessed who were assigned a final class score of 1.5, accounting for a total of 106 MMT assessments of the triceps muscle, for both right and left arms of each athlete. From these 106 assessments, only 26 (24.5%) were found to be

scored within the standardized range for a 1.5 class athlete, while 35 (33%) were scored above the standard range and 45 (42.5%) were scored below the standard range. This results in 75.5% of assessed triceps scores not fitting within the standardized scores. No assessment scores were missing from this class. Figure 3a represents the summary analysis of the assessed MMT results for the triceps muscle for the 1.5 class.

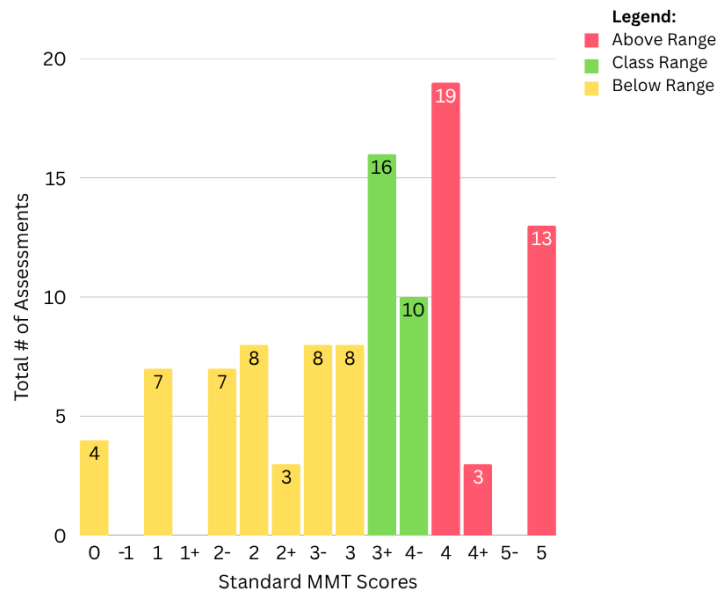


Figure 3a. Breakdown of MMT Triceps Scores for the 1.5 Class:

An athlete with a final class score of 2.0 will have assessed MMT scores for the triceps between a 4 – 5, meaning that after completing the 10 repetitions, the athlete can meet moderate resistance throughout the active range of motion, or they could have full function where they can maintain end point range against maximal resistance and the examiner cannot break the athlete’s hold position.¹⁸ This means that the muscle has close to full strength or full strength and function, and capabilities on court would therefore be more dynamic. A total of 125 athletes were assessed and assigned a final class score of 2.0, which accounted for 250 MMT

assessments of the triceps, for both right and left arms of each athlete. From these 250 assessments, 194 (77.6%) were scored within the standardized range for a 2.0 class athlete while 51 (20.4%) were scored below the standard range. Five assessment scores were missing (i.e., not recorded on the classification forms). Figure 4a. represents the summary analysis of the assessed MMT results for the triceps muscle for the 2.0 class.

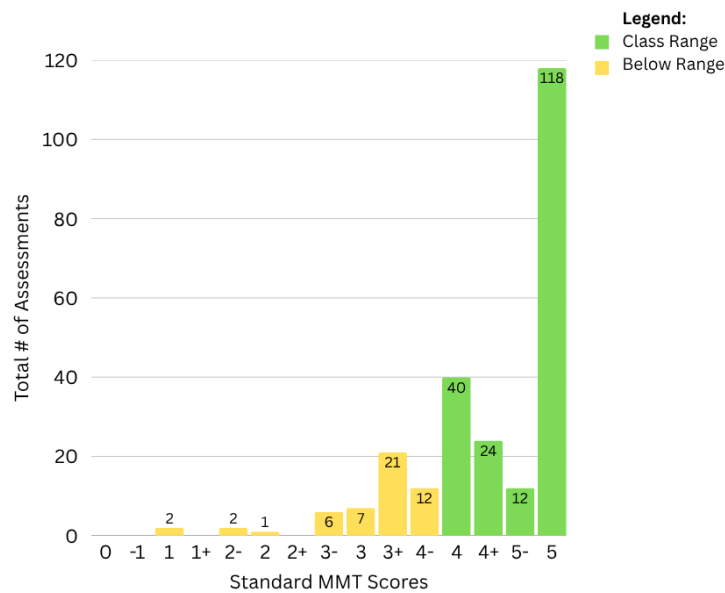


Figure 4a. Breakdown of MMT Triceps Scores for the 2.0 Class:

An athlete with a final class score of 2.5 will have assessed MMT scores for the triceps at a 5, meaning that after completing the ten repetitions, the muscle can meet maximal resistance throughout the active range of motion and they can maintain end point range where the examiner cannot break the athlete’s hold position.¹⁸ This would mean that the muscle has full strength and function, and is valuable on court. Sixty-one athletes were assigned a final class score of 2.5. This accounted for 122 MMT assessments of the triceps muscle, for both right and left arms of each athlete. From these 122 assessments, 72 (59%) were scored within the standardized range

and 48 (39.3%) were scored below. Two assessment scores were missing. Figure 5a, is a summary analysis of the assessed MMT results for the triceps muscle for the 2.5.

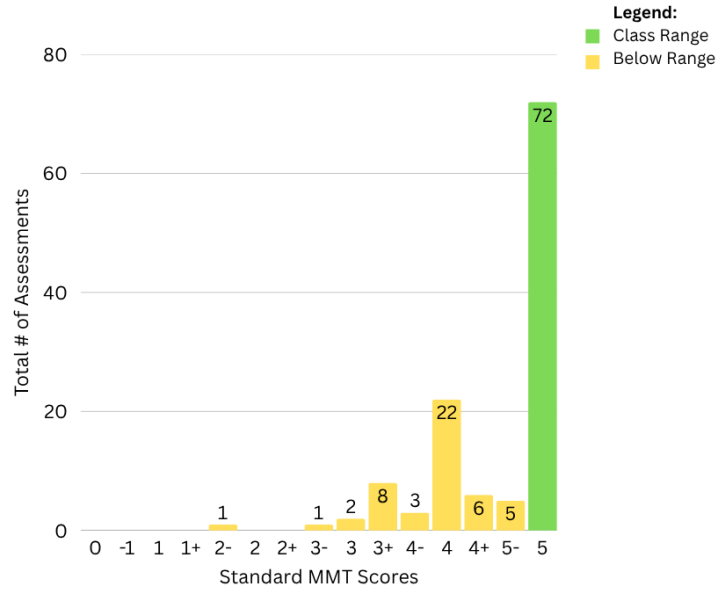


Figure 5a. Breakdown of MMT Triceps Scores for the 2.5 Class:

A summary of all MMT results for the modified triceps test across all classes can be found in Figure 6a. Findings suggest that assessed MMT scores for the triceps muscle frequently do not align with standardized MMT scores for each class as outlined in the IWRF Classification Manual. The greatest discrepancies were found within the 1.5 class, where 75.5% of the assessments did not fall within the range for that class.

