THE INTRA-AND INTER-RATER RELIABILITY OF MANUAL MUSCLE TESTING IN THE NEW HAND CLASSIFICATION OF WHEELCHAIR RUGBY

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ABSTRACT

Introduction:

Before 2015 the hand classification in wheelchair rugby consisted of non-sport specific tests. The hand classification was not in accordance with the classification code introduced by the International Paralympic Committee in 2003. In 2015, the newly revised wheelchair rugby classification manual was released, containing the revised wheelchair rugby hand classification. Hand tests that were not functional sport-specific tests were removed from the bench test in wheelchair rugby classification. Lumbrical, interossei and thumb opposition manual muscle testing were added to the bench test in wheelchair rugby classification.

On both national and international levels of classification, classifiers verbalised their uncertainty to their fellow panel members regarding their hand placement on the athlete's hand and interpretation of the manual muscle testing of the hand that was observed and tested. This justified reliability testing of the new hand classification.

Aim:

The aim of this study was to determine the intra and inter-rater reliability of the manual muscle testing in the new hand classification of wheelchair rugby.

Study design:

This study followed a quantitative non-experimental, cross-sectional design.

Method:

The raters who took part in the study were active international wheelchair rugby classifiers from all over the world. The raters received an electronic questionnaire consisting of biographic information and three videos repeated two times. Each video showed an athlete's hand being classified by a classifier. The raters had to give a manual muscle test grade for each subject (muscle) tested in each video by using tick boxes. The manual muscle test grades that could be given were: 0-1, 2, 3 and 4-5. The

first three raters in each international wheelchair rugby classification level who completed the questionnaire were used for the data analysis.

Data Analysis:

The statistician used the two way model for the ICC in which each subject was rated by the same raters to determine the absolute agreement for each objective. The Medcalc program was used. To indicate the strength of agreement the ranges provided by Landis and Koch (1977) were used: 0.0 – 0.2 slight, 0.21 – 0.4 fair, 0.41 – 0.6 moderate, 0.61 – 0.8 substantial and 0.81 – 1.00 almost perfect.

Conclusion:

Raters one, two, five, seven, eight and nine's intraclass correlation coefficient values fell between 0.81-1.00 which is descriptive of almost perfect levels of intra-rater reliability. Raters three, four and six's intraclass correlation coefficient values fell between 0.61-0.80 which is descriptive of substantial levels of intra-rater reliability. However, none of the raters scored 100% when accuracy was determined. All three levels had intraclass correlation coefficient values which is descriptive of almost perfect levels of intra-rater reliability within each level.

Level 2, 3 and 4 classifiers had intraclass correlation coefficient values between 0.81-1.00 which is descriptive of almost perfect levels of inter-rater reliability when the manual muscle testing grades for the first and repeated videos were compared. Across all nine raters there was a high intraclass correlation coefficient value which was descriptive of almost perfect inter-rater reliability. The accuracy in each level and across all nine raters was low.

Finger extensors, thumb abductor and thumb flexor showed intraclass correlation coefficient values between 0.41-0.6 which is descriptive of moderate levels of intra-rater reliability. The only subjects (muscles) that were graded accurately when compared to a memorandum were subjects with a manual muscle test grade 0-1 and 4-5. Most of the accurate manual muscle test grades were for athlete two in the video footage. Athlete two was classified as having a 2.0 hand.

Keywords:

Classification, Paralympic sports, wheelchair rugby, manual muscle testing, Paralympic athletes, evidence-based practice, intrinsic muscles of the hand, extrinsic muscles of the hand, validity and reliability.

DEFINITION OF KEY TERMS

Key term	Definition
Classifier	A physical therapist, occupational therapist or physician, or anyone with formal training in neuromuscular evaluation, who has undergone training in WCRC.[1]
Classification	According to the IWRF website[2] "*The purpose of classification is to ensure fair and equitable competition at all levels of sport and to allow athletes to compete at the highest level, regardless of individual differences in physical function".*[2, 3]
National classifier	This level of classifier can only classify within his or her country of certification and not at an international level. They complete a basic formal workshop supervised by an IWRF international classifier level 3 or 4.[1]
International classifier	This level of classifier can classify on an international level. An international classifier can be a level 2, 3 or 4 depending on the degree of accreditation and level of evaluation passed. The international classifiers are evaluated after each tournament by the panel that they classified with.[1]
Active classifier	Classifiers registered at the IWRF who attend at least one international tournament every two years.
Inactive classifier	Classifiers registered at the IWRF who attended less than one international tournament every two years.
New hand classification 2015	Manual muscle testing of intrinsic and extrinsic muscles of the hand. The following are tested according to the wheelchair

	rugby classification form: finger extension, finger flexors, interossei, lumbricals, thumb abductor, thumb adductor, thumb extensor, thumb flexor and thumb opponens.[1]
Hand classification before 2015	The previous hand classification consisted of nine functional sub-tests that were not related to WCR e.g. clawing of the hand, piano playing and picking up coins.
Extrinsic muscles of the hand	Muscles that have their origin outside of the hand and insertion in the hand.[4] Extensor carpi radialis longus, extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, extensor carpi ulnaris, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, extensor indicis, flexor carpi ulnaris, palmaris longus, flexor carpi radialis, flexor digitorum profundus, flexor digitoruim superficialis, and flexor pollicis longus.[5]
Intrinsic muscles of the hand	Muscles that have their origin and insertion in the hand.[4] Lumbricals, opponens digiti minimi, flexor digiti minimi brevis, interossei, adductor pollicis, abductor pollicis brevis and opponens pollicis.[5]
Interossei muscles	Muscles that form part of the intrinsic muscles of the hand.[4]
Manual muscle testing	Includes accurate measurement of strength within the context of functional tasks and movement.[6]
Wheelchair Rugby	According to the IWRF website *"WCR is a team sport for male and female tetraplegic athletes. It is an invasion and evasion game, the object being to carry the ball across the opposing team's goal line to score points".*[2]

Spinal cord injury	It is an insult to the spinal cord resulting in a change, either temporary or permanent, in the cord's normal motor, sensory, or autonomic function. Spinal cord lesions will produce tetraplegia or paraplegia depending on the level of damage.[6]
Rater	A level 2, 3 or 4 international wheelchair rugby classifier who took part in the study and completed the questionnaire.
Inter-rater reliability	Inter rater reliability is concerned with the reproducibility of measurements by different raters. [13-18]
Intra-rater reliability	Intra-rater reliability is concerned with the self-reproducibility of the rater.[7]
Intra-class correlation coefficient	" The measure of the reliability of measurements or ratings".[8, 9]
Accuracy	The percentage score that the raters correctly graded the subjects (muscles) when compared to a memorandum, thus the correct score divided by the number of subjects (muscles) graded.
Single measures	The ICC for one single rater.[8, 9]
Average measures	The ICC for different raters averaged together.[8, 9]

LIST OF ABBREVIATIONS

Abbreviation	Meaning
EBP	Evidence-based practice
HPCSA	Health Professions Council of South Africa
ICC	Intraclass correlation coefficient
ICF	International Classification of Functioning, Disability and Health
IOC	International Olympic Committee
IPC	International Paralympic Committee
IWRF	International Wheelchair Rugby Federation
MMT	Manual Muscle Testing
MRC	Medical Research Council
ROM	Range of Motion
SA	South Africa
WCR	Wheelchair Rugby
WCRC	Wheelchair Rugby Classification

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“What lies behind us

and what lies before us

are tiny matters

compared to what lies within us”.

-Ralph Waldo Emerson

CHAPTER ONE – INTRODUCTION

1.1 INTRODUCTION

Wheelchair rugby (WCR) was originally developed in 1977 as a sport for people with tetraplegia due to spinal cord injury.[2, 10-12] The sport quickly evolved to include people with other conditions, such as neuromuscular and orthopedic conditions affecting the function of at least three of the four limbs.[2, 10-12]

Wheelchair rugby is played by both genders and combines elements of rugby, basketball and handball. Players play in a manual wheelchair specifically made for WCR. Teams can include up to 12 athletes but only four compete at a time. The main purpose is to carry the ball across the opposing team's goal line. Contact between wheelchairs to block and hold opponents is encouraged. The ball used in WCR is a soft, covered volleyball and can be passed, dribbled or bounced to team members.[2] During the game the ball must be bounced once every ten seconds. To be able to play WCR, players must meet the minimum disability criteria and be classifiable (eligible) under the sport classification rules[2] (see ANNEXURE A: Eligibility test for classification in wheelchair rugby).[1]

Classification in Paralympic sport has existed since the origin of WCR,[2] the goal being to promote participation and avoid predictable outcomes of competitions. Classifiers first determine the eligibility of athletes and then group eligible athletes in terms of severity of impairment. There are seven sports classes, ranging from 0.5 (most impaired) to 3.5 (least impaired) at 0.5 intervals.[1, 2, 11] During competition a maximum of 8.0 points can be represented on the court at any time.[1, 2] This ensures that there are athletes with different functional levels on the court. WCR's specific classification system comprises three distinct stages: 1) physical assessment or bench test; 2) technical assessment (including a range of sport-specific, functional activity tests and novel non-sport tests); and 3) observation assessment (observation of sport-specific activities on court)[1, 2] (see ANNEXURE B: Athlete classification pathway).[1] The physical assessment or bench test of the hand and the trunk[1, 11] is conducted during the first stage of wheelchair rugby classification (WCRC). During this assessment classifiers make use of manual muscle testing (MMT) of selected muscles in the upper limb to determine muscle strength. Wheelchair rugby specifies that WCRC relies on Daniels and Worthingham's system of MMT[1] to ensure that all raters use the same method for MMT; thus the interpretation of MMT should be uniform for all WCR classifiers.[13] Wheelchair rugby classification is one of a few Paralympic sports that specify which MMT should be used during classification. Classifiers hail from all over the world and all have different training backgrounds. Standardisation of assessment methods is thus vital to minimise potential sources of intra- and inter-panel variability in classification.

Before 2015, scores in the classification manual for WCR hand function could be 2.0, 2.5, 3.0 or 4.0 (normal hand). Should the classification panel be unsure as to whether an athlete had a 3.0 or a 4.0 score, nine further hand tests could be used to reach a decision (see ANNEXURE C: Hand classification before 2015 in WCR).[1] These tests covered a variety of Daniels and Worthingham's MMT, sport-specific and novel activities. In each hand test the athlete could score 1.0, 0.5 or 0.0. The classification panel calculated the total point value by adding the scores for each hand muscle function test. A sum score of 1.0 to 8.0 points indicated a 3.0 hand and a sum score of 8.5 to 9.0 points indicated a 4.0 hand.[1, 2]

In a conversation with Altman, PhD (August 2013) a level 4 WCR classifier (see ANNEXURE D: Classifier certification criteria)[1] at the 2013 European Championships, she proposed that there were three reasons for the hand classification in WCR needing revision: 1) commitment to the IPC after signing the classification code in 2007 with a clear distinction between MMT and activities testing; 2) current WCR hand tests were not being applied and interpreted in the same way by all WCR classifiers; and 3) there was a large gap in point value between the hand class with a slight impairment (3.0 hand) and the hand class with minimum to no impairment (4.0 hand), which did not reflect the impact on activity limitation.

In the new hand classification (introduced in 2015) there are no separate hand tests. Hand tests that were not functional sport-specific tests (e.g. clawing of the hand, piano playing and picking up coins) were removed. Lumbrical, interossei and thumb opposition MMT were added to the physical assessment and observation of wasting was no longer a separate test. The sub-tests of palming the ball overhead and "walking" the ball up the wheel, were added to the off-court, sport-specific, functional activities testing. The scoring for hand classification in WCR is currently: normal intrinsic and extrinsic muscle function (3.5 hand); limited intrinsic muscle function and normal extrinsic muscle function (3.0 hand); absent intrinsic muscle function and normal extrinsic muscle function (2.5 hand); and absent intrinsic and extrinsic muscle function (2.0 hand)[1] (see ANNEXURE E: New hand classification in WCR).[1]

Technical assessment and observational assessment are conducted by WCR classifiers to verify the results of the physical assessment. All the information gathered during the WCRC for an athlete is recorded on the IWRF classification form and stored in a database (see ANNEXURE F: IWRF classification form).[1]

The International Paralympic committee (IPC) adopted the research paper by Tweedy and Vanlandewijck as the standard reference for the position statement on background and scientific rationale for classification in Paralympic sport.[14] According to Tweedy and Vanlandewijck [13(p. 10)] "*MMT grades can have a profound impact on classification outcomes*". The class to which an athlete is assigned can influence his/her degree of success, which in turn has an impact on self-esteem and self-perception, peer and community recognition, as well as access to sponsorship and other financial rewards. For these reasons, inconsistency should be minimised. This is one of the reasons why it is stated in the WCR classification manual that WCR classification should use Daniels and Worthingham's MMT.[1]

1.2 PROBLEM STATEMENT

Classification in wheelchair rugby must be based on evidence according to the IPC classification code. The reliability and validity in the use of MMT for patients with neuromuscular dysfunction is good.[5, 15] In wheelchair rugby it is specified that Daniels and Worthingham's MMT[1] be used during the physical assessment. The new hand classification, introduced in 2015, is based on scientific evidence by eliminating irrelevant sub-tests and adding Daniels and Worthingham's MMT of specific muscles to the physical assessment.

The researcher has observed the new hand classification on national and international levels, at both of which classifiers expressed uncertainty to their fellow panel members regarding their hand placement on the athlete's hand and interpretation of the Daniels and Worthingham's MMT of the hand that was observed. An important aspect that adds to classifiers' confusion is that in WCRC, finger and wrist movements are tested as a whole movement (as indicated by Daniels and Worthingham MMT), e.g. wrist extension and not each individual muscle (extensor carpi radialis longus, extensor carpi radialis brevis and extensor carpi ulnaris); contrary to what classifiers would do in practice. The intra-rater and inter-rater reliability of the new hand classification in WCR thus seems to be questionable due to inconsistency among classifiers.

1.3 RESEARCH QUESTION

What is the intra-and inter-rater reliability of MMT in the new hand classification of WCR?

1.4 AIM

To determine the intra-and inter-rater reliability of MMT in the new hand classification of WCR.

1.5 OBJECTIVES

The following objectives were derived from the research aim:

1. To determine the intra-rater reliability of each classifier regarding MMT outcome.
2. To compare the intra-rater reliability between classifier level 2, level 3 and level 4 regarding MMT outcome.
3. To determine the inter-rater reliability within each classifier level regarding MMT outcome.
4. To compare the inter-rater reliability across all classifiers regarding MMT outcome.

5. To determine the accuracy of Daniels and Worthingham MMT grades for the new hand classification in WCR.

1.6 IMPORTANCE AND BENEFITS OF THE STUDY

This study will: 1) contribute in transforming WCRC from an expert opinion-based system to an evidence-based system; 2) make classifiers aware of how Daniels and Worthingham's MMT is executed and interpreted (this has a large effect on determining sport class for an athlete); 3) improve the confidence of athletes and coaches in the classification system by transforming WCRC from an expert opinion-based system to an evidence-based system; 4) improve the knowledge of current WCR classifiers by making them aware of the importance of intra-and inter-rater reliability; 5) supply information that can form the basis for another study in WCRC through providing evidence-based information to influence training and 6) improve the knowledge of occupational therapist working in hand therapy on MMT.

1.7 DELIMITATIONS AND ASSUMPTIONS

Delimitations

The researcher set the following boundaries:

- The researcher did not determine the intra-and inter-rater reliability of the second and third stage in WCRC which is the assessment of off-court activities and observational assessment during games. The focus of the study is on Daniels and Worthingham's MMT of the hand during the physical assessment.

- The researcher only examined the intra-and inter-rater reliability of the intrinsic and extrinsic muscles of the hand and not the complete upper limb tested during the physical assessment. This is due to the fact that the hand classification was added to the original test and the main area of concern for the classifiers was the new hand classification.

- Wheelchair rugby was developed for people with spinal cord injuries. The video footage in the simulated assessment therefore only contain hand classifications of athletes with less than normal muscle strength values due to complete or incomplete spinal cord injury, although WCR is played by athletes with various other conditions.

Assumptions

The researcher assumed the following:

- Hand classification will continue to be crucial in WCRC, due to the eligibility criteria of WCR.
- All classifiers were able to read and write English as first or second language (this is a prerequisite in WCRC).
- Even though the classifiers had varied training they would still be able to apply Daniels and Worthingham's MMT, as this is required for the physical assessment in WCRC.

CHAPTER TWO - LITERATURE REVIEW

2.1 REVIEW METHODOLOGY

The database search for literature included Medline, PubMed and Google Scholar to access full text articles through the University of Pretoria library service from 17 May 2016 to 24 June 2016. The literature review consists of recent articles (not older than ten years) and older articles (older than ten years) due to a lack of relevant current research. Informal searches were also conducted and include international presentations and unpublished research on the changes in the new hand classification for WCR. Key words used included: *Classification, Paralympic sports, wheelchair rugby, manual muscle testing, Paralympic athletes, evidence-based practice, classification in wheelchair rugby, history of Paralympic sport, intrinsic muscles of the hand, extrinsic muscles of the hand, validity and reliability and- Daniels and Worthingham's MMT, Medical research council (MRC) MMT.*

Inclusion criteria for the literature search were the following: articles published from 2006 to 2016, articles relevant to Paralympic classification, MMT of the hands and upper limb and articles with sufficient data for applicability.

Exclusion criteria were the following: articles older than ten years and articles that had no relevance to the study.

2.2 INTRODUCTION

To fully grasp the concept of Paralympic sport, the importance of classification and WCR, the literature review first focussed on the history and impact of Paralympic sport, classification in Paralympic sport past to present, evidence-based classification and WCR. Current research, description and concepts of validity reliability, anatomy of the hand. MMT was clarified and described before looking at classification in WCR, the new hand classification in WCR and lastly the patient becoming the athlete.

2.3 HISTORY AND IMPACT OF PARALYMPIC SPORT

The term Paralympic sport (combination of paraplegic and Olympic) was a confronting term to Olympian traditions where excellence and perfectly formed bodies were celebrated. Over time the term was reinterpreted to 'Paralympics' derived from the Greek preposition 'para', meaning 'beside' or 'alongside'. Paralympics are thus viewed as games parallel to the Olympics, existing side-by-side with the event commonly viewed as the 'World games'.[16]

In 1888 the first Sports Club for the Deaf was founded in Berlin and led to the establishment of national sports federations for the deaf in Belgium, Czechoslovakia, France, Great Britain, the Netherlands and Poland in 1924. In 1924 these six federations sent 140 athletes to Paris to participate in the First International Silent Games. The Deaflympics was born. The Deaflympics retained a separate existence from the movement that would create the Paralympics.[16]

The Paralympics stemmed from the treatment of spinal cord injured servicemen at the end of World War II.[19-17] Ludwig Guttmann was a Jewish neurosurgeon, who arrived in Britain as a refugee from Germany in 1939. After several research positions, Guttmann became director of what would become the National Spinal Injuries Centre at Stoke Mandeville Hospital (Aylesbury, Buckinghamshire). Guttmann postulated that paraplegia was the 'most neglected and depressing subject in all medicine'. He believed that sport was a pathway that might help even severely disabled people to live a healthier, happier life, to gain confidence and self-esteem and to achieve a degree of independence. He established a sports festival for people with disabilities to promote contact with other people with disabilities and address attitudes about capabilities of the disabled.[16]

On 28 July 1948, an archery competition took place on the front lawns of the hospital where Guttmann was stationed, involving 16 competitors arranged into two teams.[16, 18] This event was held on the same day as the opening ceremony of the Olympics,[16, 17] and was called the Stoke Mandeville Games.[14] In 1949 they hosted a larger competition with 60 competitors. In 1952, another Olympic year yet again, a group of

Dutch war veterans joined the movement and the International Stoke Mandeville Games were founded.[14, 16, 19] The war veterans called for wider European participation and in 1953 teams from Finland, France, Israel, the Netherlands and Canada joined the games. In 1955 the United States of America participated for the first time and in 1957 Australia. During this time the games gained the nickname "Paralympics". Over time there was a shift from sport being used for therapeutic purposes to development of training and fitness programmes to promote the health and well-being of people with disabilities.