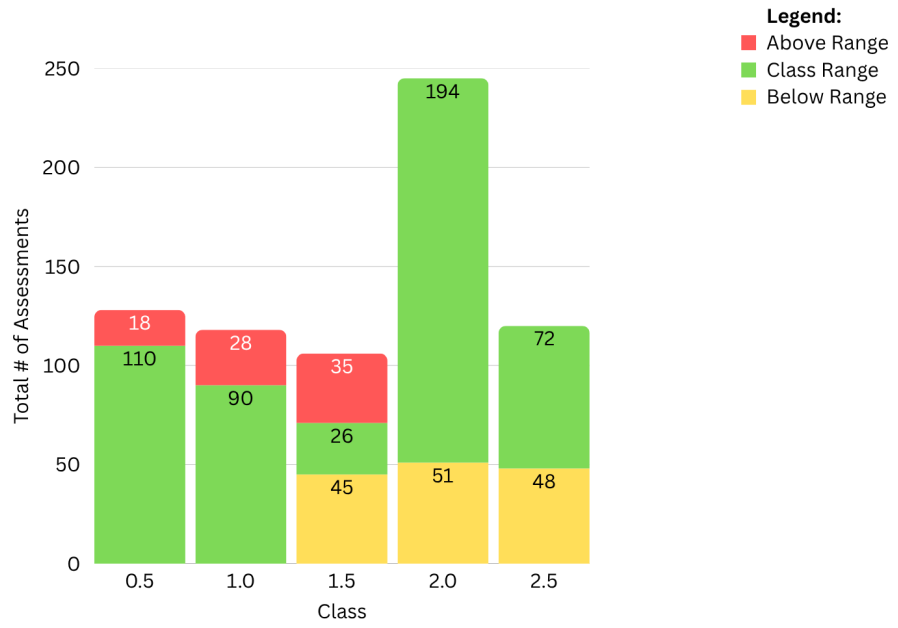


Figure 6a. Summary of MMT Triceps Scores

Chapter 5: Discussion

The overall findings of this study indicate that the triceps MMT scores recorded during classification often differ from the standardized score ranges specified in the IWRP Classification Manual. The most notable inconsistencies were observed in the 1.5 class, where 75.5% of assessments fell outside the expected range. These discrepancies raise questions regarding the evaluations, assessment consistency, and the application of MMT within the classification system. Further explorations into the validity and reliability of MMT within functional classification systems and the modified triceps test is recommended.

MMT Results and Impact on Final Class Outcomes

Sport Class Math

To better understand the results, it is helpful to revisit how sport class scores are determined during the classification process. After completing the bench test, which includes all MMT for both the right and left sides, classifiers assign an upper extremity score to each side. This score is not derived through a fixed calculation but is instead determined by identifying the “best fit” for the athlete’s individual MMT results within the standardized classification scores outlined in the classification manual. It is not expected that every muscle score will align perfectly with a single class, therefore the classifier must use their judgment to decide which class most appropriately reflects the athlete’s overall profile based on the MMT outcomes. While the technical assessment may be used to supplement this decision, it is skill-based and does not influence the MMT scoring. Final classification is determined by averaging the two upper extremity scores and then adding the trunk score (if applicable), which can range from 0 to 1.5. This study focused solely on low and mid-point athletes, as high-point athletes typically score 5/5 for triceps and thus fall outside the scope of this investigation. Conveniently, this also

excludes most athletes with significant trunk function, although a small number of mid-point athletes may still present with some trunk involvement.

This scoring system raises several concerns related to consistency and objectivity. Determining upper extremity scores based on ‘best fit’ introduces a level of subjectivity, particularly when the range of acceptable MMT scores varies across muscle groups. For instance, a latissimus dorsi score of 1/5 could reasonably correspond to a 0.5, 1.0, or 1.5 class athlete, suggesting that this muscle may hold less functional relevance in lower-point classes.^{18,22} This can perhaps assist classifiers in aligning scores for more functionally significant muscles, but when the difference between standardized scoring for some muscle groups is narrow between classes—such as between standardized scores for critical muscle groups—the importance of accurate, objective scoring becomes even more apparent.

The triceps scoring range, in particular, exemplifies the need for clarity or better standardization of the inclusion of a modified MMT/endurance test. According to standardized strength scores, a 0.5 athlete should score between 0–1, a 1.0 athlete between 0–3, a 1.5 between 3+ and 4-, a 2.0 between 4–5, and a 2.5 athlete should score a full 5/5 for triceps.^{18,22} This suggests the triceps muscle may play a more central role in distinguishing between classes as the scoring differences between classes are very small. Scoring accuracy is therefore critical with this particular muscle. There may, therefore, be a need to better delineate which MMT scores are functionally significant in classification, such as the triceps in low and mid-point athletes, and how they correspond with class characteristics and class-specific abilities on court. Incorporating visual tools such as listing these standard scores directly onto classification forms could assist classifiers in identifying best fit more consistently. When the basis for these

decisions is unclear or overly subjective, it becomes challenging to verify, challenge, or protest classification outcomes with confidence or transparency.

Standardized Values and Assessment Accuracy

A closer examination of the MMT scores for the triceps reveals how heavily class distinctions depend on the classifier's precision and consistency during assessment. For athletes in the 0.5 class, triceps scores should fall between 0 and 1, indicating either no detectable muscle function or, at most, a slight flicker of contraction felt during palpation or barely visible to the eye.^{18,22} It is clear that athletes in this class do not have functional triceps use, therefore this muscle does not contribute at all to any on court mechanics. In contrast, a 1.0 class athlete could technically have the same triceps MMT score as a 0.5 athlete if it is between 0-1, however the range in this class is 0-3. At the upper end of this range, a MMT score of 3/5, indicates the athlete can complete the modified triceps test, performing up to 10 elbow extensions through full range of motion without resistance, with -3 being slightly less, completing between 5-10 repetitions.^{18,22} While the muscle is still functionally limited, some movement exists, which may provide minor advantages during gameplay. As reported in Figure 2a, 90 out of 118 scores fell within the standardized range. Within those 90 assessments, 44 (37.3%) scored on the higher end, between -3 and 3, and 28 (23.7%) scored above the standard range. This demonstrates that there is a significant functional difference with this muscle group between the 0.5 and 1.0 classes.

The challenge of precise classification becomes more apparent with 1.5 class athletes. These individuals are expected to score between 3+ and 4- for the triceps muscle. A score of 3+ indicates the athlete can perform the 10 repetitions and then produce some force against minimal resistance, while a 4- suggests the athlete can generate force against moderate resistance,

however, not through the full range.^{18,22} Distinguishing between these two scores hinges on the classifier's ability to detect subtle differences in resistance tolerance, particularly when the athlete is fatigued following repeated movements of elbow extension. This raises important questions about whether the current 10 repetition protocol is sufficient to reveal meaningful endurance-related fatigue, and whether the timing of the test may play a factor—such as conducting it after a training session or game—may unintentionally skew results. Figure 3a shows that only 26 (24.5%) were found to be scored within the standardized range for triceps for a 1.5 class athlete. A total of 75.5% of scores did not fit within the standardized range, where 33% of scores were above range for this class, and 42.5% of scores were below. The above range scores may put the athletes triceps function closer to that of a mid-point class athlete with more offensive capabilities, whereas the below range scores likely put athletes at a competitive disadvantage within this class as their scores are closer to a 1.0 class athlete with increased limitations in functional capacity on court.

For 2.0 class athletes, triceps scores fall between 4- and 5, meaning the difference between a 1.5 and 2.0 athlete may be as subtle as the ability to maintain moderate resistance now through a complete range of motion.^{18,22} These are fine distinctions that rely heavily on the classifier's *subjective* interpretation of resistance and muscle performance. Finally, athletes in the 2.5 class (and beyond into 3.0 and 3.5) are expected to demonstrate full triceps strength with an MMT score of 5/5, indicating normal function.^{18,22} This study's review of these classes demonstrated much greater consistency in the triceps test (Figure 5a), emphasizing the challenges and discrepancies in the lower-mid class categories for the modified triceps test (Figure 6a). These athletes have complete use of their triceps on the court, providing clear functional advantages. Altogether, the small margins separating classes in the 1.5 class in

particular highlight the importance of classifier accuracy, as well as the need to continually evaluate the reliability and context of the current testing protocol.

Overall Impact of Results of MMT Scores for Triceps

This study found that within the 0.5 class, ~83% of the triceps MMT assessments fell within the standardized range, but a meaningful portion (13.6%) scored above that range (Figure 1a). This indicates that a subset of athletes in this class demonstrate greater triceps function than expected, with most of these elevated scores aligning with the 1.0 classification (12.1%). Although this increased function may offer a minor competitive advantage, the on-court impact is likely limited. One hallmark characteristic of the 0.5 class is the presence of a forward head bob during propulsion, which reflects weakness or absence of triceps function in combination with proximal shoulder muscle weakness.¹⁸ While this is primarily assessed during the technical component of classification, sternal pectoral muscle strength is also considered an important factor for this class. Future research may benefit from examining additional muscles or muscle groups to better understand how classifiers make best-fit decisions within this category.

In the 1.0 class, ~76% of assessments were within the standardized range, with nearly a quarter (23.7%) above this range (Figure 2a). Within the above range scores, 12.7% of assessments aligned with the 1.5 class and 11% with the 2.0 class. These elevated scores represent a substantial functional advantage, where athletes in this group may demonstrate the ability to resist force during elbow extension or even exhibit near-complete triceps strength. Such gains can meaningfully enhance push mechanics, speed, agility, and ball control.¹⁸ Given these on-court advantages, the classification of athletes who score above the standard range in this class may warrant further scrutiny, especially in terms of whether their placement truly represents a best fit.

Athletes in the 1.5 class demonstrated the highest degree of variability. Of the analyzed assessments, **only 24.5% fell within the standardized range**, with 33% above range and 42.5% below range (Figure 3). In other words, 75.5% of scores did not align with the standardized expectations. Among these, one-third of athletes presented with near-complete or complete triceps function, which could significantly improve their on-court performance, especially in chair maneuverability, overhead passing, and general offensive capacity. Conversely, athletes who scored below the expected range may struggle to keep pace, experiencing deficits in speed, ball security, and technical skill.¹⁸ This wide distribution in scores highlights a pressing need to explore the reasons behind these inconsistencies. Future research should investigate the accuracy of assessments, consistency of testing protocols, and contextual factors such as fatigue or timing that may influence results.

In the 2.0 class, 77.6% of triceps scores were within the standardized range, while 20.4% were below, indicating that one in five athletes in this category may exhibit insufficient triceps strength relative to their classification (Figure 2a). Reduced triceps function could hinder essential skills such as speed, overhead passing, and ball control, which may limit an athlete's role to more defensive responsibilities or reduce their overall impact during gameplay.¹⁸

For the 2.5 class, 59% of the recorded triceps scores were within the standardized range and 39.3% had scores falling below range. While triceps strength at this level is expected to be full (5/5), many athletes demonstrate some degree of reduced function. In this class, the difference between athletes often comes down to raw strength rather than changes in movement mechanics. Athletes on the lower end of the spectrum may still perform the same skills as those on the higher end, but with less power and endurance. In a highly competitive team sport, these

subtle differences can have a major impact, affecting court positioning, the ability to win contested plays, and maintaining possession.¹⁸

It is important to acknowledge that functional variability exists within every class. Athletes will naturally fall at different points along the scoring spectrum. From a team strategy standpoint, coaches will always prioritize athletes with the highest functional capacity allowed within a class, as this maximizes performance and provides a competitive edge. This creates a complex challenge for classifiers, especially when athletes appear to straddle the boundary between two classes. In such cases, precise, objective, and research-informed assessments are essential to ensure fair and consistent classification outcomes. Based on the result of this study, this is especially true for the 1.5 class of athletes.

Importance of Technical Assessment and On-Court Observations

The technical assessment occurs immediately following the completion of the bench test and serves as a critical component of the classification process. This stage includes both sport-specific and non-sport-specific tasks designed to simulate functional demands in a controlled, non-competitive environment. Athletes are assessed with and without equipment across a range of wheelchair and ball handling activities, allowing classifiers to observe how impairments affect performance.¹⁸ By applying specific conditions and analyzing task execution, classifiers gain valuable insight into how particular functional limitations due to impairments, translate into activity limitations.

This component is particularly valuable because it allows classifiers to control the environment and observe athletes as they repeatedly perform targeted tasks. Repetition can reveal subtle compensatory strategies and inconsistencies in movement that may not be immediately apparent during a single effort. However, this setting does not fully replicate the

intensity or unpredictability of a competitive match. Athletes may not exert maximum effort, and without the pressures of opposition and game speed, some limitations or compensations may be less obvious.

The observation assessment, which takes place during live gameplay, serves as the final and arguably most critical phase of classification. Here, classifiers observe athletes in real-time, under full-speed, competitive conditions. This provides a more authentic view of functional performance and potential impairment-related limitations.¹⁸ This is an uncontrolled setting however, where tasks can occur quickly and without repetition, meaning classifiers must make rapid judgments based on brief moments of observable performance. Furthermore, since classifiers are positioned courtside, their visual perspective can often be limited, affecting their ability to observe mechanics from multiple angles. Observations must occur during pool play games, meaning assessment time is limited. Given these constraints, it is essential that this stage is conducted with a high degree of expertise and confidence.

While video recording is permitted during gameplay, its use in classification is not common, and it is not yet a standard part of the process. Incorporating video analysis could significantly enhance the accuracy and validity of the observation assessment. The ability to replay game sequences, especially in slow motion or from alternative angles, would allow classifiers to more clearly distinguish between functional compensation and true impairment. Given the complexity of movement in wheelchair rugby, the inclusion of video review may serve as a valuable tool to strengthen decision-making during classification.

Recognizing gaps in technical expertise among classification panels, efforts have recently been made to integrate Technical Classifiers into the process. Traditional classifiers are highly trained professionals with medical or health-related backgrounds and are experts in

neuromuscular evaluation. However, they may lack sport specific knowledge and firsthand understanding of the demands of wheelchair rugby. To address this, the International Federation (WWR) has begun piloting the use of Technical Classifiers, who are typically retired athletes, who bring a unique perspective and deeper insight into the tactical and functional aspects of the game. These individuals not only understand the biomechanics and flow of the sport but also offer lived experience of disability. Their inclusion represents a significant and positive step toward enhancing the accuracy, fairness, and validity of the classification process.

Impact of Classification Results on Wheelchair Rugby Programs

Impact on the Team

As noted previously, coaches in wheelchair rugby are consistently seeking to roster athletes with the highest level of functional ability permitted within each class. During games, the combined classification scores of the four athletes on the court must not exceed 8.0 points.^{18,22} While various lineup combinations are possible, some configurations are more strategically advantageous than others. Regardless of specific combinations, coaches strive to maximize performance by selecting athletes who are at the upper functional range of their assigned classes.

Classifications occur during the pool play rounds of competition, and each team is limited to 12 athletes on a roster at each event. When deciding to bring a player who still requires classification to an event, coaching staff often have a strong sense of the likely class outcome. For athletes who appear to be either at the upper limit of one class or the lower limit of another, predicting the final classification can be challenging. The subjective nature of several components of the classification process contributes to this unpredictability. As a result, teams may arrive at a competition with carefully rehearsed lineups, only to have a classification

outcome disrupt those plans. In some cases, an athlete may receive a class that is higher than anticipated, which can significantly alter lineup possibilities. While an athlete on the higher end of function within one class may be strategically valuable, the same athlete classified into a higher class may fall at the lower end of that class's functional range, therefore diminishing their overall contribution in a game. Additionally, this reclassification can potentially eliminate previously planned lineup combinations due to the 8.0 point limit.

Classification outcomes can impact entire teams, as each athlete's class directly affects the construction and flexibility of lineups. An unexpected classification outcome may result in an athlete being incompatible with planned lineups or reduce their strategic value, potentially jeopardizing that athletes place on the roster moving forward. When classification assessments are inaccurate, particularly if an athlete's final class does not reflect their functional performance on court, the consequences are substantial. Inaccurate classifications compromise the fairness and integrity of competition and can have a profound impact on team success, athlete careers, and national performance outcomes. A single poorly assessed MMT score or an incorrectly assigned upper extremity score can derail an athlete's career, damage a team's competitive strategy, and cast doubt on the legitimacy of results. Such misclassifications can also influence funding, affect international rankings, and contribute to mental health challenges for both the misclassified athlete and their teammates.³⁷

When an athlete is assessed as borderline between two classes, classifiers must determine the most appropriate temporary class before the observation component begins. However, because final classification decisions will be made after the athlete has been observed in a game, there is a risk that the temporary classification will not align with their final class. Consequently, an athlete may be playing under a lower or higher classification during the pool play period than

what will be assigned as a final class. This creates a window during which teams may experience a significant advantage or disadvantage. Since classification changes can occur after any pool play game depending on the amount of time observed on court, it is possible that tournament outcomes may be affected by athletes whose classifications are still under observation—particularly when critical games fall within this period.