In 1959 the International Stoke Mandeville Games Committee was established to address the demands for greater professionalism, funding and management of international sport for the disabled.[16, 18] In 1960 the first Paralympic games took place in Rome, Italy featuring 400 athletes from 23 countries, and continued to take place every four years.[14, 19] In 1984 the first International Olympic Committee (IOC) recognised Paralympics was held in America (New York) and Stoke Mandeville (the latter due to withdrawal of funds from the University of Illinois). In 1982 the International Coordinating Committee of the World Sports Organisations was established after the need to coordinate activities and eliminate duplication of events required further institutional arrangements. This brought together the four major International sports organisations: the International Stoke Mandeville Wheelchair Sports Federation, the International Blind Sports Federation, the Cerebral Palsy International Sport and Recreation Association and the International Sports Organization for the Disabled. This resulted in sports for people with disabilities having a single voice for the first time.[16] The geographical convergence of the summer games at Seoul in 1988 and the winter games at Albertville in 1992 were finally achieved. [14, 16]

The Paralympic games continued to grow and received their own custom-designed opening and closing ceremony. The final stage in the evolution of the institutional basis for the games came with the establishment of the International Paralympic Committee (IPC) in 1989. They serve as the umbrella body for 162 National Paralympic committees, five regional bodies and four international disability-specific sports federations. They also act as the international federation for 13 of the 24 Paralympic sports. The IOC and IPC clarified their relationship in 2000 and 2006 by signing agreements and co-opting the IPC president to the IOC and including an IPC representative on 11 of the IOC commissions. The IOC also pays an annual subvention towards the IPC. In June 2001 an agreement was signed that the Paralympic Games will always be at the same location as the Olympic host city and would take place shortly after the Olympic Games using the same facilities and venues.[16] Countries now bid for the right to host the Olympics and Paralympics based on a series of economic, environmental and social justifications.[18] Table 2.1 shows all the sports governed by the IPC and its member federations.

Table 2.1: Sports governed by the IPC and its member federations as of January 2009

Sports governed by IPC	**Sports governed by IPC member federations**			
	IOSDs		**International Federation Sports**	
	Sports	**Organisation**	**Sport**	**Organisation**
Alpine skiing (W)	Boccia	CPISRA	Archery	Fédération international de Tir à l'Arc
Athletics	Football 5-a-side	IBSA	Cycling	Union cycliste internationale
Ice sledge hockey (W)	Football 7-a-side	CPISRA	Equestrian	International equestrian federation
Nordic skiing (biathlon and cross-country skiing)	Goalball	IBSA	Rowling	International rowing federation
Powerlifting	Judo	IBSA	Sailing	International foundation for disabled sailing
Shooting	Wheel-chair fencing	IWAS	Table tennis	International table tennis federation
Swimming	Wheel-chair rugby	IWRF	Volleyball (sitting)	World organisation for volleyball for disabled
Wheelchair dance sport			Wheelchair basketball	International wheelchair basketball federation
			Wheelchair tennis	International tennis federation
			Wheelchair curling (W)	World curling federation

In 2002 the IOC required host cities to undertake a comprehensive longitudinal study to measure the economic, social and environmental impact of the games. The one that was prominent was the economic benefits which can be attained through improved tourism, external investment and infrastructure.[18] The Paralympics challenged existing ways of thinking about sport and disability. It played a major part in changing attitudes by emphasising achievement rather than impairment. They accelerated the agenda of inclusion and helped to promote the concept of a barrier-free environment within town planning and architectural discourse. The biggest impact was made on the parts of the world where disability was ideologically problematic, forcing changes in official attitudes, if only to accommodate international opinion in order to win the bidding process to hold the event. According to John Gold and Margaret Gold, the Paralympics have raised the status of disabled sport to the point where participants earn esteem as athletes in their own right, thereby challenging prevailing assumptions and stereotypes about 'disability'.[16] Athletes with disabilities are seen as heroes and show determination in a new light. On more than one occasion WCR athletes also verbalised the above mentioned and added how WCR "gave me my life back". In the documentary entitled: Murderball (where WCR was seen for the bone-jarring full contact sport it is) the sport is depicted as a community, *" in which one senses as being one's own — as both mine and ours and yours, as ours rather than theirs"*.[20]

2.4 WHEELCHAIR RUGBY

Wheelchair rugby is one of the fastest growing wheelchair sports in the world.[21] WCR was originally developed in 1977 as a sport for people with tetraplegia due to spinal cord injury and as a recreational outlet.[2, 21, 22] The sport quickly evolved to include people with other health conditions, such as neuromuscular conditions and orthopedic conditions affecting the function of at least three of the four limbs.[2, 12] WCR is a sport for male and female athletes. [3, 28, 29]

Wheelchair rugby combines elements of rugby, basketball and handball. It consists of four eight-minute quarters. Wheelchair rugby is played on an indoor wooden surface (15m x 28m).[22, 23] The ball used in WCR is a soft covered volleyball and can be passed, dribbled or bounced to team members.[2, 24] Wheelchair rugby players play in a manual wheelchair specifically made for WCR.[2, 22, 23] The main purpose is to carry the ball across the opposing team's goal line, marked with two cones. Contact between wheelchairs is allowed; it is an essential element of the game which allows players to block and hold opponents.[2, 22, 24] The clock starts once the ball is in play, the team then has 40 seconds to score a goal otherwise they concede possession.[23] During the game the ball must be bounced once every ten seconds. To be able to play WCR, players must meet the minimum disability criteria and be classifiable under the sport classification rules.[2, 12] All athletes in wheelchair rugby are held to the same classification system [21] which results in the wide range of athletes with different disabilities in each class. WCR athletes are classified into seven classes ranging from 0.5 (most impaired) to 3.5 (least impaired). Two teams compete against each other on court.[22, 24] Teams can comprise up to 12 athletes but only four compete on court at a time. The four players on court each has a different classification ranging from 0.5 (most impaired) to 3.5 (least impaired). The total classification value of the four players on court cannot exceed eight.[23] In 2000 WCR became a full medal sport at the Sydney 2000 Paralympics Games.[2, 22]

New rules of WCR were introduced after the Beijing 2008 Paralympics.[2] The new rules stipulate that 1) the team has 12 seconds to advance the ball from their back court into the front court (15 seconds according to the old rules), 2) a team in possession of the ball has 40 seconds to score a point or concede possession. (There are no such stipulations in the old regulations). These new rules are controversial due to the risk that low-point class players might not be able to take active part in offensive play within the designated limit of 40 seconds. This led to an increase in popularity of WCR low-point tournaments. Low-point tournaments are when athletes with a low-point classification, 0.5, 1.0 and 1.5, compete against each other. In low-point tournaments, the total classification value on court of all players cannot exceed three and a half points, contrary to eight points in a full tournament. Wheelchair rugb is one of the fastest growing sports in the world, causing a rise in requests from athletes who have too much function to compete in WCR, to have a 4-point tournament. An athlete who is classified as a 4-point athlete is seen as too strong to compete against athletes classed in one of the other seven classes. A reliable classification system is thus important to make sure that athletes are classified according to their potential so that fair competition is assured.

2.5 CLASSIFICATION IN PARALYMPIC SPORTS PAST TO PRESENT

Classification in Paralympic sports is required when a group of athletes want to compete in the same event/sport, but some have more function than others, so the athletes are classified/grouped together on the basis of observable properties that they have in common.[25, 26] Classification in sport reduces the likelihood of one-sided competition and in this way promotes participation.[25, 26] Paralympic classification systems aim to promote participation in sport by people with disabilities, by controlling the impact of impairment on the outcome of competitions.[25]

In 1940 Dr Ludwig Guttmann described Paralympic sport as an extension of the rehabilitation process. In 1950 impairment-based classification was introduced when higher and lower spinal cord lesions were separated to ensure equal competition in sport. There were separate classes for people with spinal cord injuries, amputations and other neurological or orthopaedic conditions. Athletes were thus classified according to their medical diagnoses, into classes that covered all the relevant sports. Thus, paraplegics and double amputees would not compete against each other.[12, 26]

In 1980 the focus switched from rehabilitation to sport.[3] The Games organising committees demanded a reduction in the number of sport classes in various sports and classification transformed into functional classification (excluding visual impairment, which still remains medically based).[12, 26] The main factors that determine class in sport-specific classification are how much an athlete's impairment impacts on sport performance. Now a person with paraplegia and a person who has bilateral leg amputations can compete against each other despite having different medical diagnoses. Functional classification is sport-specific because any given impairment may have a significant impact in one sport and a relatively minor impact in another. For example, the impact of a below-elbow arm amputation in swimming is greater than in running.[12, 26] In 1989 an agreement stipulating that all sports at the Games were to be conducted using sport-specific functional classification systems was signed. When this decision was made, many sports had not yet introduced functional classification systems and due to the short timeframe and absence of relevant scientific evidence, the classification systems developed were based on expert opinions.[12, 26]

In 2003 the IPC governing board approved a classification strategy. This classification strategy focuses on three primary elements: 1) the classification code; 2) international standards to supplement the classification code; and 3) models of best practice.[12] The Paralympics Movement approved the IPC Classification Code in November 2007, which defines Paralympics Classification as *"accurate, reliable and consistent sport-focused classification systems".*[26] It further states that the Paralympics Movement is committed to the development of evidence-based classification systems.

The IPC classification code helps to support and co-ordinate the development and implementation of accurate, reliable and consistent sport-focused classification systems. Adherence to the international standards is mandatory for compliance with the code. The classification code applies to all sports within the Paralympics Movement, and compliance is monitored by the IPC Classification Committee.[12, 25] The IPC Classification Code requires all classification systems to: 1) identify eligible impairments for that particular sport; and 2) describe methods for assessment of athletes so that the impact of the impairment on the activity is proven.[12] These methods should be based on evidence.

2.6 EVIDENCE-BASED CLASSIFICATION

To understand evidence-based classification one should first look at evidence-based practice. Evidence-based practice (EBP) is the procedure where clinicians incorporate clinical expertise, research evidence and patient values into therapy, resulting in the most appropriate and efficient services to their patients.[27] The process of an EBP has five steps: 1) the development of a clinical question; 2) assimilation of the best available evidence in order to answer the question; 3) systematic and critical appraisal of this evidence; 4) applying this evidence to a clinical problem; and 5) evaluation and revision of the previous steps in the process and identifying any areas of change for future applications.[27]

An evidence-based classification system is one in which scientific evidence indicates that the methods used for assessing impairments and assigning class will result in classes that are made up of athletes who have impairments that cause approximately the same amount of difficulty in a given sport.[12, 25] The IPC adopted the research paper *"IPC Position Stand – Background and Scientific Rationale for Classification in Paralympics Sport"* from Tweedy and Vanlandewijck as the standard reference for evidence-based classification.[26] The implementation of sport-specific classification systems must match the principles explained therein. Methods used to assess and classify impairments should be reliable and based on research. This approach is called an evidence-based system of classifications. Tweedy and Vanlandewijck state that, to promote participation of people with disabilities, one has to minimise the impact of impairment on the outcome of the competition. Describing eligibility criteria in terms of type of impairment and severity of impairment, and describing methods for classifying eligible impairments according to the extent of activity limitation they cause, are two ways of minimising the impact of impairment on the outcome of the competition.[13]

According to Tweedy and Vanlandewijck development of evidence-based methods requires the following four steps: [25]

<u>Stage one: Identification of eligible impairments</u>

The first stage is when the classifiers establish whether the athlete has a health condition that will lead to eligibility for the specific sport the athlete wants to pursue.[25] This process might be straightforward at times e.g. amputation, but if athletes present with complicated or unclear cases they have to submit detailed documentation and relevant test results to the relevant governing body. This will assist the classifiers in determining whether the athlete is eligible for a specific sport.[25]

In wheelchair rugby there is an eligibility test for classification in WCR (see Annexure A: eligibility test for classification in WCR) that needs to be followed according to a flowchart to determine if the athlete is eligible and can undergo the physical assessment/ bench test. During the physical assessment/bench test there is still the possibility to be found ineligible for wheelchair rugby.[1]

<u>Stage two: Development and evaluation of valid measures of impairment</u>

Valid measurements of impairment consist of MMT of the upper limb and trunk testing which is essential in playing wheelchair rugby.

Stage three: Development and evaluation of valid measures of sport-specific performance

In WCR, this consists of the off-court functional assessment that consist of ball skills and chair skills needed to play wheelchair rugby.

Stage four: Assessment of the relative strength of association between measures of impairment and sports performance[25]

As a last step, in the third stage, the athlete is observed in competition (Tweedy & Bourke, 2009). In WCRC the athlete is observed on court. Functional skills observed on court are then compared to the physical assessment/bench test and off-court functional assessment.

Then, a key purpose of the classification process is to minimise the impact of the impairment on the outcome of competition. Then, impairment is the unit of classification, and the basis of the ICF and the IPC position regarding classification is to classify impairments according to how much they affect the core activities of the sport or activity limitation.

Functional system classification is sport-specific. This is due to the fact that a physical impairment that can have a minor impact on one sport and a major impact on another as mentioned above at point 2.4.[28]

There are still some sports that use other classification systems e.g. classification for athletes with visual impairments remain medically based, and powerlifting and judo are organised by weight and sex classification criteria.[28]

One of the most important classification systems that contribute towards adapted physical activity and provide a standard language and framework for the description of health-related states, is the International Classification of Functioning, Disability and Health (ICF).[28] The ICF is a multipurpose classification tool/process intended for a wide range of uses in different sectors, from sanitary and healthcare services to Paralympic sport.[26] The ICF changed the understanding of health and disability. The ICF (classification process) evaluates what a person with a health condition can do in a standard environment (their level of capacity), as well as what they actually do in their usual environment (their level of performance). These areas are classified from body, individual and societal perspectives by using two lists: a list of body functions and structures and a list of domains of activity and participation. When the ICF uses the term 'functioning', it refers to all body functions, activities and participation; thus, what the athlete can do. The term 'disability' looks at impairments, activity limitations and participation restrictions; thus, what the athlete cannot do. The ICF made the shift to focus on the person's level of health, what the athlete can do, and not disabilities, i.e. what the athlete cannot do.[28]

In summary: The Paralympics Movement is committed to the development of evidence-based classification systems. Tests used during classification should thus be reliable and valid to comply with the classification code.

2.7 THE CONCEPT OF VALIDITY AND RELIABILITY

Validity is the extent to which an instrument measures what it purports to measure. It requires an instrument to be reliable, although an instrument can be reliable without being valid.[5, 29-31] There are different types of validity. Content validity is the extent to which a measure represents all the facets of a given construct. Criterion-related validity tests whether an instrument measures what it is expected to measure by comparing it to another measure that is known to be valid. Construct validity is the extent to which scores on an instrument reflect the desired construct rather than some other construct.[32] Convergent validity is the relationship between the scale used and other scales that are intended to measure the same construct.[32] Face validity requires the instrument to be tailored to the needs of the subjects for whom it is intended.[32] From the abovementioned, it can be concluded that reliability should be tested before validity, thus this study will focus on reliability.

Reliability is consistency in measurement.[29, 30, 33] The process of developing and validating an instrument is largely focused on reducing error in the measurement process. Test-retest/ intra-rater reliability is the stability of measures administered at different times to the same individuals.[29-31] Parallel-form reliability is similar to test-retest reliability but changes the original test slightly at the second testing.[32] Inter-rater reliability is the degree to which different judges or raters agree in their assessment decisions at any given point in time[5, 29, 30, 33, 34] (intervals between assessments are brief). Internal consistency is a measure of reliability used to evaluate the degree to which different test items that probe the same construct produce similar results.[32] Intra- and inter rater reliability are applicable to this study. Each classifier needs to be consistent when doing MMT and all classifiers must agree when classifying WCR athletes.

2.8 ANATOMY OF THE HAND

Extrinsic muscles of the hand have their origin outside the hand and insertion in the hand. In WCRC they consist of the wrist flexors and extensors, finger flexors (excluding metacarpophalanges joint flexors/lumbricals and interossei), finger extensors, thumb flexors (excluding flexor pollicis brevis) and thumb extensors.[4, 15, 15, 35]

Intrinsic muscles of the hand have their origin and insertion in the hand. In WCR classification they consist of the thumb abductors (excluding abductor pollicis longus), thumb opposition, thumb adductors, lumbricals (metacarpophalangeal joint flexion), interossei and abduction of the small finger.[4, 15, 15, 35]

When doing MMT of the hand during WCRC the classifiers test the intrinsic and extrinsic muscles of the hand. All classifiers have different backgrounds with regards to training and type of MMT used in practice.

2.9 MANUAL MUSCLE TESTING

Functional movement needs muscle strength and range of motion.[36] When an examiner counteracts the force produced by a limb of a subject manually, it is called MMT.[37] MMT comprises both subjective and objective factors. The subjective factors are the therapist’s impression of the amount of resistance given before the actual test and then the actual amount of resistance a patient tolerates. The objective factors are the ability of the patient to complete a full range of motion or to hold a position after passive placement, ability or inability to move the part against gravity.[36] MMT encompasses assigned grades from 0 (no voluntary muscle contraction) to 5 (normal strength through normal anatomic range of movement)[15, 25] (see Table 2.2: Muscle strength testing scale according to the IWRF classification manual).

Table 2.2: Muscle Strength Testing Scale.[1]

Muscle Strength Testing Scale	
0	Complete lack of voluntary muscle contraction. The examiner is unable to feel or see any muscle contraction.
1	Faint of “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-	Gravity eliminated movement that is less than full range of motion
2	Very weak muscle contraction with movement through complete range of motion in a position that eliminates or minimises the force of gravity. This position is often described as the horizontal plane of motion.
2+	In gravity minimised position, completes full available range and takes maximal resistance; or against gravity, up to half or full range or notion.
3-	Against gravity, more than half but less than full range of motion.
3	Muscle can complete a full range of motion against only the resistance of gravity.
3+	Completes full range of motion against gravity and holds end position against mild resistance.
4	Able to complete the full range of motion against gravity and can tolerate strong resistance without breaking the test position. The grade four muscle clearly brakes with maximal resistance.
5	Able to complete full range of motion and maintain end point range position against maximal resistance. The examiner cannot break the athlete’s hold position.

There are different manual muscle strength testing grade scales and methods. Methods include but are not limited to Daniels and Worthingham MMT, Medical Research Council MMT, Modified Medical Research Council scale and the Oxford scale. The Paralympic classification system prefers just two: Daniels and Worthingham

MMT and that of the Medical Research Council.[13] The Medical Research Council of Great Britain's system is one of the grading systems used for MMT. Dyck et al. traced the development of the MRC system to the treatment of war injuries and poliomyelitis. The MRC system of MMT is used to grade recovery from paralysis, placing emphasis on grades 1 to 3.[38]

Daniels and Worthingham's MMT differs from the MRC MMT in several aspects. Daniels and Worthingham use ROM as a descriptor and MRC does not. Daniels and Worthingham test a single muscular complex and MRC tests individual muscles.[36] Daniels and Worthingham take gravity into consideration and MRC does not. Daniels and Worthingham use the break test as the preferred method and MRC does not specify how resistance should be applied.[13] The break test is when an athlete is asked to position the muscle tested at its end range. Then the athlete is asked to hold the part at that point and not allow the therapist to "break" the hold with manual resistance.[36]

MMT is an integral component in Paralympic sports classification, because it is practised internationally, requires little equipment and is easy to administer.[39] Other ways of testing strength include the hand-held dynamometer, pinch and grip strength measurement, and isokinetic dynamometry.[37] These methods are more expensive and logistically difficult to manage at international tournaments. On the down side, MMT has several disadvantages. Firstly, acceptable inter-rater reliability is difficult to achieve, a problem exacerbated by the wide range of MMT techniques. Inter-rater reliability for MMT tends to be low but increases with examiner experience; increased training and strict adherence to testing methods.[13] Clinical experience and expertise are thus important for the reliability of MMT.[5, 40] Examiners/classifiers must be trained in anatomy, physiology and neurology of muscle function.[1, 2, 5, 15, 25] Medical research councill MMT does not appear to be sensitive enough to determine improvements in muscle strength over the course of rehabilitation.;[39] However, WCR is one of the Paralympic sports that stipulates that the Daniels and Worthingham MMT be used and an athlete is only classified after rehabilitation. An article by Van Tuijl J.H. states that in people with tetraplegia (injury level C3-C7) MMT is sensitive enough to detect changes in strength of key muscles over time.[37] Secondly, the relationship between muscle grade and activity limitation is weak, e.g. an athlete with full passive range of motion but only 15° of active elbow extension against gravity is likely to experience much more activity limitation in shot-put than an athlete with a 100° active range of motion; yet the correct muscle grade for both actions is 2/5. This reduces validity. WCR is one of five Paralympic sports that specifies which of the published methods for MMT should be used. In WCR, Daniels and Worthingham's MMT is used[13]. This means that nine of the 14 Paralympic sports use various MMTs. Lastly, MMT lacks sensitivity as shown by Beasley. He reported that patients with various neurological disorders who had grade four knee extension force were only about 48% of normal, rather that the traditionally defined 75% of normal. The grade three group actually had force generation that was only 9% of normal rather than 50% of normal usually assigned with MMT.[36] Even though this is true, MMT appears to be both reliable and valid in the presence of profound weakness such as that seen in neuromuscular diseases.[36]

Standardisation of assessment methods is vital to minimise potential sources of intra- and inter-panel variability in classification. Due to classifiers being trained at different institutions and having different backgrounds and professions, it is of utmost importance to follow the correct MMT technique as prescribed in the classification manual for WCR. If classifiers do not adhere to this and use different MMT techniques it can result in an athlete being classified as eligible when using the Daniels and Worthingham MMT and ineligible when using the MRC muscle testing.[13] The class to which an athlete is assigned can influence his/her degree of success, which in turn has an impact on self-esteem and self-perception, peer and community recognition, as well as access to sponsorship and other financial rewards. For these reasons, inconsistency should be minimised.[13] To achieve accurate results in MMT the following factors must be considered: proper positioning and adequate stabilisation; observation of how the test is performed; consistent timing, pressure and position; avoidance of preconceived impressions; and non-painful contacts and adherence to the contraindications.[5] There are four modifications that can be done to improve MMT reliability, validity and utility: 1) selection of movements to be assessed (those movements that are judged to be sufficiently important to sports performance should be evaluated); 2) specification of movement testing technique (the movement classification is seen to be more important for sport performance); 3) changing the reference ROM (instead of using normal anatomical range as the full range of motion, rather use the reference range to the maximum range of movement needed for the specific sport); and 4) adjustment of movement assessment techniques (positioning and stabilisation techniques).[13]

The MMT for IPC athletics classification modified their classification using the above mentioned guide to improve the reliability, validity and utility.