For this reason, it is essential that classification assessments, including the assignment of temporary classes, are conducted with the highest possible level of precision before an athlete is observed on court. The observation assessment is a vital element of the classification process, but these challenges highlight how significantly MMT outcomes can influence tournament results and competitive equity during this stage.³⁸ Consequently, MMT must be grounded in the most recent, relevant scientific evidence to enable the highest level of objective measurement possible.

Impact on the Athlete

Inaccurate classification assessments can dramatically alter an athlete's role and contribution within a team. An athlete who was once a key performer may suddenly find themselves unable to meet the functional demands of their class, reducing their effectiveness and impact on court. At the Paralympic level, the consequences extend beyond the sport. In many countries, athletes receive financial support through carding programs, which often form a significant portion of their income. Carding can also include additional benefits such as tuition assistance, and access to sport science, medical services, and mental health resources. As such, classification outcomes can directly affect not only an athlete's position on the team but also their overall livelihood and wellbeing. In a team setting, classification changes rarely affect just one person. A single athlete's reclassification can disrupt team dynamics, alter lineup strategies,

and impact the status and roles of other athletes. These significant impacts reinforce the necessity of making classification decisions that are objective, consistent, and supported by research.

Impact on the Sport

When classification systems lack objectivity, they can create unequal opportunities for athletes, making it more difficult for some to succeed while potentially inadvertently favouring certain impairment types. This imbalance risks excluding some athletes altogether or positioning specific disabilities as more advantageous within the sport. Such inequities can lead to decreased participation, as athletes may feel undervalued or perceive the system as unfair. Furthermore, when trust in the classification process is lost, there is a greater risk of athletes attempting to manipulate outcomes, such as through sandbagging during evaluations by hiding functional capabilities. Although classification systems have evolved significantly with many improvements made to enhance objectivity and fairness, continued progress is essential. Strengthening the integrity and transparency of classification not only upholds the values of the IPC, but also helps build trust among athletes and enhances the sport's reputation on the global stage.

Critical Gaps in Valid and Reliable Classification Measures

Objectivity in Functional Sport-Specific Classification Systems

Paralympic classification has evolved significantly, transitioning from a medical model which categorized athletes based primarily on their diagnosis or type of disability, to a more functional, sport-specific model. This shift considers not only an athlete's health condition, but also their ability to perform key movements and tasks within the context of their sport. By

focusing on function rather than diagnosis, this approach aims to reduce the impact of impairment on the outcome of competition and encourages broader participation, allowing athletes with varying degrees of impairment to compete alongside one another.¹⁰.

While the move toward a functional classification system represents progress, achieving full objectivity remains a significant challenge. Despite efforts to refine classification protocols, subjective elements persist. Manual muscle testing (MMT), for example, is influenced by clinician judgment and athlete effort, and upper extremity scores are based on a “best fit” rather than exact metrics. Observational assessments during competition can also be affected by a range of contextual variables, including the level of opposition, game intensity, and athlete engagement, all of which may influence the extent to which an athlete’s true functional abilities are demonstrated.

Although the classification system has been repeatedly revised to improve objectivity and fairness, it is widely recognized that complete objectivity may be unattainable. Continued efforts to make positive change are necessary to enhance the reliability and validity of classification outcomes and to uphold the integrity of competition.

Classifier Training and Technical Expertise

Accuracy in both the bench test and technical assessment components of the classification process is essential, as athletes are assigned a temporary sport class based on these assessments and are then subsequently evaluated during competition. In wheelchair rugby, efforts have been made to reduce subjectivity in manual muscle testing (MMT) by ensuring that all classifiers refer to the same resource, the Daniels and Worthingham method, for procedures and testing protocols. Given that classifiers often come from a variety of professional

backgrounds, this shared reference promotes greater consistency in testing positions and techniques, however, additional measures could further enhance this consistency. For instance, ensuring that all classifiers are thoroughly trained in the exact testing procedures and addressing discrepancies between the classification manual and the textbook—such as variations in how individual muscles versus muscle groups are assessed, or the use of plus and minus grading—could provide much-needed clarity. Improved training, accountability, and standardization in these areas would help minimize subjectivity and contribute to more valid classification outcomes.

The inclusion of Technical Classifiers, particularly retired athletes, represents a valuable and underutilized resource that should become routine moving forward. As more athletes retire from high-performance competition, there is an opportunity to engage individuals who possess deep sport-specific knowledge and a lived experience of disability. Retired coaches may also serve as strong candidates for this role, offering complementary expertise. Their involvement could help advance the technical assessment component, which currently includes a suggested list of chair and ball handling skills outlined in the classification manual. Formalizing these skill assessments and integrating consistent tools such as video recordings could support a more objective and reproducible approach.

Representation of persons with disabilities in leadership roles, such as classifiers, coaches, and decision-makers remains limited in high-performance sport. This lack of inclusion can contribute to the marginalization of athletes with disabilities when it comes to professional opportunities in sport governance and development. The International Paralympic Committee Strategic Plan 2015–2018 highlights the need to promote representation and strengthen the involvement of individuals with disabilities in leadership positions as a key priority for the

growth and integrity of the Paralympic Movement.³⁶ Including retired athletes in roles such as classification not only enhances technical expertise but also provides a first-person perspective that can drive more equitable and informed decisions, representing a meaningful step toward inclusion and sustainability in the classification system.

Timing of Classification Assessments

In wheelchair rugby, classification assessments are typically conducted one to two days prior to the start of competition. This timeline allows for both the bench test and technical assessment components to be completed ahead of time so that the athlete's first appearance during gameplay can serve as the observation assessment. Given that classification in the Paralympic version of the sport can take place at any sanctioned event, including many major international competitions, the accuracy of classification outcomes carries high stakes. Inaccurate classifications not only affect competitive equity but may also influence the outcome of entire tournaments.

Mirroring trends in health care, where assessments are increasingly based on the evaluation of competencies over time rather than single point-in-time evaluations, wheelchair rugby has adopted a longitudinal approach to achieving class confirmation. Specifically, athletes must undergo three separate assessments, each at least 11 months apart, that all result in the same class assignment in order to receive a confirmed class status. While this model supports a more reliable assessment of athlete function, it also highlights the importance of initial accuracy. Athletes continue to compete under their most recent assigned class until reassessment, which may occur much later than the 11-month minimum. As a result, an inaccurate initial classification could provide an athlete and team with an unintended advantage or disadvantage for a prolonged period.

Currently, the time allocated for the bench test and technical assessment is approximately one hour. For athletes whose impairment profile clearly aligns with a specific class, this may be sufficient. However, in more complex cases, athletes may need to return for further assessment. While classifiers do receive medical documentation in advance, allowing them to gain some background on an athlete's condition, one hour offers only a narrow window to perform detailed assessments that carry significant competitive implications. Extending the assessment period, particularly for the MMT component, could allow more time for confirming proper testing positions and enhance reliability. In some cases, involving multiple classifiers in conducting the MMT could also strengthen inter-rater consistency and reduce subjectivity. While logistical constraints such as the travel schedules of teams and the workload of classifiers pose challenges, an expansion of assessment duration may offer a worthwhile return in improving classification accuracy and fairness.

Testing Conditions

A notable gap in the current wheelchair rugby classification system is the lack of documentation and formal consideration of testing conditions during athlete evaluations. This omission raises important concerns, particularly in relation to the modified triceps test, where fatigue and muscular endurance may significantly influence performance outcomes.