> *"To enhance inter-classifier reliability, classifiers should use the Daniels and Worthingham (D&W) methods, as published in the 2002 edition , WITH THE FOLLOWING MODIFICATION: Background and Rationale: According the D&W methods, the muscle grade assigned for a given muscle action is influenced by the range of movement that can be achieved. For example, if an athlete is assessed as having passive range of movement (ROM) of 1200 at the hip (normal anatomical range) and can then only actively flex the hip to 1000 against gravity, according to the conventional D&W scale the athlete must receive a grading of 2, because he/she cannot complete the available range of movement against gravity. However, even athletes performing at the very highest levels in athletics do not use full anatomical ROM at every joint. For example, the range of hip flexion required for elite level sprinting is only 900. If a person can actively flex the hip to 1000, an assignment of a grade 2 will not be a valid reflection of the activity limitation such a person would experience in the activity of running. To address this discrepancy, the reference range of movement for assessment of muscle power in this system is not normal anatomical range but rather the range of movement required for the activity (either running or throwing)".*[41]

Other small factors that can also lead to an increase in reliability, validity and utility that are not taken into consideration currently are the following: as seen in the MMT scale used in the IWRF classification manual, there are plusses and minuses. In the manual, it is stipulated that Daniels and Worthingham's MMT be used but according to Hislop [et al.] using plusses and minuses adds a level of subjectivity that lacks reliability.[36] Proper training in Daniels and Worthingham's MMT (which is more detailed and comprehensive than the Medical Research Councill method)[13] must be given to WCR classifiers. As mentioned in the research, this will increase reliability by adhering to the same procedure for each test. The wording used on the WCR classification chart for testing should also be revised to use the movement of the joint rather than a single muscle as stipulated in Daniels and Worthingham's MMT e.g. finger abduction and not interossei. The descriptions in the physical assessment are: lateral deltoid, pectoralis sternal, pectoralis clavicular, latissimus dorsi, serratus anterior, internal rotators, external rotators, biceps, triceps, wrist extension, wrist flexion, interossei, lumbricals, thumb abductor, thumb adductor, thumb extensor, thumb flexor and thumb opposition. This can add to confusion due to the mixture of specific muscles and joint movements described. The last factor to increase reliability is to provide clear instructions to the athlete and by having a quiet and comfortable environment while testing; this is done during WCRC.[36]

2.10 CLASSIFICATION IN WHEELCHAIR RUGBY

WCR is a very popular sport today and is not only played by athletes with tetraplegia but also other health conditions such as multiple amputations, cerebral palsy, neuromuscular disease and incomplete spinal cord injury. These impairments result in loss of muscle power, reduced limb length or impairments in coordination. Some of these athletes with other health conditions have voluntary control of their trunk and leg muscles. This has led to classification in WCR being more difficult and changes had to be made to the classification system towards a more evidence based system. This led to a review by V. Altman, PhD (August 2013) on the four priority areas that need revision of the classification system in WCR. The four areas identified by the athletes and stakeholders were: 1) minimum eligibility criteria, 2) impact of trunk function on performance, 3) reliability of sport-class decisions, and 4) classification of athletes without SCI. Most of the stakeholders supported adjustments to the current classification system and not a completely new system. Stakeholders who did not support change and propagated a whole new classification system expressed concerns about the application of classification. The abovementioned issues should be addressed in the evaluation of classification procedures and in educating and training classifiers and athletes. The researchers were thus convinced that adjusting the system instead of developing a whole new system was the best choice.[10] This led to changes in the trunk and hand classification in WCR. The previous trunk classification system consisted of three tests that were evaluated while the athlete sat in his/her WCR chair. Many factors were not taken into consideration during these tests e.g. back rest supporting the trunk and the base of support in athletes with amputations. The athlete would receive a 0 score (no trunk function), 0.5 (some trunk function) or 1.0 score (full trunk function) depending on the tests passed of failed. The old hand classification consisted of tests that were not relevant to WCR. Scores in the classification manual for WCR hand function could be 2.0, 2.5, 3.0 or 4.0 (normal hand).

The new trunk classification system was introduced in 2013 and the new hand classification introduced in 2015. WCR athletes are classified according to their functional level[11] in a sport-specific system composed of three distinct stages: 1) physical assessment/ bench test; 2) technical assessment (including a range of sport-specific tests and novel non-sport tests); and 3) observation assessment (observation of sport-specific activities on court) (see Annexure B: Athlete classification pathway).[12, 24]

During the physical assessment/bench test the WCR classifiers make use of MMT on selected muscles of the upper limb to determine a total score for each upper limb (including the hand function). The MMT used in WCR classification is Daniels and Worthingham's MMT as stipulated in the WCR classification manual. The trunk assessment also forms part of the physical assessment/ bench test. It consists of a maximum of ten tests and follows a flow chart to determine the total trunk score. The trunk score for an athlete can be 0, 0.5, 1.0 or 1.5. At the end of the physical assessment/bench test the two arm scores are added then divided by two. The trunk score is added to the total of the combined upper limb score (as previously described) which is equal to the WCR class for the athlete (see Annexure F: IWRF classification form).

The technical assessment consists of WCR chair skills and WCR ball handling skills. The wheelchair skills include but are not limited to; pushing forward and backward, starting, stopping, turning and changing direction. The ball handling skills include but are not limited to; one-hand and two-hand passes, catching, retrieving the ball from the floor, dribbling, blocking and picking.[1, 24] After the physical assessment/bench test and technical assessment the athlete is allocated a preliminary sport class.[1] There are seven sport classes in wheelchair rugby with 0.5 point intervals ranging from 0.5 (most impaired) to 3.5 (least impaired).[1, 10] A 4.0 sport class indicates that the extent of impairment is not sufficient to meet the eligibility criteria for wheelchair rugby at an international competition.[10]

Lastly, the observational assessment includes but is not limited to observation of the athlete during warm-up, training practice and competition. Finally, the WCR classifier will verify the results of each assessment to determine the sport class total.[1, 24] The classification panel will then inform the athlete of his confirmed sport class and the athlete will receive an IWRF classification card. All the athlete's information is recorded on the IWRF classification form and stored in a database, accessible to all international WCR classifiers.[12]

According to Rhodes J.M. there is a close relationship between classification and on-court roles of WCR athletes. Low-point athletes (class 0.5-1.5)[1] have a defense role on court due to their limited shoulder and wrist stability that impedes ball-handling capabilities and reduces wheelchair manoeuverability.[1, 23] High-point athletes (class 3.0-3.5) have an attach role or ball carrier role on court due to their good shoulder and wrist stability that enables them to perform ball handling tasks and wheelchair handling skills effectively.[1, 23] As classification class increases, the total distance, mean speed and peak speed values also increase. With low-point WCR athletes the longer durations of low speed activity correlates with the roles on court. [11,23] Another study by Morgulec-Adamowicz N. et al. reported that the longest time on court was spent by 2.5 and 2.0 class players, followed by 0.5, 3.0 and 3.5 class players, and 1.5 and 1.0 class players. This can be due to coaches selecting players for the 2.0 to 2.5 classes which is most beneficial for the most optimal team tactics.[24]

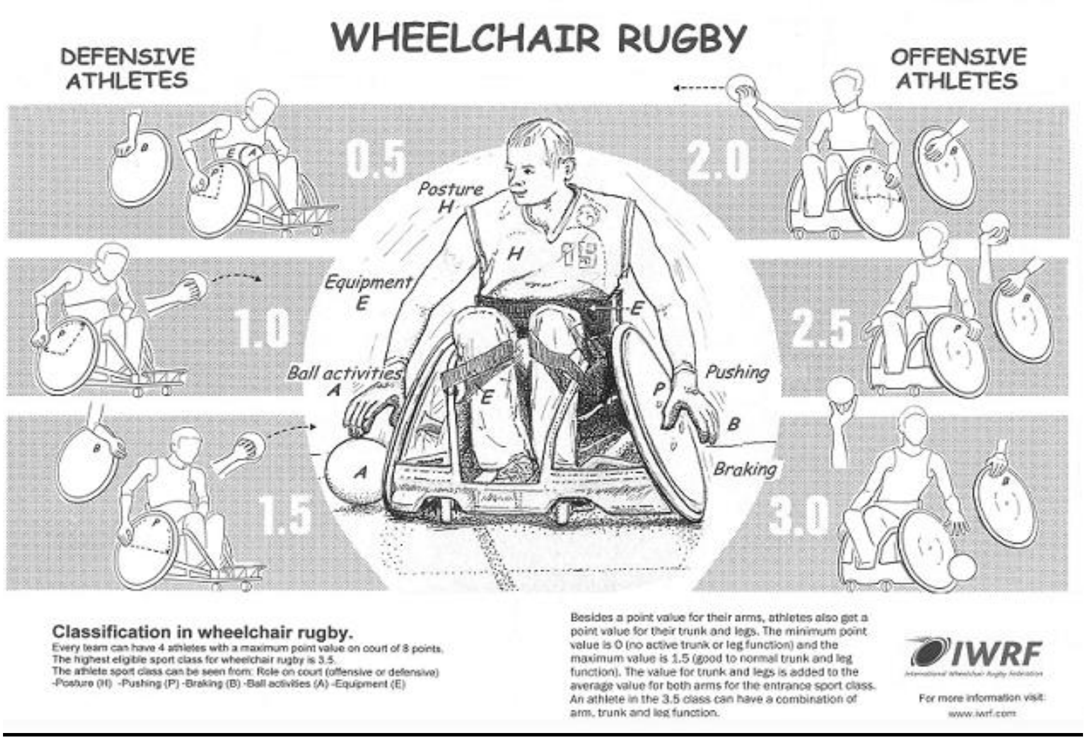


Figure 2.1: Picture illustrating different classes and skills in the specific class.

Wheelchair rugby athletes want their classification to be as low as possible. Some wheelchair rugby athletes will even go so far as to not show their full potential during classification but rather try and "trick" the classification panel during the whole classification process.[21] If caught, this will lead to severe consequences e.g. being banned from WCR.[1] In an article by Lindemann K. one athlete reported that: *"you only give the classifiers the information they asked for and you don't offer information".*[21] He also indicated that athletes try to 'get away' with as much as they can. Athletes will even go as far as "boosting" to improve performance on court. "Boosting" means inducing autonomic dysreflexia.[42] Autonomic dysreflexia increases blood pressure, peak heart rate, circulating norepinephrine levels, maximum oxygen consumption and lower peak power. Athletes report that "boosting" improves sporting performance e.g. increased arm strength and endurance, decreased arm stiffness, improved breathing and increased alertness and aggressiveness.[42] Due to the serious complications that can be caused by "boosting" (increased blood pressure can cause intracerebral bleeds, seizures, myocardial ischemia and even death) it was banned by the IPC. Yet, despite being banned by the IPC and the potential severe complications, WCR athletes still continue to "boost".[42]

The reason why they do this is because, as a team they will then be able to use a greater number of mobile players (and, presumably, more skilled players) on court at one time which increases the likelihood of winning.[21] It is in the opposing team's interest to monitor other players for evidence of misrepresentation of their abilities; it gives them grounds to file a protest to the classification panel.[1, 1, 21]

WCR athletes who competed in other sports reported that the classification system of WCR maximises the range of players who could play while also keeping team performance equitable, whereas other sports can create situations of exclusion based solely on the classification system such that individual gains in skill and training are lost to basic differences in level of impairment.[20] WCR classification provides a level playing field whereby athletes feel they are working as part of a team. In individual disability sports, athletes with very different functional abilities can find themselves competing against each other.[20] One athlete expressed his experience of classification as follows:

> *"It is an alienating experience as each time a different team of individuals determines whether your body fits into the textbook of carnal typology that is acceptable to those who govern this aspect of Paralympic sport officialdom. My body is poked and prodded. It is measured. The team of classifiers look like they have been working all night long and I wonder whether this will lead to an inaccurate diagnosis. Will any of the athletes I race against have beaten the system? It seems rather robust but rumours of cheating abound."*[43]

This raises concern regarding the athlete's faith in the classification system and stresses the importance of evidence-based classification, reliability and validity of the new hand classification in WCR.

2.11 THE NEW HAND CLASSIFICATION IN WHEELCHAIR RUGBY

The assessment of the hand is conducted during the physical assessment of wheelchair rugby classification (WCRC). During this assessment classifiers make use of manual muscle testing (MMT) of selected muscles in the upper limb to determine muscle strength. Wheelchair rugby classification relies on Daniels and Worthingham's system of MMT[1] to ensure consistency amongst raters; thus the interpretation of MMT is expected to be uniform for all WCR classifiers.[13]

Before 2015, scores in the classification manual for WCR hand function could be 2.0, 2.5, 3.0 or 4.0 (normal hand). Should the classification panel be unsure as to whether an athlete had a 3.0 or a 4.0 score, nine further hand tests could be used to reach a decision (see ANNEXURE C: Old hand classification in WCR).[1] These tests covered a variety of Daniels and Worthingham's MMT, sport-specific and novel activities. In each hand test, the athlete could score 1.0, 0.5 or 0.0. The classification panel calculated the total point value by adding the scores for each hand muscle function test. A sum score of 1.0 to 8.0 points indicated a 3.0 hand and a sum score of 8.5 to 9.0 points indicated a 4.0 hand.[12]

In the new hand classification (introduced in 2015) there are no separate hand tests. Hand tests that were not functional sport-specific tests (e.g. clawing of the hand, piano playing and picking up coins) were removed. Lumbrical, interossei and thumb opposition MMT were added to the physical assessment and observation of wasting was no longer a separate test. The sub-tests of palming the ball overhead and "walking" the ball up the wheel, were added to the off-court, sport-specific, functional activities testing. The scoring for hand classification in WCR is currently: normal intrinsic and extrinsic muscle function (3.5 hand); limited intrinsic muscle function and normal extrinsic muscle function (3.0 hand); absent intrinsic muscle function and normal extrinsic muscle function (2.5 hand); and absent intrinsic and extrinsic muscle function (2.0 hand) (see ANNEXURE E: New hand classification in WCR).[1] The new hand classification introduced in 2015, is based on scientific evidence by eliminating irrelevant sub-tests and adding Daniels and Worthingham's MMT of specific muscles to the physical assessment. Table 2.3 gives an overview of the changes in the hand classification.

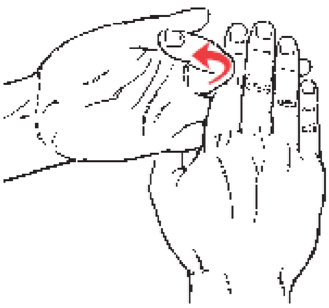
Table 2.3: Overview of changes to the hand test in WCRC

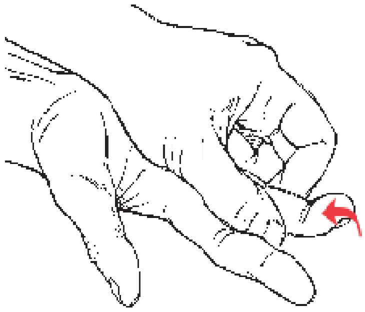
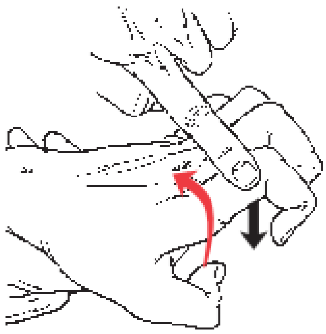
Hand classification before 2015	Notes	New test
Observe the hand for wasting	Not functional, part of general observation	Removed
Playing the piano	Extrinsic instead of intrinsic	Removed
Lumbrical position	Not functional but impairment testing	Moved to MMT way of applying resistance adjusted
Claw position	Not functional, test for extrinsic and range	Removed
Making O's	Not functional, but impairment testing of thumb opposition	Moved to MMT thumb opposition
Picking up coins	Not sport specific for wheelchair rugby	Removed
Adduction of fingers with paper sheet	Not functional but impairment testing of interossei	Moved to MMT interossei
Palm ball overhead	Sport specific, functional activity	Moved to functional activities test
"Walk" the ball up the wheel	Sport specific, functional activity, but mainly balance flexion and extension, not intrinsic	Moved to functional activities test

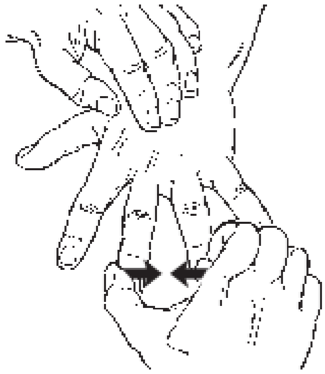
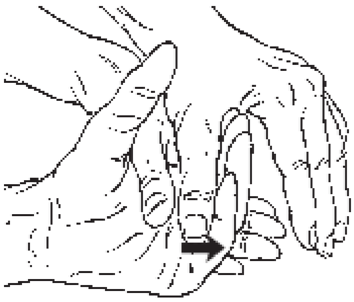
The researcher has observed the new hand classification on national and international levels and has noted that classifiers expressed uncertainty to their fellow panel members regarding their hand placement on the athlete's hand and interpretation of the Daniels and Worthingham's MMT of the hand that was observed.

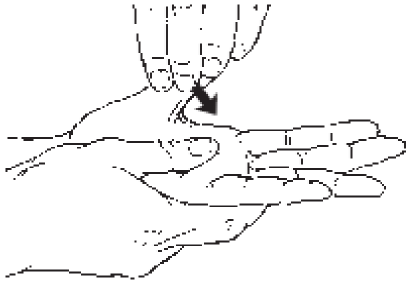
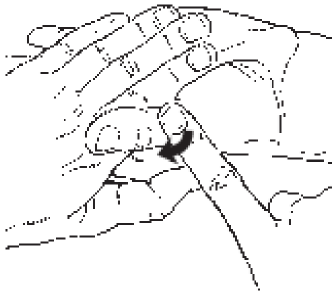
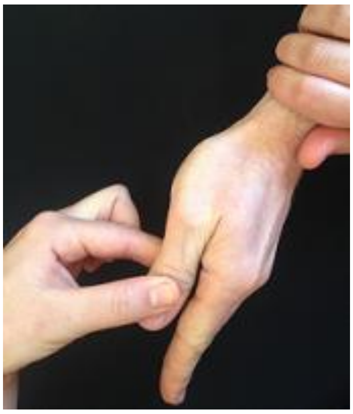
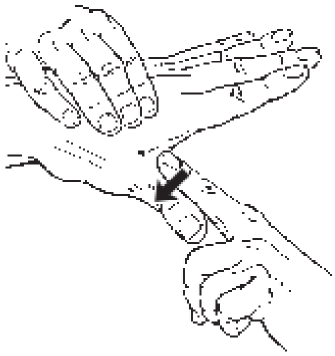
Where does this confusion come from and what might the reason be? An important aspect that adds to classifiers' confusion is that in WCRC, finger and wrist movements are tested as a whole movement, e.g. wrist extension and not each individual muscle (extensor carpi radialis longus, extensor carpi radialis brevis and extensor carpi ulnaris); contrary to what classifiers would do in practice. It is also stated in the WCRC manual that the Daniels and Worthingham's MMT should be used but details regarding the testing method are not supplied. If classifiers want to learn this specific method, the textbook should be bought, there are no other cheaper or free ways to obtain this information. The MMT for the classification of the hand at this stage also combines tests e.g. the Daniels and Worthingham's MMT for flexor digitoruim profundus and the flexor digitoruim superficialis test are combined to determine finger flexion during classification. The hand and finger biomechanics and muscle innervation are complex and no anatomical explanation is given for the hand, yet by the time a therapist becomes a classifier it is accepted that the therapist would know all the anatomy. However, the hand and therapy for hand injuries is a field of study on its own. The training the classifiers receive currently does not contain any detailed information; classifiers are taught by other higher level classifiers and there is no certainty whether they are being taught the details of Daniels and Worthingham's MMT. Table 2.4 reflects a comparison of current methods In WCR classification to Daniels and Worthingham's MMT according to the researcher's observations. The focus is on muscle grade 4-5.

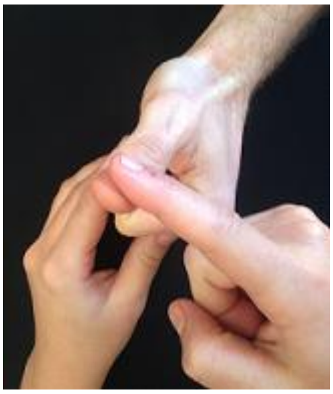
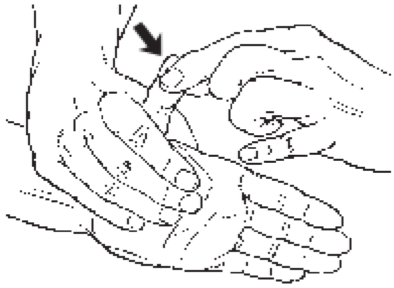
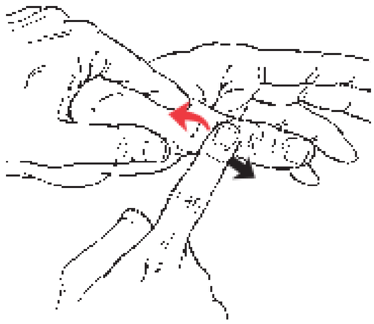
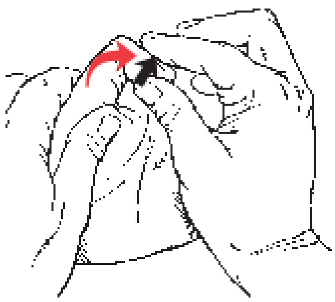
Table 2.4: A comparison of current methods with Daniels and Worthingham's MMT for 4-5 muscle grades

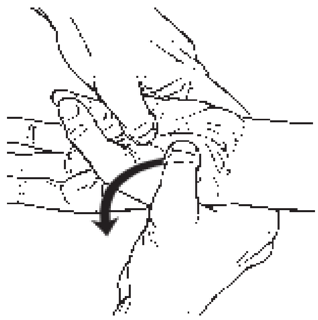
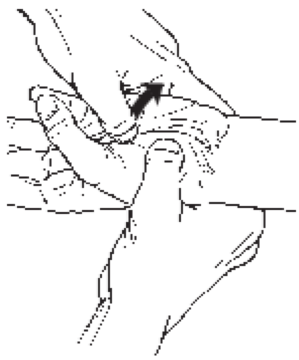
Test	Current WCRC method	Daniels and Worthingham's MMT
Finger Flexion		Flexor Digitoruim Superficialis 

<table>
<tr><td></td><td></td><td>Flexor Digitoruim Profundus
</td></tr>
<tr><td colspan="3">Notes on Finger Flexion test:</td></tr>
<tr><td colspan="3">Current methods used in WCRC are a combination of D&W flexor digitoruim profundus and flexor digitoruim superficialis MMT. Both muscles are extrinsic muscles of the hand. They cause flexion of the DIP and PIP joints of the fingers. Together with the Lumbrical muscles of the hand, they provide flexion of the MP joint.</td></tr>
<tr><td>Finger Extension</td><td></td><td>Extensor Digitorum, Extensor indicis, Extensor digiti minimi
</td></tr>
<tr><td colspan="3">Notes on Finger Extension test:</td></tr>
<tr><td colspan="3">Current methods used in WCRC when testing finger extension involve testing each finger in full extension. The extensor muscles of the hand are extrinsic muscles. Extension of the fingers involve extrinsic and intrinsic muscles of the hand. During full finger extension extensor digitorum, inidicis, digiti minimi and lumbricals are used. The lumbrical MMT is one of the new tests added to WCRC. The finger extension test is therefore not in accordance with Daniels and Worthingham’s MMT as is evident in the pictures.</td></tr>
</table>

Interossei		Dorsal Interossei 
Notes on Interossei test:		
The IWRF classification form only refers to Interossei and do not stipulate if the dorsal or palmar interossei should be tested. Dorsal interossei cause finger abduction which correlates with sport-specific functioning. There are only three dorsal interossei but if the abductor digiti minimi is added, there are four. Some classifiers will only test the abduction of the index finger and pinkie to determine the muscle grade.		
Lumbricals		Lumbricals 
Notes on Lumbrical test:		
The Lumbrical test was added to physical assessment of the hand. Grade 3 lumbricals will be MP flexion with full extension of the PIP and DIP joint with wrist in neutral. At times, some athletes will position their wrists in extension to get to this position. This is not always observed by the classifiers. The Lumbrical MMT are then graded higher than what they actually are. During this test it is very important that the stabilisation of the wrist is in neutral.		

<table>
<tr>
<td rowspan="2">Thumb abductor</td>
<td rowspan="2"></td>
<td>Abductor pollicis longus
</td>
</tr>
<tr>
<td>Abductor pollicis brevis
</td>
</tr>
<tr>
<td colspan="3">Notes on Thumb Abductor test:</td>
</tr>
<tr>
<td colspan="3">Current methods include a combination of Daniels and Worthingham’s MMT abductor pollicis longus and brevis.</td>
</tr>
<tr>
<td>Thumb adductor</td>
<td></td>
<td>Adductor pollicis
</td>
</tr>
<tr>
<td colspan="3">Notes on Thumb Adductor test:</td>
</tr>
<tr>
<td colspan="3">The current methods of testing thumb adduction are consistent with Daniels and Worthingham’s MMT. The adductor pollicis is one of the intrinsic hand muscles. Research reveals that intrinsic muscles of the hand do not have to be tested against gravity.[4]</td>
</tr>
</table>

Thumb extension		Extensor pollicis longus 
		Extensor pollicis brevis 
Notes on Thumb Extension test:		
The current methods of testing thumb extension include a combination of the extensor pollicis longus and extensor pollicis brevis. It was observed by the researcher that placement of the classifiers' hands for the MMT was not constant. Some would provide resistance at the tip of the thumb while others would provide resistance to the base of the thumb.		
Thumb flexion		Flexor pollicis longus 

<table>
<tr><td></td><td></td><td>Flexor Pollicis brevis
</td></tr>
<tr><td colspan="3">Notes on Thumb Flexion test:</td></tr>
<tr><td colspan="3">Current methods to test thumb flexion are a combination of flexor pollicis longus and flexor pollicis brevis. They are extrinsic and intrinsic muscles of the hand.</td></tr>
<tr><td rowspan="2">Thumb opponens</td><td rowspan="2"></td><td>Opponens pollicis
</td></tr>
<tr><td>Opponens digiti minimi
</td></tr>
<tr><td colspan="3">Notes on Thumb Opponens test:</td></tr>
<tr><td colspan="3">Current methods for thumb opponens contain a combination of opponens pollicis and opponens digiti minimi. The researcher observed uncertainties during the hand placement</td></tr>
</table>

whilst performing MMT. For functional opposition, the thumb and the pinkie are involved. Both these fingers would have to be functional for true opposition.

There are also other methods to determine upper extremity function in persons with tetraplegia e.g. International Classification of Functioning, Disability, and Health (ICF), the Van Lieshout test (assessing upper extremity tasks that are associated with activities of daily living), the Grasp release test (which assesses only lateral and cylindrical grasp), the Graded and Redefined Assessment of Strength, Sensation, and Prehension (GRASSP) and the Jebsen Tailer hand function test. None of these tests has reached sufficient international acceptance to become a gold standard in the field of spinal cord injuries[44, 45] nor are they sport specific therefore they cannot be used for WCRC.

Surgical advances to improve function for people with tetraplegia are more common in athletes today than in the past. One of these surgeries is the deltoid-triceps transfers. This increases elbow extension strength in transfer from very limited to being able to extend the elbow against gravity. Some athletes were concerned that this surgery could increase the function of an athlete playing wheelchair rugby. A study that determined the differences in throwing ability among wheelchair rugby athletes who had triceps, no triceps or deltoid-triceps transfers found that the athletes who had active elbow extension provided by the deltoid-triceps transfer showed less throwing capability across all throwing techniques than those with no triceps. The athletes are still not able to compete in ball handling roles in WCR like athletes who have natural triceps function.[46] Other surgeries include tendon transfers in the hand to increase functional grasps.
Wheelchair rugby classifiers should be kept up to date regarding all these new procedures and determine the impact they have on the sport and also the consequences they will have on classification. The deltoid-triceps transfer does not have any effect on the sport; thus, grading a 0.5 player to a 1.0 player just because of more triceps would be unfair as is evidenced by research that these athletes are not at an advantage.

2.12 THE PATIENT BECOMING THE ATHLETE

Rehabilitation after a spinal cord injury takes several years. Some people rehabilitate longer than others due to secondary complications. In Poland, the Foundation of Active Rehabilitation, organises active rehabilitation training camps. Here the patients learn how to function independently. The foundation also provides the patients with an opportunity to take part in WCR training. Patients who participated in WCR over a two year period displayed significant improvements when evaluated by the wheelchair skills test and the American Spinal Injury Association motor score.[47] An article by Goodwin D. reports that WCR players have higher self-efficacy expectation and aerobic fitness then their non-rugby playing counterparts. Wheelchair rugby athletes have a sense of community which decreases feelings of alienation and anonymity.[20] Wheelchair rugby athletes take pride in demonstrating that they can still participate in sport activities[21] and challenge the image of people with tetraplegia being fragile and passive.[20] The most frequent reasons cited for playing WRC are emotions related to sports, opportunities to exercise, opportunities to improve sport competence, the chance to get recognition and a chance to compete against others.[48] One player reported his first experience of playing wheelchair rugby as “being born again” and “healing what science cannot”.[49]

Wheelchair rugby means so much to athletes and patients in the rehabilitation phase. If an athlete is classified incorrectly it will have a tremendous effect on the athlete. His/her self-esteem will be affected by feeling that he/she is not as good as his/her peers. In addition, sponsors observe the players in their class and non-performane will result in lack of funding. Not only will it affect the athlete but also the team. The coaches will struggle to get the best line ups possible for the team, which would result in them feeling inferior when comparing themselves to players from other countries.

2.13 CONCLUSION

Inconsistencies in classification should be minimised as these can influence the athlete on various levels.[13] Athletes who are classed too low affects fair and equitable competition. Athletes classed too high may appear unskilled compared to other athletes in their class and this has a direct influence on the selection for national teams and sponsorship. Reliability of WCRC will ensure that this will not happen. To achieve accurate results in MMT the following factors must be considered: proper positioning and adequate stabilisation; observation of how the test is performed; consistent timing, pressure and position; avoidance of preconceived impressions; non-painful contacts; and adherence to the contraindications.[5] Classifiers have expressed their uncertainties pertaining to these factors, resulting in questionable intra-and inter-rater reliability, and having a direct impact on classification. However, reliability increases with examiner experience, increased examiner training time and strict adherence to testing methods.[13] Level 4 classifiers must therefore be more reliable than level 2 classifiers. Wheelchair rugby is one of five Paralympic sports that specifies which of the published methods for MMT should be used. In WCR Daniels and Worthingham's MMT is used, and if the abovementioned factors are taken into consideration, it will increase the reliability of the new hand classification in WCR.

CHAPTER THREE - STUDY DESIGN AND METHODOLOGY

3.1 INTRODUCTION

The execution and interpretation of MMT during classification of wheelchair rugby athletes has questionable reliability. Various factors can lead to decreased reliability but there are advised systems in place to increase reliability of MMT during classification. This study aimed to determine the intra-and interrater reliability of MMT in the new hand classification of WCR.

3.2 STUDY DESIGN

The researcher analysed data collected from the raters after they graded subjects (muscles) with Daniels and Worthingham MMT. The study followed a quantitative non-experimental, cross-sectional design with convenient sampling.[50]

3.3 STUDY SETTING

Wheelchair rugby is an international sport with active international WCR classifiers from various countries. The study setting can thus not be at one place in time due to logistics; therefore, the study setting was an online platform involving classifiers from across the globe.

3.4 STUDY POPULATION AND SAMPLING

3.4.1 <u>Study population</u>

All the active international WCR classifiers registered at the IWRF in 2015 were invited to take part in the research. There were 51 active international WCR classifiers at the time of data collection: 16 level 2 (31.3%), 19 level 3 (37.2%) and 16 level 4 (31.3%). These classifiers are of different nationalities and have different occupations. English is the universal language in WCR due to officials and athletes hailing from across the globe.

3.4.2 Sampling method

The 2015 study population was limited to 16 level 2 (31.3%), 19 level 3 (37.2%) and 16 level 4 (31.3%) WCR classifiers. 49 active international WCR classifiers were invited to take part in the study, as two of the classifiers took part in the pilot study. An invitation with informed consent and link to the questionnaire was emailed.[50] Clicking on the link and starting the questionnaire was regarded as consent given to take part in the study. The researcher was available via email if there were any uncertainties or comments. A period of two weeks was given to the participants to complete the questionnaire. Convenient sampling was used to verify that each level of classifiers was represented in the sample.[50] Only the first three participants in each level who completed the questionnaire formed part of the sample.

3.4.3 Sample size

The number of raters, trials and subjects needed for a study differs for inter-and intra-rater reliability. With inter-rater reliability, the number of raters does not matter and fewer trials are needed. Contrastingly, with intra-rater reliability the more raters and trials the better. With fewer trials the inter-rater reliability will be stronger but there will be a loss of precision and with more subjects the intra-rater reliability and the precision for inter-rater reliability will be stronger.[7] Number of raters, number of subject and number of trails was determined by using Kilem Gwet as reference. [7] There were two trails to address intra-rater reliability. More trails would affect the precision for inter-rater reliability. For any ICC value the range of the 95% confidence interval (CI) decreases as the number of subjects increase, thus increase in precision. According to Kilem Gwet having more than five raters will not improve the precision of the inter-rater reliability, after five raters was recruited precision improves with more subjects.

The statistical balance for inter-and intra-rater reliability consisted of nine raters who would observe 54 subjects (the 54 subjects may be repeated). Nine raters were chosen so that there would be three raters from each level. In this study each muscle tested was viewed as a subject. This resulted in three videos illustrating nine subjects (muscles) each, repeated twice which resulted in a total of 54 subjects.

There were not enough participants two weeks after emailing the questionnaire, therefore the timeline was extended by another week. A total of 29 participants gave consent to take part in the study of which fifteen questionnaires had to be discarded because they were answered after the cut-off time; two questionnaires were incomplete and were also discarded. This left a total of 12 questionnaires that were completed and answered within the time period given. The first three participants in each level (three levels) were then chosen for the sample size. The sample size was thus nine.

3.5 DATA COLLECTION

3.5.1 Measurement tools

The researcher used the software package Qualtrics™ to gather the information. The researcher developed an electronic questionnaire as a measurement tool (see ANNEXURE G and H). The questionnaire with the informed consent was mailed electronically to the possible participants after ethical clearance was obtained. The questionnaire could be completed on a computer, smartphone or tablet. The questionnaire consisted of two sections. The first section of the measuring tool collected biographic information (see ANNEXURE G: Biographic information). The second section consisted of the electronic simulated assessment containing six videos.[51] A classifier who is knowledgeable in Daniels and Worthingham MMT graded the athletes in the videos. Prior to watching the videos the classifiers were given instructions on how to complete the questionnaire. The questionnaire would not continue to the next video unless the participant had graded each of the muscles shown in the video. The participants could go back and regrade the athletes.

Three athletes were assessed for the purposes of this study. Each athlete was assessed twice, each video taken from a different angle. Therefore, each classifier watched two videos of each athlete. The videos were about three minutes long each. Nine muscles were assessed on each athlete; thus each classifier rated 18 muscles or subjects per athlete and 54 in total. The muscles tested were the intrinsic and extrinsic muscles of the hand, as tested in WCR classification. The nine muscles tested on each athlete were: finger flexion, finger extension, interossei, lumbricals, thumb abductor, thumb adductor, thumb extensor, thumb flexor and thumb opponens. The raters made use of the objective factors shown in each video to determine the MMT grade of each muscle (subject) e.g. the ability of the athlete to complete a full range of motion and the ability to move the part against gravity. Athlete one was featured in video A and D, athlete two in video B and E, and athlete three in video C and F. Each video depicted the MMT of a WCR athlete's hand using Daniels and Worthingham's MMT technique (e.g. figure 3.1).

Figure 3.1: Picture taken from video footage.

After each video the raters had to grade each muscle according to the objective signs observed in the video. Each muscle was graded a 0-1, 2, 3 or 4-5 in Daniels and Worthingham's MMT. Written instructions were provided preceding each video.

The following was considered for the questionnaire: 1) the three athletes shown in the videos were made up of a 2.0, 2.5 and 3.0 hand grading and 2) it might have been difficult for the participants to determine whether a muscle grade was a 4/5 or 5/5 because the resistance was not applied by the raters themselves. To move from one sport class to the next in WCR, muscle grades are separated into two groups: 0/5-2/5 and 3/5-5/5; these two groups were observable in the videos because full active range of motion could be observed in the video footage and whether the movement was against resistance. However, the muscle grades that the participants could choose from were 0-1, 2, 3 and 4-5 (see ANNEXURE H: Video instructions and form).

3.5.2 Measurement technique

Daniels and Worthingham's manual muscle testing, as mentioned in the WCR classification manual, was used (see Annexure I: Muscle strength testing scale).

3.5.3 Inclusion criteria

This study included all the active international wheelchair rugby classifiers (levels 2-4) with internet access.

3.5.4 Exclusion criteria

Inactive international classifiers or level 1 national classifiers were not included in this study since they may not have had exposure to the new hand classification. Questionnaires that were answered outside the timeline given and that were incomplete were excluded.

3.5.5 Measurement procedure

The pilot study was emailed to two raters after ethical clearance was obtained.

↓

The two raters reviewed the measurement tool with the informed consent and provided the researcher with comments via email.

↓

The researcher addressed the comments provided by the participants of the pilot study. Changes were incorporated into the electronic simulated assessment.

↓

All the international WCR classifiers (raters) received the electronic simulated assessment via email with the informed consent attached.

↓

Informed consent was given by the raters if they started the electronic simulated assessment.

↓

The raters were given two weeks to complete the simulated assessment. This period had to be extended with one week due to poor participation.

↓

Three raters for each level WCR classifier were chosen. The sample size consisted of nine raters.

↓

Numeric values were given for each answer and indicated on an Excel spread sheet

↓

The Excel spreed sheet was emailed to the statistician for data analysis.

↓

The statistitian used the two-way model to determine the ICC.

↓

Results were written and presented in chart format by the researcher.

3.5.6 Quality control

This research proposal was read and evaluated by experts in the field of WCRC. The research proposal was also evaluated by the post-graduate, The School of Healthcare Sciences Research Committee and The *Ethics* Committee of the Facility of Health

Sciences of the University of Pretoria. The researcher made use of the knowledge of a statistician at the University of Pretoria (see ANNEXURE J: Letter from statistician) for the data analysis, and a language editor to proofread the research document.

The measurement tool had *content validity*[32] due to the following: 1) the questions asked in the electronic simulated assessment linked with the objectives of the study; 2) the videos consisted of electronic simulated assessments of hand classification in WCR; 3) the videos covered a realistic range of severity of impairments; and 4) a pilot study was done. *No questions were asked that might have offended the raters*. The measurement tool was *written in English* which is the universal language used in communication among classifiers.

The videos were taken by a professional videographer from the University of Pretoria to ensure good *quality.* A solid colour was chosen for the background of the video footage to emphasise the hands in the video footage. The videographer ensured that no voices are heard in the video footage and no faces seen. The videographer took close up footage to make sure all muscles can be observed. The repeated videos were taken from another angle to exclude the fact that the videos were shown for the second time. The videos were taken from a stationary point.

Researcher bias[32, 33, 40, 41, 48, 49] was limited by the following: the researcher did not choose the raters; they gave consent to take part and all raters received the same measurement tool to determine the answer of the research question. A cut-off time of two weeks was given to the raters to allow enough time to answer the questionnaire. The researcher encouraged participation after two weeks because of a low response rate. After the follow-up there was a far better response rate. The researcher included an explanation of the importance of the research and highlighted the fact that the answers to the electronic simulated assessment would not be traced back to the raters.

3.6 PILOT STUDY

The aim of the pilot study was to ensure that the measurement tool was suitable, effective and free from possible errors.[50] The pilot study also indicated any methodological and measurement errors that needed to be addressed.