During the bench test component, testing conditions can vary widely. For instance, was manual muscle testing (MMT) conducted first thing in the morning when the athlete was rested, or after a demanding training session or scrimmage? Did the athlete have to push a considerable distance to the venue, or did they have transport? These seemingly minor variables can introduce inconsistency in results, especially in a test like the triceps assessment, where fatigue may affect muscular endurance. An athlete who is already fatigued at the time of testing may

underperform compared to their actual functional capacity, potentially resulting in a lower classification. In contrast, an athlete assessed under optimal conditions where they are rested, alert, and physically fresh, may yield more accurate results. Without recording and accounting for these contextual details, interpretation of MMT outcomes, particularly those with an endurance component like the modified triceps test, may lack reliability and validity.

The importance of testing conditions also extends to the observation assessment. Factors such as the quality of the opposing team, the level of competition (e.g., a top-tier international tournament versus a regional event), the number of minutes an athlete is on court, and how long an athlete was observed for on court all influence how fully an athlete's functional capacity is demonstrated. Without this contextual information, classification outcomes may not reflect an athlete's true performance potential.

Additionally, some athletes may be asked to undergo further testing following on-court observation to clarify inconsistencies between earlier bench tests and game performance. If this additional testing occurs after a game however, when the athlete is already fatigued, the results may not be directly comparable to the conditions of the first assessment. In cases where scores differ, questions arise: should the post-game results be accepted as definitive, or should re-evaluation under consistent conditions be required to confirm accuracy? Incorporating formal consideration of testing conditions at both the initial assessment and during any follow-up testing may offer a pathway to enhancing the reliability and validity of classification outcomes, particularly with tests like the modified triceps assessment where performance is sensitive to physical fatigue.

Efficacy of Modified Triceps Test

Given the findings of this study and the previously outlined concerns around objectivity, there is a clear need to further evaluate the effectiveness of the modified triceps test. Although the test was introduced with the positive goal of incorporating a sport-specific element into the assessment of this key muscle group, its development was not based on objective data or supported by scientific validation. To determine whether the test achieves its intended purpose, further research is needed to evaluate both its structure and outcomes. For instance, it is still uncertain whether performing ten repetitions of elbow extension before applying manual resistance effectively measures triceps endurance, or whether this method accurately mirrors the movement patterns of the sport.

If research confirms that the current design of the test is effective, it could provide a rationale for modifying other muscle assessments to better reflect sport-specific demands. However, without strong supporting evidence, making similar changes to additional tests would be premature and potentially unjustified. Conversely, if the current format of ten repetitions is shown not to effectively represent triceps endurance or functional relevance in sport, alternative strategies should be explored. This could involve adjusting the number of repetitions, revisiting the use of the standard MMT as outlined in Daniels and Worthingham, or further modifying the procedure to improve alignment with observed sport demands. Additionally, including clear and detailed positioning guidelines for this modified triceps test within the classification manual to mirror the level of specificity found in Daniels and Worthingham would help enhance consistency and reduce variability between classifiers.

Ultimately, classification processes are intended to provide structure and ensure that the degree of impairment an athlete presents is meaningfully related to their sport performance.¹¹

The IPC mandates that classification systems developed by International Sport Federations include objective, reliable, and sport-specific measures of impairment.¹⁴ Given the importance of triceps function for low and mid point athletes in wheelchair rugby, further efforts to validate this modified test are essential to uphold the integrity, fairness, and accuracy of the classification system.

Research Implications

The reliability of strength testing methods has been a popular topic of research in various populations, but research on para athletes is very limited.¹⁸ In 2011, the IPC published a position statement to further progress the development of classification systems which advocated for the development of classification systems in Paralympic sport that are evidence-based. To achieve this requires that sports identify eligible types of severities of impairment, along with valid tests of impairment and ensure that relationships are established to sport-specific measures of performance.¹⁶ This study focused on classification assessments that were completed from 1992 to 2019.

The goal of this study was to positively contribute and spark interest for further research in the area of classification in the sport of wheelchair rugby, and present further topics for potential investigation. To our knowledge, this is the first study evaluating classification scores of the triceps test in wheelchair rugby specifically.

Chapter 6: Limitations, Future Directions, and Conclusions

Study Limitations

While there were several noteworthy results from this study, there were some limitations to the design and analyses. First, this study utilized historical data from the Canadian Classification Database for wheelchair rugby, analyzing a total of 492 classification assessments conducted on a total of 283 Canadian athletes between 1992 and 2019. Assessments completed after 2019 were excluded, as revisions to the classification manual were introduced to align with the updated Classification Code, which came into effect on January 1, 2020.²²

Although the changes implemented in 2020 are not expected to significantly alter the findings of this study, their inclusion may have introduced new or additional inconsistencies in data interpretation and comparison. To maintain clarity and analytical consistency, a decision was made to limit the dataset to assessments completed under the same classification framework.

While the Canadian data provides valuable insights, especially given Canada's long-standing involvement in the sport, it may not fully reflect the diversity of the international athlete population. Countries with more or less established wheelchair rugby programs, and varying athlete pool sizes, may exhibit different trends. For a more representative understanding of global classification patterns, future research should consider using a larger dataset, such as the International Classification Database for wheelchair rugby.

Future Directions

Based on the findings of this investigation, several important considerations emerge for future directions in Paralympic classification research and practice. First, there is a clear need for evidence-based validation of modified MMT procedures, particularly those that have been adapted for use in classification but not yet formally studied. For example, the modified triceps

test, developed to capture sport-specific demands in wheelchair rugby, has theoretical and clinical relevance but has not yet been validated through empirical research. To ensure fair and accurate classification, future research must rigorously evaluate the reliability, validity, and applicability of such modified tests within para athlete populations, rather than relying on protocols designed for non-disabled individuals.

In addition to refining impairment assessment tools, research should also explore more effective ways to evaluate muscle function during sport-specific tasks. Current systems may benefit from a more integrated approach that includes greater contributions from Technical Classifiers, particularly those with sport experience as retired athletes, coaches, or classifiers with diverse professional backgrounds such as Athletic Therapists, Biomechanists, and Kinesiologists. These individuals bring unique insight into the mechanics and functional demands of the sport, which can enrich the accuracy and context of classification decisions. To support this approach, the sport may consider the implementation of using game film, allowing classifiers to review athlete performance using slow-motion or multi-angle replays. A split-second action viewed from a single angle can significantly influence classification outcomes, highlighting the need for objective, repeatable review tools in the decision-making process. Further investment in classifier training specific to the sport context would also enhance inter-rater reliability and consistency across events.

The field of classification research is showing positive momentum and continued development. Recent updates to classification manuals are beginning to incorporate more detailed breakdowns of MMT procedures and impairment-specific scoring, providing clearer guidelines for assessing different types of impairment. For instance, current manuals now

outline differentiated strength expectations for various muscle groups depending on the nature and level of neurological injury, which helps reduce ambiguity in scoring.

Nevertheless, it is important to acknowledge that no classification system will ever be perfect, given the inherent variability and complexity of para sport. Factors such as fatigue, training adaptations, equipment variability, and health fluctuations all influence functional performance in ways that are difficult to fully control. However, because classification outcomes have profound effects on athletes, teams, and the broader parasport ecosystem, it is essential that decisions are as accurate, transparent, and evidence-based as possible. Any proposed changes to classification processes must be grounded in research and involve input from all relevant stakeholders—including classifiers, athletes, coaches, and support personnel—rather than implementing modifications prior to scientific validation. Only through collaborative, data-driven processes can classification continue to evolve in a way that is fair, functional, and athlete-centered.