After permission from the Ethics Committee of Health Sciences Faculty of the University of Pretoria was obtained, the researcher invited two classifiers to take part in the study. The researcher used purposive sampling to invite rater 1: an international wheelchair rugby classifier, level 4, who has completed research in WCR and rater 2: a level 2 classifier whose first language is not English to test whether the questionnaire is easily understandable. This ensured that the research project satisfied international standards and that the electronic simulated assessment would be understood by all the raters. A third level 4 classifier was invited to verify a memorandum. The memorandum was used in the data analysis to measure the accuracy of the answers. Even though answers are consistent they still have the possibility to be inaccurate. The level 4 classifier is trained in Daniels and Worthingham MMT and has extensive experience in WCRC. The level 4 classifier verified the memorandum by objective and subjective assessment.

The pilot study participants received electronically mailed informed consent for permission to take part in the study. When the raters gave consent, they could click on a link that would take them to the measurement tool. The measurement tool consists of biographic information and the electronic simulated assessment. The researcher requested the participants to provide written electronic feedback after two weeks of receiving the measurement tool. Both the raters provided feedback within the required time frame.

The comments and information provided by the raters pertaining to the measurement tool were implemented to make the measurement tool more suitable and effective. The following comments were made by the participants: "*Passive range of motion was not observed in the video footage".* This was addressed by adding to the paragraph preceding each video that the athletes in each video had full passive range of motion for each joint. The second comment was that "*It is difficult to determine 2+ and 3- muscle grades".* Daniels and Worthingham's MMT does not include pluses and minuses in muscle grading, thus it was added to the instructions before each video that pluses and minuses should not be added to the grading. One rater commented that because of a sore on one of the athlete's hands, it could be a tell-tale sign that the videos were shown to the raters twice. Unfortunately, this could not be edited out of the video footage, but the second video was taken from another angle showing the sore at a later stage; the repetition of the assessment was thus less obvious. One of the raters commented that she had to go back and familiarise herself with the right way of testing finger extensors. The correct way to do this, according to Daniels and Worthingham, is shown in the video footage.

The raw data collected in the pilot study was checked by the researcher to verify that the data would give the necessary information required to answer the aim and objectives.

3.7 DATA MANAGEMENT AND ANALYSIS

Every muscle in each video is presented as a subject. The subjects (muscles) were rated with one of the following: 0-1. 2, 3 or 4-5 grading of Daniels and Worthingham MMT. Each grade was given a nominal value for data analysis. 0-1 on Daniels and Worthingham MMT were given a 1, 2 a 2, 3 a 3 and 4-5 a 4. The nominal values for each subject were recorded on an Excel spreadsheet (Annexure K: Example of excel spread sheet). Duplicate data entries were made to check the accuracy of the data input.

The spreadsheet was emailed to the statistician for data analysis. The statistician used the Medcalc program and the two-way regression model for a nominal scale (modified Daniels and Worthingham MMT) to determine the degree of absolute agreement among measurements by means of calculating the ICC for each objective.[89] The ranges provided by Landis and Koch (1977) were used to describe the strength of agreements: [52]

Table 3.1: Strength of agreement explained by Landis and Koch (1977)

Numeric value	Descriptive statistics
0.0 – 0.2	Slight
0.21 – 0.4	Fair
0.41 – 0.6	Moderate
0.61 – 0.8	Substantial
0.81 – 1.00	Almost perfect

The results were written and presented in table and chart format by the researcher. Percentage values were also determined for each objective to determine the accuracy of the MMT grades.

For objective one (to determine the intra-rater reliability of each rater regarding MMT outcome) the ICC was determined by comparing the 27 subjects from the original three videos to the 27 subjects in the repeated three videos. The single measurement was used to report the ratings. To determine if the MMT grades was accurate a “memorandum” of reference to the Daniels and Worthingham’s MMT textbook was compiled. Once compiled, the memorandum was verified by a level 4 WCR classifier. If the answers in reading one and reading two were the same as the memorandum, a mark was allocated. Each rater received a score out of 27 which was then calculated to a rounded off percentage score.

For objective two (to compare the intra-rater reliability between classifier Level 2, Level 3 and Level 4 regarding MMT outcome) the ICC was determined by comparing the 27 subjects for each rater from the original three videos to the 27 subjects for each rater in the repeated three videos. Thus 27 times 3 equals 81 subjects. The average measurement was used in the reporting of the results.

For objective three (to determine the inter-rater reliability of the three classifiers within each classifier level regarding MMT outcome) two different ICCs were determined for inter-rater reliability. The first ICC was determined by comparing the numerical values allocated by three raters in each level for the original videos. The second ICC was determined by comparing the numerical values allocated by three raters in each level for the repeated videos. The average measurement was used. To determine the accuracy of the MMT the answers of the three raters were compared to a memorandum. If all three raters numerical values corresponded to the memorandum one point was allocated. A total out of 27 was determined for the first and repeated videos separately. The totals were calculated to present rounded off percentages.

For objective four (to determine the inter-rater reliability across all nine raters) two different ICCs were determined for inter-rater reliability. The first one compared the numerical values allocated by all nine raters for the original video and the second for the repeated videos for all the athletes. The average ICC measurement and 95% confidence interval were used. To determine the accuracy of all the answers of all the raters for the first video, they were compared to a memorandum. If an answer for one subject was the same across all the raters and correlated with the memorandum, one point was allocated. A score out of 27 was determined for the first and repeated videos. Each mark thus presents a correctly-scored subject in correlation to a memorandum. The researcher will determine where the marks were allocated and what grade was given to each subject.

For intra-rater reliability the ICC was determined for raters individually for each grading made on each subject by each particular rater. For inter-rater reliability the ICC was determined using both measures (average measure) made on each subject by each rater.

3.8 ETHICAL AND LEGAL CONSIDERATIONS

International norms and standards were upheld by first asking the permission of the International Wheelchair Rugby Federation to conduct the study (see ANNEXURE R: Permission letter from IWRF).

Ethical and legal considerations were accounted for by following the ethical principles of Helsinki and the Health Professions Council of South Africa (HPCSA) guidelines for health researchers. [53] The ethical application was sought from the University of

Pretoria, SA, and the referral number for the protocol is 67/2016 (see Annexure Q: approval letter from Ethics committee)

The dignity, integrity, rights to self-determination, privacy and confidentiality of the athletes and classifiers in the videos, as well as that of the raters, were upheld. The athletes and classifiers who appeared in the videos were not recognised; only their hands were filmed. The video participants provided informed consent, received via email from the video participants, (see Annexure P: Informed consent for video participants). The researcher was available during the recording of the video footage for any questions or unclarity related to the study. All raters gave informed consent to take part in the study (see Annexure Q: Informed consent for raters). The electronic questionnaires were not linked to the raters; the researcher does not know who completed which electronic questionnaire.

There were no risks or burdens in this study. The athletes (people with disabilities) who appear in the videos for the questionnaires were not harmed and their identities will be kept private by the researcher.

There was no funding or sponsorship for the study and the student is able to carry the costs. The researcher is not affiliated to any institution.

The research was compiled in such a way that there could be no conflict of interest. The researcher submitted the protocol to the Faculty of Health Science Research Ethics Committee at the University of Pretoria for approval for the study to take place. At all times the researcher, acted in the best interests of the raters. If the athletes and classifiers in the video wished to stop their participation at any given moment, they were free to do so.

The researcher will store all information and main data for fifteen years; as stated before, the raters did not provide their names at any stage thus information is not traceable to the raters (see ANNEXURE S: Declaration of storage). No traceable information of the raters was required.

3.9 CONCLUSION

The researcher chose the research method from a quantitative non-experimental perspective allowing for the implementation of a cross-sectional design with convenient sampling. This which was supported by the main aim and objectives of the study. The data were analysed numerically according to the specified aim and objectives to confirm/deny intra-and inter-rater reliability. Extra numeric and percentage values were added to determine the accuracy of all the ratings.

CHAPTER FOUR – RESULTS

4.1 INTRODUCTION

This chapter encapsulates the results regarding the intra-and inter-rater reliability of MMT in the new hand classification of WCR. These results are presented in terms of the quantitative analysis in accordance with the following four objectives: the intra-rater reliability of each rater; the intra-rater reliability among level 2, level 3 and level 4 classifiers; the inter-rater reliability within each classifier level respectively; and lastly, the inter-rater reliability across level 2, level 3 and level 4 classifiers. The data were used to determine the ICC for each list by using the two-way model.[8, 9] The single or average measurement was used depending on the pair of ratings. If there was more than one rater the average measurement was used. To indicate the strength of agreement, the ranges provided by Landis and Koch (1977) were used. A total score and percentage value were determined by comparing the answers to a memorandum to indicate the accuracy of raters and levels, the best score being 100%.

4.2 THE SAMPLE

All international WCR classifiers were invited to take part in the research. There were 51 active international classifiers of which three participated in the pilot study. 29 Participated in the study and three were chosen for the pilot study. Availability sampling was used and the first three research participants/raters (WCR classifiers) in each level who completed the questionnaire were chosen for the study sample. Table 4.1 contains an illustration of the characteristics of the raters selected for the study sample.

Table 4.1: Characteristics of sample group

Occupation	Level classifier	Years of national experience	Years of international experience	Rater number
Physiotherapist	Level 2	5-10 years	0-2 years	1
Occupational therapist	Level 2	3-5 years	0-2 years	2

Other	Level 2	3-5 years	3-5 years	3
Physiotherapist	Level 3	>10 years	>10 years	4
Physiotherapist	Level 3	5-10 years	3-5 years	5
Physiotherapist	Level 3	5-10 years	5-10 years	6
Physiotherapist	Level 4	>10 years	>10 years	7
Physiotherapist	Level 4	>10 years	>10 years	8
Occupational therapist	Level 4	>10 years	5-10 years	9

4.3 INTRA-RATER RELIABILITY OF EACH RATER

To indicate the strength of agreement, the ranges provided by Landis and Koch (1977) were used: 0.0 – 0.2 slight, 0.21 – 0.4 fair, 0.41 – 0.6 moderate, 0.61 – 0.8 substantial and 0.81 – 1.00 almost perfect.[52]

Objective one was to determine the intra-rater reliability of each rater regarding an MMT outcome. Tables 4.2 to 4.10 represent the data displaying the intra-rater reliability for each of the nine raters by means of an ICC between readings one and two (repeated video). Single measures were used. The single measure ICC is the estimated reliability of one pair of ratings.

Table 4.2 displays the ICC for the first rater (level 2) between reading one and reading two. The ICC value between these two readings is 0.8990, with a confidence interval between 0.7930 and 0.9524.

Table 4.2: Intra-class correlation coefficient for the first rater.[54]

Statistical characteristic	Rater 1
ICC (Single measure)	0.8990
Upper CI	0.9524
Lower CI	0.7930

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.3 displays the ICC for the second rater (level 2) between reading one and reading two. The ICC value between these two readings is 0.8560, with a confidence interval between 0.7051 and 0.9321.

Table 4.3: Intra-class correlation coefficient for the second rater.[54]

Statistical characteristic	Rater 2
ICC (Single measure)	0.8560
Upper CI	0.9321
Lower CI	0.7051

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.4 displays the ICC for the third rater (level 2) between reading one and reading two. The ICC value between these two readings is 0.6782, with a confidence interval between 0.4140 and 0.8383.

Table 4.4: Intra-class correlation coefficient for the third rater.[54]

Statistical characteristic	Rater 3
ICC (Single measure)	0.6782
Upper CI	0.8383
Lower CI	0.4140

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.5 displays the ICC for the fourth rater (level 3) between reading one and reading two. The ICC value between these two readings is 0.7013, with a confidence interval between 0.4441 and 0.8518.

Table 4.5: Intra-class correlation coefficient for the fourth rater.[54]

Statistical characteristic	Rater 4
ICC (Single measure)	0.7013
Upper CI	0.8518
Lower CI	0.4441

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.6 displays the ICC for the fifth rater (level 3) between reading one and reading two. The ICC value between these two readings is 0.9459, with a confidence interval between 0.8862 and 0.9749.

Table 4.6: Intra-class correlation coefficient for the fifth rater.[54]

Statistical characteristic	Rater 5
ICC (Single measure)	0.9459
Upper CI	0.9749
Lower CI	0.8862

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.7 displays the ICC for the sixth rater (level 3) between reading one and reading two. The ICC value between these two readings is 0.6999, with a confidence interval between 0.4379 and 0.8517.

Table 4.7: Intra-class correlation coefficient for the sixth rater.[54]

Statistical characteristic	Rater 6
ICC (Single measure)	0.6999
Upper CI	0.8517
Lower CI	0.4379

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.8 displays the ICC for the seventh rater (level 4) between reading one and reading two. The ICC between these two readings is 0.8670, with a confidence interval between 0.7310 and 0.9370.

Table 4.8: Intra-class correlation coefficient for the seventh rater.[54]

Statistical characteristic	Rater 7
ICC (Single measure)	0.8670
Upper CI	0.9370
Lower CI	0.7310

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.9 displays the ICC for the eighth rater (level 4) between reading one and reading two. The ICC value between these two readings is 0.9195, with a confidence interval between 0.8312 and 0.9625.

Table 4.9: Intra-class correlation coefficient for the eight rate.[54]

Statistical characteristic	Rater 8
ICC (Single measure)	0.9195
Upper CI	0.9625
Lower CI	0.8312

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.10 displays the ICC for the ninth rater (level 4) between reading one and reading two. The ICC value between these two readings is 0.8145, with a confidence interval between 0.6363 and 0.9106.

Table 4.10: Intra-class correlation coefficient for the ninth rater.[54]

Statistical characteristic	Rater 9
ICC (Single measure)	0.8145
Upper CI	0.9106
Lower CI	0.6363

ICC: intra-class correlation coefficient

CI: confidence interval

4.4 COMPARISON OF INTRA-RATER RELIABILITY BETWEEN LEVEL 2, 3 AND 4

Objective two was to compare the intra-rater reliability between classifier level 2, level 3 and level 4 regarding MMT outcome. Tables 4.11 to 4.13 represent the data displaying the intra-rater reliability for each level by means of an ICC among the three raters in each level. Average measures were used. The average measure is the average ICC of all pairs of ratings.

Table 4.11 displays the ICC for the level 2 raters, between reading one and reading two. The ICC value between these two readings is 0.9195, with a confidence interval between 0.8312 and 0.9625.

Table 4.11: Intra-class correlation coefficient for level 2.[54]

Statistical characteristic	Level 2
ICC (Average measure)	0.9195
Upper CI	0.9625
Lower CI	0.8312

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.12 displays the ICC for the level 3 raters, between reading one and reading two. The ICC value between these two readings is 0.8703, with a confidence interval between 0.7986 and 0.9165.

Table 4.12: Intra-class correlation coefficient for level 3.[54]

Statistical characteristic	Level 3
ICC (Average measure)	0.8703
Upper CI	0.9165
Lower CI	0.7986

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.13 displays the ICC for the level 4 raters, between reading one and reading two. The ICC value between these two readings is 0.9279, with a confidence interval between 0.8880 and 0.9536.

Table 4.13: Intra-class correlation coefficient for level 4.[54]

Statistical characteristic	Level 4
ICC (Average measure)	0.9279
Upper CI	0.9536
Lower CI	0.8880

ICC: intra-class correlation coefficient

CI: confidence interval

4.5 INTER-RATER RELIABILITY WITHIN EACH LEVEL

Objective three was to determine the inter-rater reliability of the three classifiers within each level regarding MMT outcome. Tables 4.14 to 4.16 represent the data displaying the inter-rater reliability for each level by means of an ICC across all the raters in each level, for readings one and two (repeated video). Average measures were used. The average measure is the average ICC of all pairs of ratings.

Table 4.14 displays the comparison between readings one and two (repeated video) across all the raters in level 2. The ICC for both readings is 0.8888, with a confidence interval between 0.7591 and 0.9490.

Table 4.14: Intra-class correlation coefficient for level 2 reading one and two (repeated video).[54]

Statistical characteristic	Level 2
Reading one	
ICC (Average measure)	0.8888
Upper CI	0.9490
Lower CI	0.7591
Reading two (repeated video)	
ICC (Average measure)	0.8888
Upper CI	0.9490
Lower CI	0.7591

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.15 displays the comparison between reading one and two (repeated video) across all the raters in level 3. The ICC for reading one is 0.9156, with a confidence interval between 0.8410 and 0.9490. The ICC for reading two is 0.9189, with a confidence interval between 0.8462 and 0.9604.

Table 4.15: Intra-class correlation coefficient for level 3 readings one and two (repeated video).[54]

Statistical characteristic	Level 3
Reading one	
ICC (Average measure)	0.9156
Upper CI	0.9490
Lower CI	0.8410
Reading two (repeated video)	
ICC (Average measure)	0.9189
Upper CI	0.9604
Lower CI	0.8462

ICC: intra-class correlation coefficient

CI: confidence interval

Table 4.16 displays the comparison between readings one and two (repeated video) across all the raters in level 4. The ICC for reading one is 0.9194, with a confidence interval between 0.8478 and 0.9605. The ICC for reading two is 0.9404, with a confidence interval between 0.8878 and 0.9708.

Table 4.16: Intra-class correlation coefficient for level 4 reading one and two (repeated video).[54]

Statistical characteristic	Level 4
Reading one	
ICC (Average measure)	0.9194
Upper CI	0.9605
Lower CI	0.8478
Reading two (repeated video)	
ICC (Average measure)	0.9404
Upper CI	0.9708
Lower CI	0.8878

ICC: intra-class correlation coefficient

CI: confidence interval

4.6 INTER-RATER RELIABILITY ACROSS LEVEL 2, 3 AND 4

Objective four was to compare the inter-rater reliability among classifiers level 2, level 3 and level 4 regarding MMT outcome. Table 4.17 represents the data displaying the inter-rater reliability among classifier level 2, 3 and 4 by means of an ICC across all nine raters for reading one and reading two (repeated video). Average measures were used. The average measure is the average ICC of all pairs of ratings.

The ICC for reading one is 0.9589, with a confidence interval between 0.9304 and 0.9787. The ICC for reading two is 0.9655, with a confidence interval between 0.9413 and 0.9821.

Table 4.17: Intra-class correlation coefficient for all raters readings one and two (repeated).[54]

Statistical characteristic	Rater 1-9
Reading one	
ICC (Average measure)	0.9589
Upper CI	0.9787
Lower CI	0.9304
Reading two (repeated video)	
ICC (Average measure)	0.9655
Upper CI	0.9821
Lower CI	0.9413

ICC: intra-class correlation coefficient

CI: confidence interval

4.7 ACCURACY OF DANIELS AND WORTHINGHAM MMT

To determine the accuracy of each rater, a total score presented as a mark out of 27 was given. Each rater graded nine subjects per athlete. Three athletes were graded resulting in 27 subjects. Nine subjects for each athlete, three athletes, thus 27 times 3 equals 27 subjects. There are 27 subjects in the original videos and 27 subjects in the repeated videos. The total score is also presented as a rounded off percentage score; the best score being 100%. A mark was allocated when the MMT scores for each subject were the same in the first video, repeated video and correlated with the memorandum. During WCRC classifiers should execute and interpret the Daniels and Worthingham's MMT in the same way so that an athlete will be classified in the same class by different panels. Each classifier must therefore classify the same athlete the same way each time, MMT must therefore be accurate (in accordance with Daniels and Worthingham's MMT). Table 4.18 illustrates the total score and percentage score for each rater.

Table 4.18: The total score and percentage value for raters one to nine presenting accuracy.

Rater	Level 2, 3 or 4	Score over 27 subjects (one mark was allocated if scores in the first and repeated video correlated with the memorandum)	Percentage
1	Level 2	13/27	48.12%
2	Level 2	16/27	59.26%
3	Level 2	15/27	55.56%
4	Level 3	15/27	55.56%
5	Level 3	14/27	51.85%
6	Level 3	16/27	59.26%
7	Level 4	12/27	44.45%
8	Level 4	17/27	62.96%
9	Level 4	10/27	37.04%

The percentages indicate that the highest score is a level 4 classifier who scored 62.96% and the lowest score 37.04%. None of the raters scored 100%.

To determine the accuracy of each level, the same method was followed as previously mentioned. However, a total score was determined for the first and repeated videos separately. A mark was allocated when the MMT scores for each subject were the same across all the raters in each level and it correlated with the memorandum. Table 4.19 presents the total score and percentage value (accuracy) for each level.

Table 4.19: Representation of total score and percentage value (accuracy) compared to the memorandum.

		Rater 1-3 Level 2	Rater 4-6 Level 3	Rater 7-9 Level 4
First videos	**Median score for all three raters vs the total score**	11/27	11/27	9/27
	Percentage value (accuracy)	40.74%	40.74%	33.33%

Repeated videos	**Median score for all three raters vs the total score**	11/27	11/27	11/27
	Percentage value (accuracy)	40.74%	40.74%	40.74%

Levels two and three scored the same in the first and second video. Level four scored higher in the repeated video. None of the levels scored higher than 40.74% when compared to the memorandum.