Conclusions

This study highlighted critical inconsistencies in manual muscle testing (MMT) outcomes for triceps function among low and mid point wheelchair rugby athletes, raising concerns about the objectivity and reliability of classification outcomes. While 0.5 class athletes generally aligned with expected MMT ranges, a notable proportion scored above standardized range, suggesting potential misclassifications. The 1.0 and 1.5 classes exhibited the greatest variability, with over 75% of 1.5 class triceps scores falling outside the standardized range which could allow some athletes to compete with more functional capacity than intended, while others may be unfairly limited. These findings emphasize the need for enhanced precision in classification protocols, especially where small score differences define sport class boundaries.^{18,22}

Although the modified triceps test is designed to reflect sport-specific demands, it has not been empirically validated, casting doubt on its reliability in assessing true functional capacity and endurance. Its results may be influenced by contextual variables such as fatigue and testing conditions, making consistent interpretation more challenging for classifiers.^{18,22}

Additional concerns emerged related to the timing and conditions under which classification assessments are conducted, the inherent subjectivity in assigning ‘best fit’ classes, and the limited integration of objective tools like video analysis. Enhancing classifier expertise through further education, the routine inclusion of Technical Classifiers, and formalized sport-specific skill assessments could improve classification consistency and better reflect functional performance in competition.^{37,38} Any errors in classification, especially at the high performance level, can have significant consequences, disrupting team strategies, altering athlete roles, and directly impacting athlete livelihoods and team programs.

Ultimately, the findings highlight a pressing need to further refine the classification system by strengthening classifier training, enhancing standardization, and rigorously evaluating assessment tools—especially the modified triceps test—through empirical research to maintain fairness, validity, and an athlete-centered approach.^{11,14,36}

References

1. Houlihan B, Chapman P. Talent identification and development in elite youth disability sport. *Sport in Society*. 2017;20(1):107-125. Doi: <http://dx.doi.org/10.1080/17430437.2015.1124566>
2. Canadian Paralympic Committee. History of the paralympic movement in Canada. Paralympic.ca. Published n.d. Accessed December 6, 2024. <https://paralympic.ca/about/history-of-the-paralympic-movement-in-canada/#>
3. Bailey S. *Athlete First: A History of the Paralympic Movement*. Chichester, UK: John Wiley & Sons, Ltd; 2008. ISBN: 978-0-470-05824-4.
4. International Paralympic Committee. Paris 2024 set for record Paralympic coverage. Paralympic.org. Published August 28, 2024. Accessed December 6, 2024. <https://www.paralympic.org/paris-2024/news/new-record-paralympic-coverage>
5. Dehghansai N, Lemez S, Wattie N, & Baker J. A systematic review of influences on development of athletes with disabilities. *Adapted Physical Activity Quarterly*. 2017;34:72-90. Doi: <https://doi.org/10.1123/APAQ.2016-0030>
6. International Paralympic Committee. IPC classification. Paralympic.org. Published n.d. Accessed December 6, 2024. <https://www.paralympic.org/classification>
7. International Paralympic Committee. About the International Paralympic Committee. Paralympic.org. Published n.d. Accessed June 13th, 2025. <https://www.paralympic.org/ipc/who-we-are>
8. International Paralympic Committee. Strategic Plan 2023-2026l Paralympic.org. Published March 2nd, 2023. Accessed June 13th, 2025. https://www.paralympic.org/sites/default/files/2023-03/2023_01%20Strategic%20Plan_ACC.pdf
9. Beckman EM, Connick MJ, Tweedy SM. Assessing muscle strength for the purpose of classification in Paralympic sport: A review and recommendations. *Journal of Science and Medicine in Sport*. 2017;20:391-396
10. Tweedy, SM. Taxonomic theory and the ICF: foundations for a unified disability athletics classification. *Adapted Physical Activity Quarterly*. 2002;19(2):220-237
11. International Paralympic Committee. Classification code. Paralympic.org. Published n.d. Accessed December 6, 2024. <https://www.paralympic.org/classification-code>
12. Tweedy SM, Vanlandewijck YC. International Paralympic Committee position stand—background and scientific principles of classification in Paralympic sport. *British Journal of Sports Medicine*. 2011;45(4):259-269. doi:10.1136/bjism.2009.065060

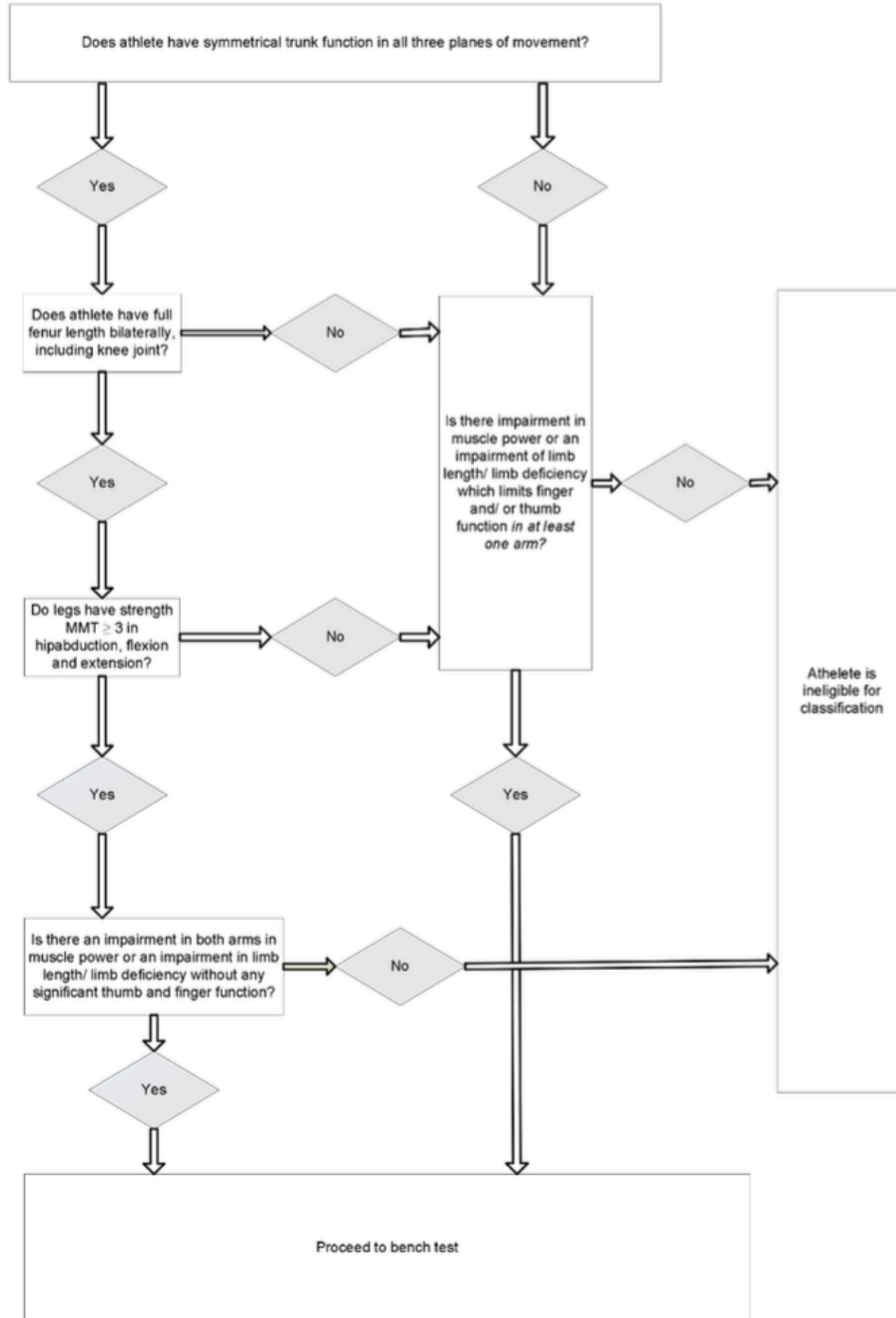
13. Burns J. Disability, classification and the Paralympics: inclusion and exclusion of elite athletes with disabilities. In: Chatziefstathiou D, García B, Séguin B, eds. *Routledge Handbook of the Olympic and Paralympic Games*. 1st ed. Routledge; 2021:Chapter 3.
14. Hutchinson MJ, Phillips JK, Mason BS, Goosey-Tolfrey VL, Beckman EM. Measures of impairment applicable to the classification of Paralympic athletes competing in wheelchair sports: a systematic review of validity, reliability and associations with performance. *Journal of Sports Sciences*. 2021;39:40-61. doi:10.1080/02640414.2020.1815957
15. Altmann VC, Janssen M, de Wit JIJ, van der Slikke RMA. Standardised activities in wheelchair rugby: comparison between athletes with coordination impairment and athletes with other impairments. *Frontiers in Sports and Active Living*. 2025;doi:10.3389/fspor.2024.1519232.
16. Mason, BS, Altmann, VC, Hutchinson MJ, Goosey-Tolfrey VL. Validity and reliability of isometric tests for the evidence-based assessment of arm strength impairment in wheelchair rugby classification. *Journal of Science and Medicine in Sport*. 2020(23):559-563
17. Wheelchair Rugby Canada. About the sport. Wheelchairrugby.ca. Published n.d. Accessed December 6, 2024. <https://wheelchairrugby.ca/the-sport/>
18. International Wheelchair Rugby Federation. IWRF classification manual 3rd edition revised. IWRF.com. Published 2015. Accessed December 6, 2024. [https://www.iwrf.com/resources/iwrf_docs?IWRF_Classification_Manual_3rd_Edition_rev-2015_\(English\).pdf](https://www.iwrf.com/resources/iwrf_docs?IWRF_Classification_Manual_3rd_Edition_rev-2015_(English).pdf)
19. World Wheelchair Rugby. Classification Resources. Worldwheelchair.rugby. Published n.d. Accessed December 6, 2024. <https://worldwheelchair.rugby/classification-resources/>
20. Canadian Paralympic Committee. Wheelchair Rugby. Paralympic.ca. Published n.d. Accessed July 13th, 2025. <https://paralympic.ca/sport/wheelchair-rugby/>
21. World Wheelchair Rugby. International Rules for the Sport of Wheelchair Rugby. Worldwheelchair.rugby. Published January, 2025. Accessed July 13th, 2025. <https://worldwheelchair.rugby/wp-content/uploads/2025/02/241223-Wheelchair-Rugby-International-Rules-WWR-FINAL.pdf>
22. International Wheelchair Rugby Federation. IWRF classification manual 4th edition revised. IWRF.com. Published 2021. Accessed December 6, 2024. [https://www.iwrf.com/resources/iwrf_docs?IWRF_Classification_Manual_4th_Edition_rev-2021_\(English\).pdf](https://www.iwrf.com/resources/iwrf_docs?IWRF_Classification_Manual_4th_Edition_rev-2021_(English).pdf)
23. Spathis JG, Connick MJ, Beckman EM, Newcombe PA, Tweedy SM. Reliability and validity of a talent identification test battery for seated and standing paralympic throws. *Journal of Sport Science*. 2025;33(8):863-71. Doi: 10.1080/02640414.2014.969294