To determine the accuracy across all nine raters, a total score presented as a mark out of 27 was given. The total score is also presented as a rounded off percentage score; the best score being 100%. A mark was allocated when the MMT scores were the same for each subject across all nine raters and it correlated with the memorandum e.g. rater one to nine graded 0-1 for finger flexion in the first video, their answers correlated with the memorandum which was 0-1 for finger flexion. Table 4.20 presents the total score and percentage value (accuracy) across all nine raters.

Table 4.20: Representation of score and percentage compared to the memorandum.

		Rater 1-9, Level 2-4
First videos	**Median score for all the raters vs the total score**	5/27
	Percentage	18.52%
Repeated videos	**Median score for all the raters vs the total score**	5/27
	Percentage	18.52%

The mean percentage score across all nine raters was 18.52% for both the original and repeated videos. The raters score vs the total score was 5/27. This indicates that there were only five subjects scored correctly across all nine rates when the MMT scores were compared to the memorandum. Table 4.21 presents the subjects (muscles) that were scored correctly across all nine raters with the correct MMT grade.

Table 4.21: Representation of correctly scored subjects (muscles) with their MMT grade.

Subjects scored correctly	Athlete 1 (First video)	Athlete 2 (First video)	Athlete 3 (First video)	Athlete 2 (Repeated video)
Finger extensors		0-1		0-1
Finger flexors		0-1	4-5	0-1
Interossei		0-1		0-1
Lumbricals	0-1			
Thumb extensor		0-1		0-1

4.8 ICC MEASURES FOR EACH SUBJECT

Table 4.22 represents the data displaying the intra-rater reliability for each of the subjects across all nine raters by means of an ICC between the first and repeated video. Single measures were used because there was only one subject.

Table 4.22: ICC score and strength of agreement for intra-rater reliability for each individual muscle.[54]

Muscles tested	ICC (between first and repeated video)	Strength of agreement for intra-rater reliability
Thumb flexor	0.4992	ICC value descriptive of moderate intra-rater reliability
Thumb abductor	0.5332	ICC value descriptive of moderate intra-rater reliability

Finger extensors	0.5490	ICC value descriptive of moderate intra-rater reliability
Thumb extensor	0.6893	ICC value descriptive of substantial intra-rater reliability
Thumb adductor	0.7240	ICC value descriptive of substantial intra-rater reliability
Finger flexors	0.7984	ICC value descriptive of substantial intra-rater reliability
Thumb opponens	0.8096	ICC value descriptive of almost perfect intra-rater reliability
Interossei	0.9551	ICC value descriptive of almost perfect intra-rater reliability
Lumbricals	0.9803	ICC value descriptive of almost perfect intra-rater reliability

The muscles with the lowest ICC scores were the finger extensors, thumb abductor and thumb flexor.

Table 4.23 represents the data displaying the inter-rater reliability for each subject (muscle) tested by means of an ICC across all nine raters for reading one and reading two (repeated video). Average measures were used because there was more than one rater.

Table 4.23: ICC scores and strength of agreement for each individual muscle for inter-rater reliability.[54]

Muscles tested	ICC (original/first videos)	Strength of agreement for inter-rater reliability	ICC (repeated videos)	Strength of agreement for inter-rater reliability
Finger extensors	0.1818	ICC value descriptive of slight inter-rater reliability	0.5942	ICC value descriptive of moderate inter-rater reliability
Thumb flexor	0.4037	ICC value descriptive of moderate inter-rater reliability	0.4380	ICC value descriptive of moderate inter-rater reliability
Thumb adductor	0.4676	ICC value descriptive of moderate inter-rater reliability	0.7594	ICC value descriptive of substantial inter-rater reliability
Thumb extensor	0.5503	ICC value descriptive of moderate inter-rater reliability	0.5083	ICC value descriptive of moderate inter-rater reliability
Finger flexors	0.6702	ICC value descriptive of substantial inter-rater reliability	0.9195	ICC value descriptive of almost perfect inter-rater reliability
Thumb abductor	0.6897	ICC value descriptive of substantial inter-rater reliability	0.5843	ICC value descriptive of moderate inter-rater reliability
Thumb opponens	0.7458	ICC value descriptive of substantial	0.6599	ICC value descriptive of substantial

		inter-rater reliability		inter-rater reliability
Interossei	0.9494	ICC value descriptive of almost perfect inter-rater reliability	0.9261	ICC value descriptive of almost perfect inter-rater reliability
Lumbricals	0.9754	ICC value descriptive of almost perfect inter-rater reliability	0.9730	ICC value descriptive of almost perfect inter-rater reliability

As illustrated in table 4.23, the finger extensors had ICC values of 0.1818 and 0.5942. Most of the subjects had a higher ICC score for the repeated video than the first.

4.9 SUMMARY OF RESULTS

Table 4.24 presents a summary of the data collected for objective one to determine the intra-rater reliability of each rater regarding MMT outcome. All ICC scores fall within the 95% confidence interval. The percentage value presenting accuracy was added to the table. None of the raters scored 100% accuracy.

Table 4.24: ICC (single measure) for each rater and percentage value (accuracy) representing accuracy.

Rater	ICC (single measure)	Percentage value (accuracy)
1	0.8990	48.12%
2	0.8560	59.26%
3	0.6782	55.56%
4	0.7013	55.56%
5	0.9459	51.85%

6	0.6999	59.26%
7	0.8670	44.45%
8	0.9195	62.96%
9	0.8145	37.04%

Table 4.25 presents a summary of the data collected for objective two to compare the intra-rater reliability between classifier level 2, level 3 and level 4 regarding MMT outcome. All ICC scores fall within the 95% confidence interval.

Table 4.25: ICC (average measure) for each level.

Level	ICC (average measure)
2	0.9195
3	0.8703
4	0.9279

Table 4.26 presents a summary of the data collected for objective three to determine the inter-rater reliability of the three classifiers within each classifier level regarding the MMT outcome. All ICC scores fall within the 95% confidence interval. The percentage value presenting accuracy was added to the table. None of the levels scored 100% accuracy.

Table 4.26: ICC (average measure) for readings one and two; and percentage value presenting accuracy within each level.

Level	ICC (average measure) reading one	ICC (average measure) reading two	Percentage value (accuracy) reading one	Percentage value (accuracy) reading two
2 (rater 1-3)	0.8888	0.8888	40.74%	40.74%
3 (rater 4-6)	0.9156	0.9189	40.74%	40.74%

4 (rater 7-9)	0.9194	0.9404	33.33%	40.74%

Table 4.27 presents a summary of the data collected for objective four to compare the inter-rater reliability between classifier Level 2, Level 3 and Level 4 regarding MMT outcome. All ICC scores fall within the 95% confidence interval. The percentage value presenting accuracy was added to the table. None of the levels scored 100% accuracy.

Table 4.27: ICC (average measure) for readings one and two; and percentage value presenting accuracy across all nine raters.

Level 2-4	ICC (average measure) reading one	ICC (average measure) reading two	Percentage value (accuracy) reading one	Percentage value (accuracy) reading two
Rater 1-9	0.9589	0.9655	18.52%	18.52%

The muscles (subjects) tested with the lowest ICC score were finger extensors, thumb abductor and thumb flexor. The finger extensors had the lowest ICC score. The only muscles that were graded accurately when compared to a memorandum were muscles with an MMT grades 0-1 and 4-5. Most of the accurate MMT scores were scored for athlete two in the video footage. Athlete two was classified as having a 2.0 hand.

All the ICC fall within the 95% CI. The narrower the CI the more precise the ICC, e.g. the average measure CI is narrower therefor more precise than the single measure.

CHAPTER FIVE – DISCUSSION

5.1 INTRODUCTION

This results for the following objectives will be discussed in this chapter: the intra-rater reliability of each rater in relation to experience; the comparison of intra-rater reliability among levels 2, 3 and 4; the inter-rater reliability within each level; the inter-rater reliability across all nine raters and lastly to determine the accuracy of MMT grades.

5.2 THE SAMPLE

The number of raters and trials needed for a study differs for inter-and intra-rater reliability. With inter-rater reliability the number of raters does not matter and fewer trials are needed.[7] In contrast with intra-rater reliability the more raters and trials involved the better.[7] With fewer trials the inter-rater reliability will be stronger but there will be a loss of precision and with more subjects the intra-rater reliability and the precision for inter-rater reliability will be stronger.[7] Each muscle has been regarded as a subject. The statistical balance for inter-and intra-rater reliability was nine raters who observed 54 subjects each (27 subjects in the original videos and 27 in the repeated videos).[7]

When a classification panel is compiled in WCR it consists of classifiers that are at different levels and with different national and international experience. The sample therefore had to have different levels, national and international experience to represent a classification panel. 17 questionnaires had to be discarded due to incomplete questionnaires and completion after the cut-off time (this was one of the reasons why the time period had to be extended). The remaining 12 completed the questionnaire (25% level 2, 25% level 3 and 50% level 4). Three raters from each level were selected to represent each level. Among the total participants there were 25% with 3-5 years, 25% with 5-10 years and 50% with more than 10 years of national experience. The international experience of total participants consisted of 16.67% with 0-2 years, 25% with 3-5 years, 16.67% with 5-10 years and 41.67% with more than 10 years' experience.

5.3 THE INTRA-AND INTER-RATER RELIABILITY OF MMT IN THE NEW HAND CLASSIFICAITON OF WHEELCHAIR RUGBY

Objective one, the intra-rater reliability of each rater in relation to experience, was validated. The intra-rater agreement for the third (table 4.4), fourth (table 4.5) and sixth (table 4.7) raters all had the lowest ICC values of between 0.61 and 0.80 which is descriptive of substantial level of intra-rater reliability. The third rater is a level one classifier and the fourth and sixth raters are level three classifiers.[52] The reasons for these ICC values are questionable since none of the raters have low national or international experience, and they are also raters from different occupations. Rater three indicated that he/she is not an occupational or physiotherapist. Raters four and six are both physiotherapists whom would have received in-depth training in MMT for their specific occupation, but not necessarily specifically Daniels and Worthingham's MMT. The highest ICC value was achieved by the fifth rater (table 4.6).[52] What could possibly have contributed to rater five, a level 3 classifier, having the highest ICC value of 0.9459, descriptive of an almost perfect level of intra-rater reliability, might be due to sufficient knowledge of Daniels and Worthingham's MMT and good training received in MMT as rater five is a physiotherapist. According to Florence et al. physiotherapists frequently use MMT to clinically assess patients with neuromuscular deficits. Their primary responsibility as part of the research team is muscle evaluation using MMT.[55] This article also states that the methods of testing and grading muscle strength described by Kendall and McCreary and Daniels and Worthingham are most often used by physiotherapist in the United States.[55] The third, fourth and sixth raters might be raters from other countries and the fifth rater might be from the United States. The article also mentions a study done by Lilienfeld in 1954 indicating a high degree of reproducibility amongst examiners from different educational backgrounds but similar orientation to the specific methods of MMT for their studies.[55] These studies indicate that the reason for the low and high ICC values might be because of detailed knowledge of Daniels and Worthingham's MMT being either lacking or sufficient. The educational background of the raters does not play a part if the orientation/training in muscle testing procedures is the same.[55]

A trainee in classification receives training from higher level classifiers at tournaments.[1] The knowledge of Daniels and Worthingham's MMT for each of these raters is thus dependent on the amount and detailed training they receive as trainees in classification. If the higher level classifiers' knowledge of Daniels and Worthingham's MMT is scant, the information they provide to trainees will also not be sufficient resulting in ICC values descriptive of substantial level of intra-rater reliability. The reason why the ICC values of some raters are descriptive of almost perfect levels of intra-rater reliability is thus probably because they received sufficient training.

Objective two, the comparison of intra-rater reliability among levels 2, 3 and 4, was validated. Level 2 to 4's ICC values were descriptive of almost perfect levels of intra-rater reliability within the level (table 4.11 to 4.13). Level 4 had the highest ICC value across the three raters (0.9279) followed by level 2 (0.8971) and then level 3 (0.8703). What could be a reason for level 3 having the lowest ICC value might be due to the fact that two of the three raters who have the lowest ICC values fall in the level 3 category. Level 4's high ICC value is indicative of a solid knowledge of Daniels and Worthingham's MMT. The level 4 raters in this study also have the most national and international experience of all the levels. On the other hand, these ICC values can also indicate that if another MMT technique had been used to determine the MMT scores in this study, it might have high ICC values but accuracy might be insufficient with regards to Daniels and Worthingham's MMT.

Objective three, to determine the inter-rater reliability within each level was also validated. Good intra-rater reliability is indicative of good inter-rater reliability. In this study the inter-rater reliability within each level was determined by the ICC values of all three raters within each level, between readings one and two (repeated video). When classifying an athlete it is expected of the classifier to be consistent in grading the athlete at various times.[13] It is thus expected that the ICC for reading one and reading two (repeated video) to be the same and if good intra-rater reliability is indicative of good inter-rater reliability, it is expected of levels 2, 3 and 4 to have ICC values descriptive of almost perfect levels of inter-rater reliability, in accordance with the previous results. Tables 4.14 to 4.16 indicate that all three levels have ICC values between 0.81-1.00 which is descriptive of almost perfect levels of inter-rater reliability. This is true for reading one and two (repeated videos).

Level 2, as illustrated in table 4.16, has the same ICC value for readings one and two (repeated video) of 0.8888 which is descriptive of almost perfect levels of inter-rater reliability. There might be some reasons for the high ICC values e.g. good knowledge and training of Daniels and Worthingham's MMT and due to a lack of national and international experience the level 2 raters might not have been distracted by an overflow of knowledge and practical experience that might elude/exclude the basics of Daniels and Worthingham's MMT and anatomy.

Level 3, as highlighted in table 4.15, has two different ICC values for reading one and reading two (repeated video). Level 3 has ICC values of 0.9156 for reading one and 0.9189 for reading two. Both these ICC values are descriptive of almost perfect levels of inter-rater reliability. The ICC value for level 4 is descriptive of almost perfect levels of intra-rater reliability which is indicative of high ICC values for inter-rater reliability. Level 4, as seen in table 4.16, has ICC values of 0.9194 for reading one and 0.9404 for reading two. Both these ICC values are descriptive of almost perfect levels of inter-rater reliability.

Both levels 3 and 4 raters have displayed greater ICC values for reading two (repeated video). Levels 3 and 4 raters were thus not consistent in the MMT grades. The repeated videos use a different angle during the Daniels and Worthingham's MMT, which might have provided more information to the raters. If the answers were not consistent for each subject (muscle) grade, it indicates questionable accuracy. According to Tweedy (2011) inter-rater reliability for MMT tends to be low but increases with examiner experience, increased training and strict adherence to testing methods.[13, 40] This statement is also verified by Scott et al.[5] This study verifies these statements made by Tweedy (2011) and Scott et al[5] because level 4 raters with the most national and international experience have the highest ICC values for reading one and reading two (repeated videos).

The fact that the ICC values for level 3 and 4 are not the same increases the likelihood that the first and second ICC values across all raters will not be the same. Objective four the inter-rater reliability across all nine raters was validated. Table 4.17 illustrates the ICC values across all nine raters for reading one and reading two (repeated video). Both ICC values are descriptive of almost perfect levels of inter-rater reliability across all nine raters. However, the ICC value for reading one is 0.9589 and for reading two (repeated video) 0.9655. Research has suggested that acceptable inter-rater reliability is difficult to achieve due to the wide range of MMT techniques[13] that could be used, but this study's results indicate high ICC values between 0.81-1.00 which is descriptive of almost perfect levels of inter-rater reliability across all nine raters. A study done by Frese et al. where they examined the inter-rater reliability of MMT grades by assessing middle trapezius and gluteus medius muscle strength by allowing the raters to use any MMT technique with no standardisation of positions and procedures, showed results of coefficients ranging from 0.11-0.58 revealing poor agreement.[55] Even though this study indicates high ICC values descriptive of almost perfect levels of reliability they might have still been inaccurate e.g. the raters might have all used MRC MMT instead of Daniels and Worthingham's MMT techniques.

While discussing the abovementioned information another question presented itself: how accurate are the Daniels and Worthingham MMT grades that were given for each subject (muscle) by the raters? Comments from classifiers also added to the importance of this question e.g. their uncertainty (during national and international classification events) regarding hand placement and interpretation of MMT of finger extension, lumbricals, interossei, thumb adduction and thumb abduction. Some comments made by the raters while answering the questionnaire were the following: they struggled to determine MMT grades between grades two and three due to all the MMT grade testing not being shown in the video. Another comment was made on the testing method for finger extension. In the videos the finger extensors of digits two to four were tested with PIP and DIP joints flexing during testing and not extended. The method in the video footage was according to Daniels and Worthingham's testing methods.[36] This study has high ICC values which is descriptive of substantial to almost perfect levels of intra-and inter-rater reliability. Even though MMT grades are consistent they can still be inaccurate. Inaccurate MMT grades can result in an athlete being classified into a wrong class. The WCR athlete will then compete at a level which is either too high or too low; the class will thus not be representative of his/her true sport-specific skills. If an athlete at a certain stage is classified accurately, his/her sport class will change. Constant changes to lower or higher classes should not occur since this affects the athlete, team and country directly by influencing the game structure of the team and motivation and focus of the player. Over time this will also have a direct effect on the trustworthiness of the WCR classification system.

As seen in table 4.18, to determine the accuracy of each rater, a total score presented as a mark out of 27 (27 subjects were graded in the first and repeated video) was given. The total score is also presented as a rounded off percentage score; the best score being 100%. When comparing the MMT grades to the memorandum, none of the raters scored 100%. In reviewing the results of each individual rater, the lowest percentage was a level 4 rater with 37.04% and the highest percentage was 62.96% by a level 4 rater. One rater is an occupational therapist and the other a physiotherapist with more than ten years' national experience and between 5-10 years of international experience. Both are thus expected to have sufficient knowledge of MMT. The accuracy of the knowledge of specific testing with Daniels and Worthingham MMT is thus questionable and the comments made by the raters might verify this. On the other hand, the comments made by the raters during the study might also be the reason for the low accuracy. The raters might have had higher accuracy scores had they tested the athletes themselves. Their decisions would then have been based on objective (ability of the patient to complete a full range of motion or to hold a position after passive placement, ability or inability to move the part against gravity) and subjective (actual amount of resistance an athlete tolerates) information.[36] In this study raters could only make use of objective information to determine the Daniels and Worthingham's MMT grade.

When referring back to table 4.19 the results for accuracy of level 2 and level 3 raters having the same percentage for the first and the repeated videos, present as 40.74%. Level 4 has 33.33% for the first video and 40.74% for reading two (repeated video). These scores might be low for this level because the rater that was the least accurate of all the raters when the MMT grades were compared to a memorandum is part of the level 4 group of raters. When reference to the international Paralympic committee's stance which alludes to an article written by Tweedy et al, WCRC as well as other Paralympic sport classification processes were developed based on expert opinions in light of the absence of relevant scientific evidence.[26] Classification at that stage was thus not based on scientific evidence. It might be that the level 4 raters formed part of the group of trained professionals who developed the various classification systems and through the transformation process of WCRC the basics of Daniels and Worthingham's MMT were lost. The focus might thus still be more on expert opinions and not on evidence-based system of classification.

When comparing the accuracy of all nine raters in table 4.20, they scored a median of 5/27 (18.52%) for the first videos and 5/27 (18.52%) for the repeated videos. This indicates that there are only five muscles that were graded correctly in readings one and two (repeated video). The five muscles that were graded correctly in the first and the repeated videos are: finger extensors (0-1 MMT), finger flexors (0-1 MMT for athlete two and 4-5 MMT for athlete three), interossei (0-1 MMT for athlete two), lumbricals (0-1 MMT for athlete one) and thumb extensor (0-1 MMT for athlete two) as illustrated by table 4.21. A study done by Noreau and Vachon lle Vachon where they compare three methods to assess muscular strength in people with spinal cord injuries, reports that MMT does not appear to be sensitive enough to determine improvements in muscle strength over time. However, they state that MMT has acceptable accuracy for muscle groups with low MMT grades. The results of the Noreau and Vachon lle Vachon study are verified by the results in this study. However, their study focusses on the MRC MMT and not Daniels and Worthingham's MMT.[39] The correctly graded muscles across all nine raters in this study have low MMT grades.

When referring back to table 4.22, the muscles with the lowest ICC values for intra-rater reliability are the finger extensors, thumb abductor and thumb flexor. None of the muscles have the same ICC value for readings one and two (repeated video), represented in table 4.23.