24. Quinn LO, Bruce LM, Young CM. The impact of Wheelchair Rugby classification lineup structure on possession outcome. *Journal of Science and Medicine in Sport*. 2024;(27):493-498
25. Avers D, Brown M. 10th ed. Daniels and worthingham's muscle testing: Techniques of manual examination and performance testing. Elsevier; 2019
26. Beckman EM, Newcombe P, Vanlandewijck Y, Connick MJ, Tweedy SM. Novel strength test battery to permit evidence-based Paralympic classification. *Medicine (Baltimore)*. 2014;93(4)
27. van Niekerk Y. The intra- and inter-rater reliability of manual muscle testing in the new hand classification of wheelchair rugby [master's thesis]. Pretoria, South Africa: University of Pretoria; 2017.
28. O'Connor SR, Fagher K, Williamson S, Plum BM, Ardern CL, Janse van Rensburg DC, Heron N. Assessment of muscle strength in para-athletes: A systematic review of observational studies. *Sports Medicine and Health Science*. 2022;(4):225-238
29. Tweedy SM, Williams G, Bourke J. Selecting and modifying methods of manual muscle testing for classification in Paralympic sport. *EUJAPA*. 2011;3(2): 7-16.
30. Cuthbert SC, Goodheart GJ. On the reliability and validity of manual muscle testing: A literature review. *Chiropr Osteopat*. 2007;15(4).
31. Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. Muscles: testing and function with posture and pain. Lippincott Williams and Wilkins, 2005.
32. Borren GL, Gooch SD, Ingram B, Jenkins A, Dunn J. Classification efficiency in wheelchair rugby: throwing analysis. In: Proceedings of the 19th World Congress of the International Federation of Automatic Control; August 24-29, 2014; Cape Town, South Africa.
33. Kenneth S. Saladin. *Anatomy & Physiology: The Unity of Form and Function 10th Ed*. McGraw-Hill, 2024.
34. Rhodes JM, Mason BS, Malone LA, Goosey-Tolfrey VL. Effect of team rank and player classification on activity profiles of elite wheelchair rugby players. *Journal of Sports Sciences*. 2015;33(19):2070-2078. doi:10.1080/02640414.2015.1028087
35. Haydon DS, Pindoe RA, Grimshaw P, Robertson WSP. Propulsion in elite low-point classification rugby wheelchair athletes. Presented at: 34th International Conference on Biomechanics in Sports; July 18–22, 2016; Tsukuba, Japan. University of Adelaide; Australian Paralympic Committee.
36. Mauerberg-deCastro E, Campbell DF, Tavares CP. The global reality of the Paralympic Movement: challenges and opportunities in disability sports. *Motriz: Rev Educ Fis*. 2016;22(3):111-123. doi:10.1590/S1980-6574201600030001

37. Makitov AA, Vanlandewijck YC, McNamee MJ. Intentional misrepresentation of abilities in Paralympic sport: a conceptual, ethical and legal analysis. *Sports, Ethics and Philosophy*. Published online December 11, 2024. doi:10.1080/17511321.2024.2432950

Appendix A

Eligibility test for classification in wheelchair rugby^{18,22}



Appendix C

Standardized Manual Muscle Testing Scores^{18,22}

Manual Muscle Test Scores and Upper Extremity Point Values

0.5 Point Deltoid Latissimus Clavicular Pectoralis Sternal Pectoralis Biceps Triceps Wrist extensors Wrist flexors Remaining hand muscles	0-5 0-1 0-5 0-1 0-5 0-1 0-5 0-1 0	1.0 Point Latissimus Clavicular Pectoralis Sternal Pectoralis Biceps Triceps Wrist extensors Wrist flexors Remaining hand muscles	0-3 5 0-3 5 0-3 0-5 0-3 0-1
<i>Characteristics of 0.5</i> are triceps 0-1 and shoulder girdle weakness, sternal pectoralis and latissimus weakness; possible weak shoulder rotation, with limited range; and possible clavicular pectoralis weakness.		<i>Characteristics of 1.0</i> are normal strength of deltoid muscles and clavicular pectoralis fibres with overall stronger proximal muscles than 0.5. Still has proximal weakness throughout shoulder girdle. Both sternal pectoralis AND latissimus should be 3 or less. May have 0 triceps with stronger proximal muscles.	
1.5 Point Latissimus Sternal Pectoralis Triceps Wrist extensors Wrist flexors	0-3 0-3 3+– 4- 4-5 0-3	<i>Characteristics of 1.5</i> are remaining weakness of proximal muscles such as latissimus or sternal pectoralis in combination with stronger triceps and wrist muscles compared to 1.0. Either sternal pectoralis OR latissimus should be 3 or less. If there is no proximal weakness but triceps are 3+ or 4-, beware of non-neurologic weakness.	
2.0 Point Shoulder girdle muscles Biceps Triceps Wrist extensors Wrist flexors Finger flexors and extensors Intrinsic Thumb movements	5 5 4–5 4–5 4–5 0-2 0 0-2	2.5 Point Shoulder girdle muscles Biceps Triceps Wrist extensors and flexors Finger flexors and extensors Finger adductors and abductors Thumb extensor and flexor Thumb opponens, adductor and abductor Finger flexion in the MCP joints	5 5 5 4-5 3-4 0-2 3-5 0-2 0-2
<i>Characteristics of 2.0</i> are normal strength in the shoulders and chest, good to normal triceps, and strong, balanced wrist extension and flexion strength.		<i>Characteristics of 2.5</i> are limited hand function with a curling and uncurling of the hand and not functional grasp and release. The curling and uncurling motion results from action of the finger flexor muscles without the stabilizing effect of the intrinsic muscles.	
3.0 Point Shoulder girdle muscles Biceps Triceps Wrist extensors and flexors Finger flexors and extensors Finger adductors and abductors Thumb flexor, extensor Thumb abductor, adductor, opponens Finger flexion in the MCP joints	5 5 5 4-5 3-5 0-4 3-5 0-4 0-4	<i>Characteristics of 3.0</i> are functional grasp and release (opening and closing) but grip strength is impaired because of less than normal strength in intrinsic and/or thumb abduction and opposition. Atrophy is present in the hands at the thenar and hypothenar eminences. Also, interossei and lumbrical muscle weakness causes decreased maintenance of the hand arches and indicates significant hand weakness and muscle strength of less than 4–5. A value of 3 or more for interossei and/or thumb opposition and/or abduction usually excludes a hand from 2.5 and indicates a 3.0.	
3.5 Point Muscle tests of bilateral hands and arms with uniform strength of 4-5 in ALL muscle groups may indicate ineligibility (see eligibility test, Appendix A). A classifier should not determine arm value on muscle tests alone, but consider activity limitation of the entire extremity. Skill level, equipment, athletic ability or training effects should NOT be considered in the allocation of sport class.			