There are four muscles according to the literature review in this study that have not been executed or correctly interpreted when the MMT done is compared to Daniels and Worthingham's MMT. These muscles are lumbricals, interossei, opposition, finger extension and thumb extension. During classification, it was observed that classifiers would at times confuse the direction of the specific thumb tests. The execution of MMT for these muscles could not be evaluated due to the correct testing method that was shown on the video footage. Some raters commented during the data collection that finger extension was not tested the correct way; the method shown in the video footage is that of Daniels and Worthingham's MMT. This indicates that during classification finger extension is not tested according to Daniels and Worthingham's MMT.

The abovementioned results indicate high ICC values for all four objectives, which is descriptive of substantial to almost perfect levels of intra-and inter-rater reliability. Even though there are high levels of reliability, this study proposes that accuracy is low. The high reliability levels may display false “good results”. In addition, there is limited research pertaining to the reliability of Daniel’s and Worthingham’s MMT. It was thus decided to do another literature search.

5.4 A NEW LITERATURE SEARCH

A second literature review was conducted. The database search for literature included Medline, PubMed and Google Scholar to access full text articles through the University of Pretoria library service from 10 to 20 September 2016 and 3 January to 25 February 2017. The literature review consists of recent articles (not older than ten years).

The following key words were added after the results were interpreted: improvement of reliability, reasons for low reliability, inter-rater reliability, intra-rater reliability, reliability versus consistency in MMT, reliability of Daniels and Worthingham’s MMT, subjective versus objective assessment and MMT.

Inclusion criteria for the literature search were the following: articles published from 2007 to 2017; articles relevant to Paralympic classification; MMT of the hands and upper limb. Exclusion criteria were the following: articles older than ten years and articles that had no relevance to the study.

There were more than 11 100 articles which comprised the articles already mentioned in the literature review and only a few articles that had some relevance to the study. None of the articles could give more information than what was already known after the first literature review. The new articles verified the conclusions of the articles consulted in the first literature review.

A third literature review was conducted when the second literature review delivered poor results.

The database search for literature included Medline, PubMed and Google Scholar to access full text articles through the University of Pretoria library service from 15 to 26 March 2017.

The following key words were added after the results were interpreted: reliability of MMT; reliability versus accuracy of MMT; and the effect of video footage on reliability.

There were no exclusion criteria for the third literature review. More than 14 300 articles were found. These articles were published between 1980 to 2006. The articles relevant to this study were incorporated and discussed.

5.5 CLINICAL APPLICABILITY

MMT was developed by Lovett and described by Wright in 1912.[55] Over the years, several other methods of MMT were developed. Differences among the various MMTs include positioning, stabilisation, and application of force and extent of subdivision among the major categories of grades.[55] As stated before, a study done by Frese et al. examines the inter-rater reliability of MMT grades by assessing middle trapezius and gluteus medius muscle strength by allowing the raters to use any MMT technique. The positions and procedures were not standardised among examiners and the results showed coefficients ranging from 0.11 - 0.58 revealing poor agreement.[55] This study done by Frese et al. has high ICC values which is descriptive of substantial to almost perfect levels of intra-and inter-rater reliability. There is a possibility that the raters might have used other MMT techniques than that of Daniels and Worthingham; had the raters used the same MMT technique, the ICC values would probably also be high. This questions the accuracy of the MMT techniques used. The results in this study have low accuracy when the MMT grades are compared to Daniels and Worthingham's MMT.

Decreased accuracy can lead to inaccurate classification. Inaccurate classification will have tremendous effects on athletes and countries. In a study done by Ludwig Guttmann, he reports that sport is a pathway that might help even severely disabled people to live a healthier, happier life, to gain confidence and self-esteem and to achieve a degree of independence.[16] The class to which an athlete is assigned can influence his/her degree of success, which in turn has an impact on self-esteem and self-perception, peer and community recognition, as well as access to sponsorship and other financial rewards. For these reasons, inconsistency should be minimised.[13]

The IPC Classification Code requires all classification systems to: 1) identify eligible impairments for that particular sport; and 2) describe methods for assessment of athletes so that the impact of the impairment on the activity is proven.[12] These methods should be based on evidence. This approach is called an evidence-based system of classifications. Tweedy and Vanlandewijck state that, to promote participation in sports by people with disabilities, one has to minimise the impact of impairment on the outcome of the competition.[13]

As stated in an article written by Walter Schmitt and Scott Cuthbert, MMT is used in many professions as a diagnostic tool to determine a patient's progress during therapy. They postulate continue to say that MMT has been used in a large number of studies in a way that does not reflect the methods used in clinical practice. Schmitt and Scott illustrate the common mistakes made in MMT and highlight the importance of accuracy in MMT. Some of the mistakes are: not using standardised MMT and reproducible execution. They conclude by reiterating the importance of the information gathered when adding MMT during the evaluation of a patient since this will enhance clinical decision-making. However, when using MMT in practice, attention should be given to correctly and accurately execute MMT. [56] In a study done by Frese et al. they recommend that if MMT grades are to be used to make clinical decisions, the reliability should be documented according to the various MMT methods applied, age groups and patient populations.[55] Brandan states that experienced testers using standardised protocols can assess the strength of some intrinsic muscle groups quite reliably. He holds that MMT is a useful way for assessment of neuromuscular disorders.[57]

In summary, high levels of consistency but low accuracy are displayed in this study when compared to the Daniels and Worthingham MMT memorandum. There are various techniques that can be implemented to increase the accuracy of Daniels and Worthingham's MMT in WCRC and clinical practise. These techniques will be discussed in chapter 6, heading 6.3.

5.6 LIMITATIONS

The main limitations of this study were logistics and finances on international and national level. On international level, the raters are all hail from various countries. It would have been difficult to get the athletes and raters together at one point in time for the data collection. On a national level, the athletes and classifiers featured in the video footage were at one location only once. There was thus only one opportunity to record the videos. This resulted in no changes being made to the video footage after the pilot study but only to the video instructions before each video e.g. one of the comments made in the pilot study was that the full passive range of motion was not shown in the video footage. This made it difficult to determine if the active range of motion shown by the athlete was full range or not. The researcher could only address this by adding extra information before each video; by stating that each athlete had full passive range of motion for each joint.

Another comment made by the participants in the pilot study was that it was difficult to determine the exact MMT grade if more than one MMT grade for each muscle was not demonstrated in the video footage. It was considered by the researcher to add this information before the videos were recorded, but this would have increased the time of video footage. Completing the questionnaire would have taken a lot of the rater's time, decreasing the motivation and eagerness to complete the questionnaire.

The ICC values in the repeated videos are higher that that of the original videos shown. A study done byi Dockrell et al. uses video footage to determine the reliability of rapid upper limb assessment as a method of assessment of children's computing posture. The researchers use more or less the same methodology as in this study. However, before the raters (physiotherapy students) scored the video footage they attended a 45-minute training session on the use of the assessment tool followed by a practical session with time allocated to questions on the assessment tool. In the research they make use of objective assessment methods as is the case in this study. Their results demonstrate higher intra-rater reliability than inter-rater reliability. They report that there was evidence of a learning effect with higher reliability in the second videos scored. This might also be the case in this study: the ICC values in the repeated videos are higher than that of the original videos shown.[58]

The three muscles that were added to the physical assessment/bench test in the new hand classification of WCR were the lumbricals, thumb opposition and interossei. The problems observed by the researcher during the MMT of these muscles could not be evaluated in this study due to the correct testing methods, according to Daniels and

Worthingham's MMT, depicted in the video footage. The correct execution of MMT by the raters of these three muscles is thus still unknown.

If the raters scored the subjects themselves, other statistical measures could have been used e.g. standard error of measurement. Another nominal scale for scoring could also have been used. The ranges provided for the MMT scoring were very limited and small differences were not obvious. The strength between different grades was not assumed to be constant.[38]

Lastly, the raters also had the opportunity to view the video footage more than once. If the raters realised that there were repeated videos they could have returned to the first video and change their MMT grade for a subject. This would have had an influence on the reliability. The reliability would then have appeared to be higher than what it actually is.

Despite the limitations, it appears that the ICC values are descriptive of almost perfect levels of intra-rater and inter-rater reliability of the MMT in the new hand classification of WCR; thus very good consistency but poor accuracy.

5.7 REPORTING OF RESULTS

The researcher will aim to: 1) report to the IWRF at an international tournament; 2) present to the South African national classifiers; 3) present at an international tournament when the researcher is selected to attend by the IWRF; 4) report to the Occupational Therapy Department at the University of Pretoria; 5) aim to present at the Occupational Therapy Association of South Africa national congress; 6) aim to publish in the European Journal of Adapted Physical Activity (©European Federation of Adapted Physical Activity); and 7) email the article to all the IWCR classifiers.

5.8 CONCLUSION

This chapter presents the discussion of the analyses of the results compared to previous studies to validate the findings of this research study. The sample size (raters) and subjects graded were sufficient to have statistical power. There were almost perfect intra-rater and intra-rater reliability (consistency) of all the raters but poor accuracy when compared to the memorandum of Daniels and Worthingham's MMT.

CHAPTER SIX – CONCLUSION

6.1 INTRODUCTION

In this chapter the final analysis for each objective will be summarised and recommendations will be made.

6.2 CONCLUSION

The outcomes for the four objectives in this study may be summarised as follows:

To determine the intra-rater reliability of each rater regarding MMT outcome.

The ICC values are descriptive of substantial to almost perfect levels of intra-rater reliability for each rater regarding Daniels and Worthingham's MMT outcome. The accuracy is questionable so a percentage value was determined. The percentages indicate the highest score as that of a level 4 rater who has 62.96% and the lowest score 37.04%, also of a level 4 rater. None of the raters scored 100%.

To compare the intra-rater reliability between level 2, level 3 and level 4 regarding MMT outcome.

The ICC values for all three levels are descriptive of almost perfect levels of intra-rater reliability. The highest ICC value is 0.9279 for a level 4 and the lowest ICC value, 0.8703 for a level 3 rater. The ICC values for all three levels are descriptive of almost perfect levels of intra-rater reliability between classifier levels.

To determine the inter-rater reliability of the three raters within each level regarding MMT outcome.

All three levels have high ICC values which is descriptive of almost perfect levels of inter-rater reliability. Even though there is almost perfect agreement there is no evidence if the agreement is accurate.

Level two and three scored the same in the first and second video. Level four scored higher in the repeated video. None of the levels scored higher than 40.74% when correlated with the memorandum.

To compare the inter-rater reliability across all the raters regarding MMT outcome.

The repeated videos have a higher ICC value of 0.9655 which is descriptive of almost perfect levels of inter-rater reliability. Even though the ICC value is less for the first reading at 0.9589 it is still descriptive of almost perfect levels of inter-rater reliability. Even though the ICC values display high levels of agreement the accuracy is still questionable. All the raters scored 18.52% accuracy for the first and repeated videos. There are only five muscles graded accurately when compared to a memorandum. These muscles are: finger extensors (0-1 MMT), finger flexors (0-1 MMT for athlete two and 4-5 MMT for athlete three), interossei (0-1 MMT for athlete two), lumbricals (0-1 MMT for athlete one) and thumb extensor (0-1 MMT for athlete two).

6.3 RECOMMENDATIONS

MMT is an integral component of Paralympic sports classification, because it is practised internationally, requires little equipment and is easy to administer.[39]

In WCR classification the accuracy of Daniels and Worthingham's MMT needs to improve.
There are ways to improve the accuracy of Daniels and Worthingham's MMT encapsulated in the new hand classification of wheelchair rugby. It is submitted by the researcher that the following needs to change and/or put in place:

The classifiers need detailed practical training in the testing methods of Daniels and Worthingham to improve the accuracy of WCRC.[13, 36] Classifiers should be made aware of the possible implications of using other MMT for classification methods[13, 25] and the differences between Daniels and Worthingham and other MMT techniques.[13, 25] A review of the anatomy and biomechanics of the hand can also be considered to refresh the knowledge of classifiers who do not work with patients with hand injuries every day.[1, 14]

Daniels and Worthingham's MMT differs from the MRC MMT in many ways.[13] Taking gravity into consideration and using ROM as a descriptor are two of them as is done in Daniels and Worthingham's MMT. New research indicates that gravity does not have to be taken into consideration when testing the intrinsic muscles of the hand.[36] This new research has to be incorporated into classifying to ensure that WCRC is based on scientific evidence and not examiner experience.[59] When an athlete presents with decreased ROM in his/her joints the muscle strength is tested within the available range of that specific joint. The WCR classifiers then give a muscle grade within the limited ROM. This does not correspond with Daniels and Worthingham's MMT.[36] The limited ROM needs to be taken into consideration during MMT, and thus the muscle strength will be graded lower due to the decreased ROM. One might then argue that even though the athlete has limited ROM, the strength in that range is sufficient for certain functional skills to play WCR. However, in WCR, classification consists of three distinct stages: 1) physical assessment/ bench test; 2) technical assessment (including a range of sport-specific tests and novel non-sport tests); and 3) observation assessment (observation of sport-specific activities on court).[1, 2] The functional skills of an athlete with limited ROM can be observed in the technical and observation assessment and incorporated into the decision making process for the athlete's class.[1, 2] Another way forward for WCRC is to change the reference ROM: instead of using the normal anatomical range as the full range of motion, rather use the reference range to the maximum range of movement needed for the specific sport functions in WCR.[13] One last point to think about is that limited ROM be taken into consideration during the new trunk test. If an athlete has limited ROM in his/her trunk, he/she will fail certain tests. The athlete will also fail the lower limb MMT during the trunk classification if the legs do not have full ROM.[60] Limited ROM cannot be taken into consideration for only certain MMTs in WCRC, it needs to be taken into consideration for all MMTs in WCRC.

During classification, classifiers use plusses or minuses to indicate certain muscle strengths. This is an indication that other MMT techniques are being used because

Daniels and Worthingham do not use any pluses or minuses.[36] Using pluses and minuses adds a level of subjectivity that lacks reliability.[36]

Some of the MMT wording used on the classification form should be revised. Daniels and Worthingham's MMT focuses on a single muscular complex and other methods test individual muscles.[36] Table 6.1 presents possible changes to the classification form:

Table 6.1: Possible changes the WCR classification form for MMT of the hand.

Current description on WCRC form	Possible changes to WCRC form
Interossei	Finger abduction
Lumbricals	MP flexion
Thumb opponens	Opposition

To improve accuracy the following can be done: detailed training in the use of Daniels and Worthingham's MMT; supplying the classifiers with pictures and descriptions in the textbook; describing a reference range of motion for WCR in the upper limbs; and improvement of the test description on the testing sheet.

For future studies, it is advised that raters test the athletes themselves. The skill of the raters when conducting the MMT can also be evaluated. In this study the raters could only rely on objective information to determine the MMT grade for each muscle. Objective information includes the ability of the athlete to complete a full range of motion or to hold a position after passive placement and the ability or inability to move the part against gravity. The raters could not add subjective information to the scoring of each subject. Subjective information is the actual amount of resistance an athlete tolerates.[36] The researcher tried to compensate for the lack of subjective information by grouping different muscle grades together so that the raters could make a decision by only relying on their objective information. Had the raters tested the athletes themselves, the subjects tested could have been viewed and palpated from various angles and not only the two provided in the videos. This might be the main reason for the low accurate scoring of the subjects because the raters could only rely on objective information.

For future studies using video footage, it is advised that the raters not be able to go back and change the grade they chose for the muscles. If the raters noticed that the videos were repeated this might have had an influence on the reliability.

A question that can be added with a similar study would be to ask the rater/raters experience with Daniels and Worthingham's MMT.

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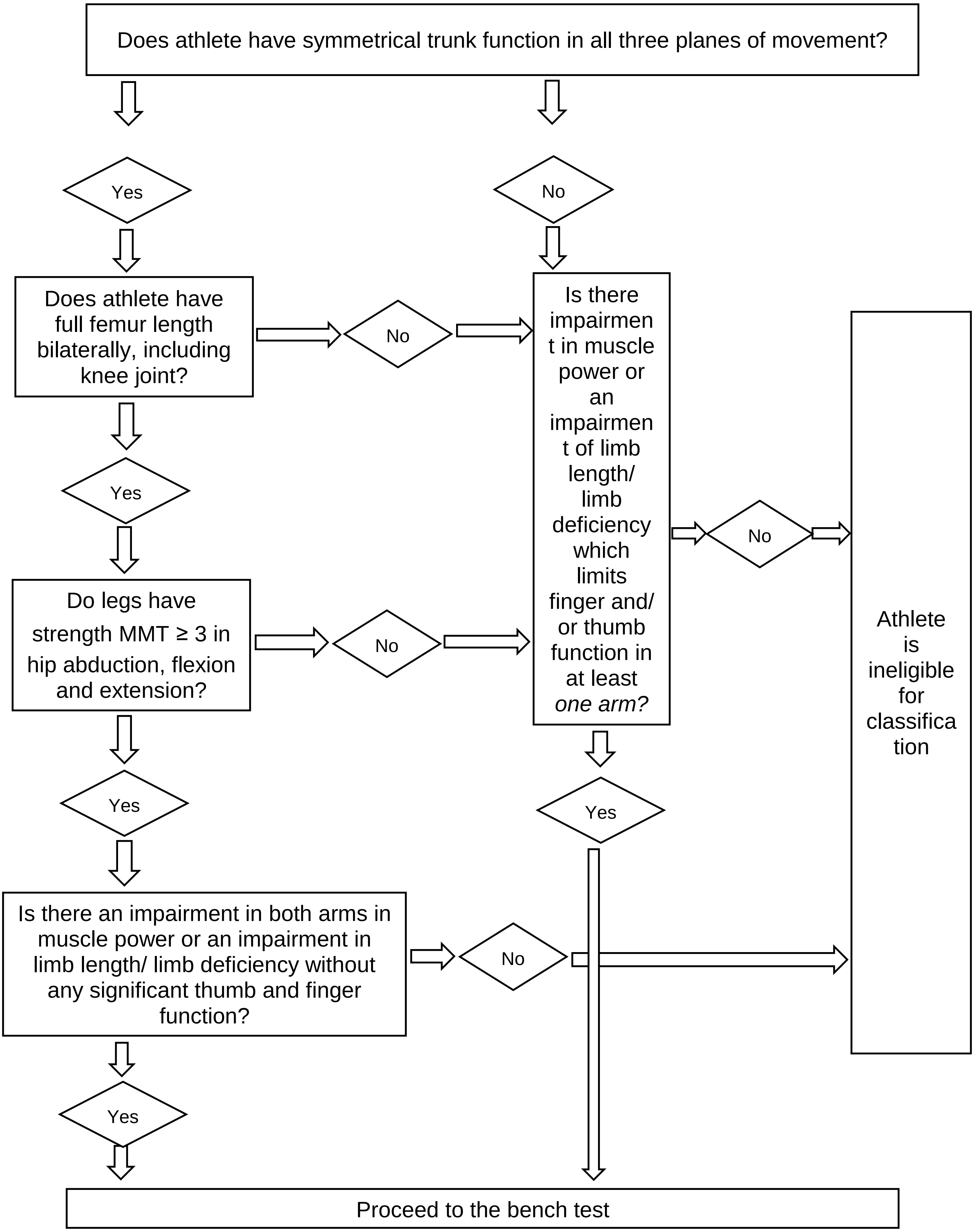
ANNEXURE A:

ELIGIBILITY TEST FOR CLASSIFICATION IN WHEELCHAIR RUGBY

ELIGIBILITY TEST FOR CLASSIFICATION IN WHEELCHAIR RUGBY[1]



ANNEXURE B:

ATHLETE CLASSIFICATION PATHWAY

---CLASSIFICATION EVALUATION PERIOD [1]----------------------------------

1. Athlete Arrives for Classification
   - Sitting in competition chair
   - With gloves, straps, tape available
   - With Coach/Team Representative and/or Translator

2. Athlete Evaluation Begins in Classification Area

   Athlete will be asked to remove jersey/uniform shirt and equipment.
   Athlete may be asked to transfer from rugby chair for specific tests.

   - Interview
   - Eligibility for Classification Determined (Eligibility Test)
   - Bench Test/ Physical assessment
     - Manual Muscle Testing
   - Trunk Tests

3. Technical Assessment
   - Functional Tests
     - Wheelchair tasks
     - Ball tasks

   Athlete will need gloves, straps, tape and equipment for functional tests.

Entry Sport Class & Sport Class Status

- Classification Card Provided
- Fee Collected for Card

4. Observation Assessment
   - During Training
   - During Competition

COMPETITION PERIOD —— *EVALUATION*

1. Sport Class and Sport Class Status Confirmed for this Competition
   - Classification Card Completed

ANNEXURE C:

OLD HAND CLASSIFICATION IN WCR

3.11 Hand Testing[1]

One of the defining characteristics of athletes in Wheelchair Rugby is impairment consistent with tetraplegia, especially impairment in the arms and hands. Specific tests were developed to evaluate the intrinsic muscles, or the small muscles of the fingers and thumb, located in the hand. These hand tests should be performed whenever there is a question about the amount of involvement in the hand.