Appendix D

Characteristics of Sport Classes¹⁸

Examples of Functional Characteristics for Wheelchair Rugby Classes

Class	Typical On Court Role	Chair Activities/Function	Ball Activities/Function
0.5	Main role is as blocker, not a major ball handler	<ul style="list-style-type: none"> • Because of extensive proximal shoulder weakness and lack of triceps function forward head bob present when pushing • Because of lack of triceps, pulls on back part of the wheel for push stroke using biceps by bending elbows; elbows are also out to side when pushing (called an "unopposed biceps push") • Because of wrist extensor weakness and lack of other wrist and hand function, may use forearm on wheel for starts, turns and stops 	<ul style="list-style-type: none"> ▪ Because of proximal shoulder weakness, arm and wrist weakness, traps direct passes on lap or bats it in from limited range ▪ Bats ball using "underhand volleyball pass" for longer range pass or for shorter range pass uses "scoop pass" with the ball forward to the side uses a two-hand toss
1.0	Blocker, may in-bound ball, not a major ball handler	<ul style="list-style-type: none"> ▪ Because of proximal shoulder weakness and triceps weakness, may have slight head bob when pushing, but has a longer push on wheel (combination of push and pull on back part of wheel) ▪ Because of increased strength in upper chest and shoulders, multidirectional start, stop and turn (Can turn in all directions without stopping; easier and faster turning than 0.5 athlete; but because of triceps and wrist weakness, 1.0 athlete may still use forearm) 	<ul style="list-style-type: none"> ▪ Forearm or wrist catch ▪ Weak chest pass or forearm pass

Class	Typical On Court Role	Chair Activities/Function	Ball Activities/Function
1.5	Excellent blocker and also may be occasional ball handler	<ul style="list-style-type: none"> ▪ Increased shoulder strength and stability allows for more effective and efficient pushing (including starts and stops) and ball handling activities 	<ul style="list-style-type: none"> ▪ Increased shoulder strength and stability allows for increased pushing speed, ability to hold ball out in front of chair and increased distance and consistency to chest pass ▪ Typically has wrist imbalance that causes limited ball security when passing ▪ May have asymmetry present in arms. If so, predominantly uses the stronger arm for chair and ball activities ▪ Has ability to perform a one handed pass but with poor control, accuracy and distance—rarely see on court during challenge but may test during classification. If used, more often used for in-bounding
2.0	Increasing role on court as ball handler	<ul style="list-style-type: none"> ▪ Typically has very strong and stable shoulder that allows for excellent quick stops and starts and good pushing speed on court 	<ul style="list-style-type: none"> ▪ Effective chest pass with control over moderate distance ▪ Because of lack of finger flexion, there is limited ball security against defence during passing ▪ Can hold the ball with wrists firmly, but does not have hand function. ▪ Weak one-hand overhead pass with limited control and distance (occasionally see on court during challenge, but may test during classification)

Class	Typical On Court Role	Chair Activities/Function	Ball Activities/Function
2.5	Ball handler and fairly fast playmaker	<ul style="list-style-type: none"> ▪ Because of excellent shoulder strength and stability will see good pushing speed on court ▪ Functional grip is used to advantage on the push rim when challenged ▪ May have some trunk control giving better stability in the chair 	<ul style="list-style-type: none"> ▪ Reasonably balanced finger flexion and extension without true grasp and release ▪ Dribbles the ball safely, but supinates forearm to scoop the ball onto the lap. ▪ Due to finger flexion strength capable of performing one-handed overhead pass, but limited accuracy and distance because of imbalance in finger strength ▪ Safe two handed catching of passes, usually scooping ball to lap. May catch passes single handed and scoop to lap or chest ▪ Improved ball security in challenge situations compared to 2.0 hands due to improved ability to isolate wrist/finger function. ▪ May have asymmetrical arm or hand function, noticeable with chair and ball handling activities

Appendix E

Eligible Impairment Types in the Paralympic Movement²²

Impairment Type:	Description:
Impaired Muscle Power	Athletes with Impaired Muscle Power have a Health Condition that either reduces or eliminates their ability to voluntarily contract their muscles in order to move or to generate force. Examples of an Underlying Health Condition that may lead to Impaired Muscle Power include spinal cord injury (complete or incomplete, tetra-or paraplegia or paraparesis), muscular dystrophy, post-polio syndrome and spina bifida.
Impaired Passive Range of Movement	Athletes with Impaired Passive Range of Movement have a restriction or a lack of passive movement in one or more joints. Examples of an Underlying Health Condition that may lead to Impaired Passive Range of Movement include arthrogryposis and contracture resulting from chronic joint immobilization or trauma affecting a joint.
Limb Deficiency	Athletes with Limb Deficiency have total or partial absence of bones or joints as a consequence of trauma (for example traumatic amputation), illness (for example amputation due to bone cancer) or congenital limb deficiency (for example dysmelia).
Leg Length Difference	Athletes with Leg Length Difference have a difference in the length of their legs as a result of a disturbance of limb growth, or as a result of trauma.
Short Stature	Athletes with Short Stature have a reduced length in the bones of the upper limbs, lower limbs and/or trunk. Examples of an Underlying Health Condition that may lead to Short Stature include achondroplasia, growth hormone dysfunction, and osteogenesis imperfecta.
Hypertonia	Athletes with Hypertonia have an increase in muscle tension and a reduced ability of a muscle to stretch caused by damage to the central nervous system. Examples of an Underlying Health Condition that may lead to Hypertonia include cerebral palsy, traumatic brain injury and stroke.
Ataxia	Athletes with Ataxia have uncoordinated movements caused by damage to the central nervous system. Examples of an Underlying Health Condition that may lead to Ataxia include cerebral palsy, traumatic brain injury, stroke and multiple sclerosis.
Athetosis	Athletes with Athetosis have continual slow involuntary movements. Examples of an Underlying Health Condition that may lead to Athetosis include cerebral palsy, traumatic brain injury and stroke.
Vision Impairment	Athletes with Vision Impairment have reduced, or no vision caused by damage to the eye structure, optical nerves or optical pathways, or visual cortex of the brain. Examples of an Underlying Health Condition that may lead to Vision Impairment include retinitis pigmentosa and diabetic retinopathy.
Intellectual Impairment	Athletes with an Intellectual Impairment have a restriction in intellectual functioning and adaptive behaviour in which affects conceptual, social and practical adaptive skills required for everyday life. This impairment must be present before the age of 18.