3.11.1 Hand Testing Guidelines

When examining muscle function of the intrinsics, including the interossei and lumbricals, the muscles being evaluated all have origin and insertion within the hand. The tests are typically applied when the classifier is inquiring whether an athlete has 3.0 or 4.0 hand function.

This hand muscle function is given a point value using nine specific hand tests described in Article 3.11.2. There are three possible point values for each of these tests:

1 point = for a positive test look for pure motion, a movement that is not substitution.
0.5 point = for a partial test look for limited movement of the muscle group you are testing; muscle performance is imperfect; some substitution may be identified.
0 point = for a negative test observe substitution instead of pure or partial performance.

Also, there are three elements to observe when performing the hand tests:

- Atrophy or "wasting" in the hands,
- Decreased or absent maintenance of the hand arches, and/or
- Quality of movement, whether pure or substituted.

The classifier doing the testing may perform the test on another classifier with normal hand function and then return to the athlete for comparison and to make a final decision.

Hand tests values are recorded for each test and then summed for the point value. The following values determine the final hand function:

1.0 – 8.0 points = 3.0 hand function
8.5 – 9.0 points = 4.0 hand function

3.11.2 Specific Hand Tests

1) Observe hands for wasting (muscle atrophy).

- 1 No to minimal wasting observed, hand arches maintained
- 0.5 Partial wasting observed
- 0 Severe hand wasting, evidence of absent intrinsic functioning

2) Athlete puts forearms on the table, palms down; athlete taps fingers digits 2-5, as if playing the piano.

- 1 Pure movement, no substitution patterns noted; movement has good quality and hand arches are maintained
- 0.5 Partial ability to perform in two of four digits, hand arch is maintained, movement is weak
- 0 No ability to perform, all substitution

3) Have the athlete assume the lumbrical position (MCPs flexed, PIPs and DIPs extended). The athlete must try to keep the wrist in neutral. Put a piece of paper between fingers and try to pull out.

- 1 Good starting position with wrist in neutral, able to give resistance
- 0.5 Partial ability to maintain starting position, but does not have good quality of movement
- 0 Unable to assume starting position, all substitution

4) Have the athlete assume the “claw position” (MCP joints extended with IP joints in slight flexion) maintaining a neutral wrist. Feel the integrity of the extensor tendons in the dorsum of the hand.

- 1 Good quality of movement with wrist maintained in neutral
- 0.5 Partial involvement with difficulty maintaining position and poor quality
- 0 Unable to assume the position

5) Have the athlete make O's with each digit and thumb, hold against resistance.

- 1 Able to do with all four digits with good resistance and quality of movement.
- 0.5 Able to do with only a few digits 1 or 2 (makes “egg” instead of “O” shape with others)
- 0 Unable to perform

6) Put coins on the table and have the athlete pick them up with tip of index finger and thumb. You are looking for pure quality of movement with this action and no substitution with sides of thumb or finger pads.

- 1 Able to assume position and pick up with finger tips
- 0.5 Can assume position but cannot pick up coins without substitution
- 0 Unable to perform

7) Place a piece of paper between the athlete’s fingers (digits 2-5). Make sure paper is all the way between fingers. Apply resistance to the paper.

1	Able to perform with good quality and with resistance
0.5	May assume position but unable to perform with resistance
0	Unable to assume position

8) Have the athlete hold the ball overhead in palm of hand and then bring ball up to fingertips.

1	Pure movement with evidence of hand arches
0.5	Partial movement, or unable only due to lack of sensation
0	Flat hand, unable to perform without substitution

9) Have the athlete "walk" the ball up the wheel of the rugby chair with fingertips.

1	Good quality of movement
0.5	Use of fingertips is partial, hand has partial flat look
0	Flat hand, unable to perform without using palm

4 Hand Function

Wheelchair Rugby is designed for athletes with tetraplegia and tetra-equivalent impairment. One of the defining characteristics of athletes in Wheelchair Rugby is impairment and activity limitation in all four limbs. This section describes the range of bench testing results as well as examples of the activity limitations associated with impairments of muscle strength in the hands.

Single muscle test values are not the most important factor in hand function. The combination of muscle values is important in the final determination of hand function.

4.1 The 2.0.Hand

MUSCLE STRENGTH

Wrist flexion	4-5
Wrist extension	4-5
Finger flexion and extension	0-2
Finger adduction and abduction	0-2
Intrinsics	0
Thumb movements	0-2

OBSERVATION

The characteristic 2.0 hand has balanced strength of wrist extension and flexion, extreme intrinsic muscle wasting, including thenar and hypothenar eminences, and no maintenance of the hand arches. If there is any visible or palpable finger muscle contraction, strength is poor and any grasp and release action is obtained with tenodesis at the wrist.

FUNCTION

- Because of lack of isolated finger flexion, there is limited ball security for passing against challenge by the defence.
- Can hold the ball firmly with wrists, but does not have useful finger activity.
- Typically, weak one-hand overhead pass with limited control and distance.
- Rarely see one-hand overhead passing on court during competition, unless for in-bounding, but may be able to perform a one-hand pass as part of functional tests during classification.

4.2 The 2.5 Hand

MUSCLE STRENGTH

Wrist flexion and extension	5
Finger flexion and extension	2-4
Lumbricals	0-3
Interossei	0-2
Thumb opposition, abduction	0-2
Thumb adduction, extension, flexion	0-4

Explanatory Note: In the athlete with 2.5 hand function, finger flexion is predominately due to the action of Flexor Digitorum Superficialis (FDS), at the proximal interphalangeal (PIP) joints of the fingers and Flexor Digitorum Profundus (FDP) at the distal interphalangeal (DIP) joints of the fingers without the stabilising influence of functional intrinsics. This lack of intrinsic muscle stabilisation results in 'curling' and 'uncurling' of the fingers, rather than true functional grasp and release seen in the athlete with 3.0 hand function.

OBSERVATION

The 2.5 hand displays marked intrinsic wasting, including thenar and hypothenar eminences, and little or no maintenance of the hand arches.

FUNCTION

- Reasonably balanced finger flexion and extension ('curling' and 'uncurling')without true grasp and release because of the absence of stabilisation from the intrinsic muscles of the hand.
- Utilises extended wrist position (tenodesis) to strengthen grip and uses flexed wrist position to release grip, but may be able to perform some grip and release manoeuvres (curling and uncurling) independent of wrist position.
- Functional grip that is used to advantage on the push rim when challenged, often more ulnar grip.
- Dribbles the ball safely, but will supinate forearm to scoop the ball onto the lap.

- Capable of performing one-hand overhead pass, but with limited accuracy and distance. May use the one-hand pass on-court in situations other than inbounding.
- Safe two-handed catching of passes, usually followed by scooping ball to lap. May catch passes with one hand and scoop to lap or to chest.
- Improved ball security compared to athlete with 2.0 hand function due to improved ability to isolate wrist/finger function.

4.3 The 3.0 Hand

MUSCLE STRENGTH

Wrist flexion and extension	5
Finger flexion extension	3-5
Finger adduction and abduction	0-4
Thumb flexion, extension, adduction	3-4
Thumb abduction, opposition	3-4

OBSERVATION

The 3.0 hand has a strong, balanced wrist; that means equal or near equal strength in both flexion and extension, with visible atrophy in interossei, and intrinsic muscles in the thenar and/or hypothenar eminences of the hand. This atrophy is often visible as a "flattening" of the thenar and/or hypothenar eminences rather than the more extreme wasting seen in the athlete with 2.0 or 2.5 hand functions. There is little or no maintenance of hand arches.

The hand should have either weakness in the intrinsics or weakness in thumb opposition and abduction. Finger flexion and extension in general is usually stronger than in 2.5 hands. A value of 3/5 or more for interossei and/or thumb opposition and/or abduction usually excludes a hand from 2.5 and indicates a 3.0 hand.

Explanatory Note: It is important to remember single muscle tests values are not the most important factor in hand function. The combination of muscle values is important in the final determination of hand function. For example, a hand with 5/5 for finger flexion and extension, 4/5 for finger abduction and adduction and 4/5 for all thumb movements is more likely to be a 4.0 hand.

FUNCTION

- Wasting/atrophy in intrinsics and/or thenar/hypothenar eminences.
- Hand arches show little or no maintenance.
- Has functional grasp and release of hand independent of wrist position.

- Because of improved activity in finger muscles, can control ball in varying planes of movement for passing, dribbling, catching and protecting ball during these activities.
- Can dribble and pass ball well with one hand.
- Multiple dribble one hand with control.
- Can stabilise with one arm to allow greater reach with the opposite arm, even if the athlete has no trunk function.

4.4 Comparison of the 3.0 and 4.0 Hand

The athlete with 3.0 hand function still displays weakness in those muscles that originate and insert in the hand (refer to Article 3.11 Hand Function Testing). The athlete with 4.0 hand function has normal or near normal strength in the hands and the ability to perform tasks in a way that is consistent with few to no activity limitations in the tasks specific to Wheelchair Rugby. The hand tests were developed to help differentiate between an athlete with impaired strength and associated activity limitation, or a 3.0 hand, and an athlete with normal or near normal hand strength and function. It is important to look at all tasks, and the combination of tasks when comparing the 3.0 and 4.0 hand.

4.4.1 Hand Test Scores and Observation

3.0 point (0 - 8 points hand function tests)

- Balance between wrist flexor and extensor muscles, at least grade 3/5.
- Visible wasting/atrophy of the intrinsic muscles and/or muscles in thenar/hypothenar eminences.
- Hand arches are not maintained.
- Muscle tone and/or sensory changes usually present.
- Functional grasp and release independent of wrist position.

4.0 point (8.5 – 9.0 points hand function tests)

- Balance between flexor and extensor muscles in wrist and hand is greater than or equal to 4/5 strength.
- Balanced and coordinated movements of the hand.
- Opposition is a pure movement without substitution.

4.4.2 Ball and Wheelchair Tasks

Palming the ball

3.0 Unable to perform in a challenged situation.

4.0 Can palm and control the ball above the head; and maintains stability of the ball in a challenged situation.

Explanatory Note: Classifiers should take caution and be very observant. Palming the ball may also be a skill depending on the size of the athlete's hand and/or the use of equipment to stick to the ball. An athlete with sufficient hand function but small hand size may not always be able to palm the ball, especially without the use of equipment. However, an athlete without hand function but with large hands and/or the right equipment can stick to the ball with one hand. It is important to evaluate this task with and without gloves and equipment.

Dribbling retrieval

3.0 Uses strong wrist and finger flexion and extension to compensate for lack of intrinsic muscles and a weak thumb. Supinates the ball into the lap because of poor grip.

4.0 Controls the ball in all planes with no substitution patterns.

Overhead, one-handed wrist flip pass

3.0 Poor stability in palm. Decreased accuracy and distance in one-hand pass.

4.0 Good accuracy and distance.

Catching passes

3.0 Two-handed catch, may immediately pull the ball to the lap.

4.0 May catch one-handed or may hold the ball away from the body with one hand.

Explanatory Note: Classifiers should take caution and be very observant. There are some athletes in the 3.0 sport class who are capable of catching with one hand, and also holding the ball away from the body with one hand. Some athletes with large hands, and/or assistive equipment and/or who have developed ball skills from participating in other sports can catch with one hand and/or hold the ball away from the body with one hand. It is important to get a complete history, check equipment and not penalize athletes for body size, equipment, training and/or athletic skill.

Gripping for stops and starts

3.0 May require increased effort and time with some slippage on the wheel.

4.0 The athlete has no limitations because of good finger flexion, extension and thumb strength.

Explanatory Note: The above characteristics are described to assist a classifier in training to understand eligibility related to hand function and are not inclusive of all possible characteristics.

ANNEXURE D:

CLASSIFIER CERTIFICATION CRITERIA

CLASSIFIER CERTIFICATION CRITERIA[1]

There are specific competencies for certification at each level. Minimal criteria for certification and advancement include, but are not limited to:

Level 1 National Classifier

1. Complete basic formal workshop supervised by an IWRF international classifier Level 3 or 4.
2. Read IWRF code of conduct.
3. Demonstrate basic knowledge of the game of rugby.
4. Begin logbook documenting rugby experience and activities

Level 2 Zone or International Classifier

1. Demonstrate minimum of one year classifying with national or zone Wheelchair Rugby.
2. Perform complete physical assessment/bench test, functional tests, and on-court observation.
3. Demonstrate ability to evaluate athlete independently and provide explanations of findings to the classification panel, athletes and appropriate athlete support personnel.
4. Communicate with chief classifier regarding classification issues at specific competition.
5. Seek guidance and assistance when needed.
6. If training with a zone panel, the classifier may be verified as Level 2 cone (Level 2 Z).
7. If training with an international panel, the classifiers may be certified as Level 2 international (Level 2 I).

Explanatory Note: If certified to work in his/her zone with other experienced classifiers but not yet competent to work independently at an international event, a trainee working with an international panel may receive a zone certification.

Level 3 International Classifier

1. Complete advanced workshop, supervised by IWRF international classifier Level 3 or 4.
2. Demonstrate minimum of two years of experience as a Level 2 classifier.
3. Appointed as a member of a Type A or B panel in at least one international tournament.
4. Instruct all or part of a basic workshop supervised by another IWRF international classifier Level 3 or 4.
5. Experience as Chief Classifier at a tournament with a minimum of four teams participating.

6. Explain the protest procedure and eligibility requirements to classification panel, athlete and appropriate athlete support personnel.

Level 4 International Classifier

1. Demonstrate leadership skills and activities in matters related to classification, such as administration and management of classification.
2. Continuing participation in training and certification of classifiers, such as teaching at advanced workshops and supervising/mentoring instructors at basic and advanced workshops.
3. Active participation in IWRF Classification Commission (ICC) meetings.
4. Continuing participation as member of classification panel at international, zone and/or national level (specifically, serve as a member on a minimum of two Type A or B classification panels within a four-year period to maintain certification as Level 4).

ANNEXURE E:

NEW HAND CLASSIFICATION WCR

7 Hand Function[1]

This section describes the range of physical assessment results as well as examples of the activity limitations associated with impairments of muscle strength in the hands.

Single muscle test values are not the most important factor in hand function. The combination of muscle values is important in the final determination of hand function.

7.1 The 2.0.Hand

MUSCLE STRENGTH

Wrist flexors	4-5
Wrist extensors	4-5
Finger flexors and extensors	0-2
Intrinsics	0
Thumb movements	0-2

OBSERVATION

The characteristic 2.0 hand has balanced strength of wrist extension and flexion, extreme intrinsic muscle wasting, including thenar and hypothenar eminences, and no maintenance of the hand arches. If there is any visible or palpable finger muscle contraction, strength is poor and any grasp and release action is obtained with tenodesis at the wrist.

FUNCTION

- Because of lack of isolated finger flexion, there is limited ball security for passing against challenge by the defence.
- Can hold the ball firmly with wrists, but does not have useful finger activity.
- Typically, weak one-hand overhead pass with limited control and distance.

  Rarely see one-hand overhead passing on court during competition, unless for in-bounding, but may be able to perform a one-hand pass as part of functional tests during classification.

7.2 The 2.5 Hand

MUSCLE STRENGTH

Wrist extensors and flexors	4-5
Finger flexors and extensors	3-5
Finger adductors and abductors	0-2
Thumb extensor and flexor	3-5
Thumb opponens, adductor and abductor	0-2
Finger flexion in the MCP joints	0-2

Explanatory Note: In the athlete with 2.5 hand function, finger flexion is predominately due to the action of Flexor Digitorum Superficialis (FDS), at the proximal interphalangeal (PIP) joints of the fingers and Flexor Digitorum Profundus (FDP) at the distal interphalangeal (DIP) joints of the fingers without the stabilising influence of functional intrinsics. This lack of intrinsic muscle stabilisation results in ‘curling‘ and ‘uncurling’ of the fingers, rather than true functional grasp and release seen in the athlete with 3.0 hand function.

OBSERVATION
The 2.5 hand displays marked intrinsic wasting, including thenar and hypothenar eminences, and little or no maintenance of the hand arches.

FUNCTION

- Reasonably balanced finger flexion and extension (‘curling’ and ‘uncurling’) without true grasp and release because of the absence of stabilisation from the intrinsic muscles of the hand and no contribution to MCP flexion by the intrinsics.
- Utilises extended wrist position (tenodesis) to strengthen grip and uses flexed wrist position to release grip, but may be able to perform some grip and release manoeuvres (curling and uncurling) independent of wrist position.
- Hook grip that is used to advantage on the push rim when challenged, often more ulnar grip.
- Dribbles the ball safely, but will supinate forearm to scoop the ball onto the lap.
- Capable of performing one-hand overhead pass, but with limited accuracy and distance and uses both hands and increased time to set up. May use the one-hand pass on-court in situations other than in bounding?
- Safe two-handed catching of passes, usually followed by scooping ball to lap. May catch passes with one hand and scoop to lap or to chest.
- Improved ball security compared to athlete with 2.0 hand function due to improved ability to isolate wrist/finger function.
- May have overhead game due to limited finger function

7.3 The 3.0 Hand

MUSCLE STRENGTH

Wrist extensors and flexors	4-5
Finger flexors and extensors	3-5
Finger adductors and abductors	0-4
Thumb flexor, extensor	3-5
Thumb abductor, adductor, opponens	0-4
Finger flexion in the MCP joints	0-4

OBSERVATION
The 3.0 hand has a strong, balanced wrist; that means equal or near equal strength in both flexion and extension, with visible atrophy in interossei and intrinsic muscles in the thenar and/or hypothenar eminences of the hand. This atrophy is often visible as a “flattening” of the thenar and/or hypothenar eminences rather than the moreextreme

wasting seen in the athlete with 2.0 or 2.5 hand functions. There is little or no maintenance of hand arches.

The hand should have either weakness in the interossei and/or lumbricals or weakness in thumb opposition, adduction and abduction. In general, finger flexion and extension is usually stronger than in 2.5 hands. A value of 3/5 or more for interossei and/or thumb opposition, adduction and/or abduction usually excludes a hand from 2.5 and indicates a 3.0 hand.

Explanatory Note: It is important to remember single muscle tests values are not the most important factor in hand values. The combination of muscle values is important in the final determination of hand function. For example, a hand with 5/5 for finger flexion and extension, 4/5 for finger abduction and adduction and 4/5 for all thumb movements is more likely to be a 3.5 hand.

FUNCTION

- Some wasting/atrophy in intrinsics and/or thenar/hypothenar eminences.
- Hand arches show limited maintenance.
- Has functional grasp and release of hand independent of wrist position.
- Because of improved activity in finger muscles, can control ball in varying planes of movement for passing, dribbling, catching and protecting ball during these activities.
- Can dribble and pass ball well with one hand.
- Multiple dribble one hand with control.
- Can stabilise with one arm to allow greater reach with the opposite arm, even if the athlete has no trunk function.

ANNEXURE F:

INTERNATIONAL WHEELCHAIR RUGBY CLASSIFICATION FORM[1]

IWRF CLASSIFICATION FORM

Revised January 2015

IWRF
International Wheelchair Rugby Federation

Name (last)		Team/No		Class/Status	
Name (first)		Country		DOB	DD MM YY
Diagnosis		Level of injury		Onset	MM YY
Prior rugby class		Experience since		Active	
Class for other sports				Female	

Manual Muscle Test (0 – 5)

Dominance (Right or Left)

	R	L
Deltoid Lateral		
Pectoralis Sternal		
Pectoralis Clavicular		
Latissimus Dorsi		
Serratus Anterior		
Internal rotators		
External rotators		
Biceps		
Triceps		
Wrist extensors		
Wrist flexors		
Finger extensors	2 3 4 5	2 3 4 5
Finger flexors		
Interossei		
Lumbricals		
Thumb abductor		
Thumb adductor		
Thumb extensor		
Thumb flexor		
Thumb opponens		
Upper Extremity Totals:		

Trunk Test

Highest passed trunk function test

Trunk Total

General Information

Examined in playing chair?

Strapping Belly Binder

Hip/pelvic belt

Knee strap

Foot strap

Spinal deformity

Contractures

Surgery

Spasticity

Ability to stand

Ability to ambulate

Sensory level

Classification Details

	Please use 24 hour time		**Class/Status**
Sports entry class determined	DD MM YY	HH:MM	
Confirmed sports class determined	DD MM YY	HH:MM	
Athlete notified of decision	DD MM YY	HH:MM	

Tournament: NAME LOCATION DATE

Classifiers

Right UE ___ **+ Left UE** ___ **= Total UE** ___ **/2 =** ___ **+ Trunk** ___ **= Total Class** ___

Remarks

ANNEXURE G:

BIOGRAPHIC INFORMATION

BIOGRAPHIC INFORMATION

Male ☐ **Female** ☐

Occupation

Occupational Therapist ☐

Physiotherapist ☐

Doctor ☐

Biokineticist ☐

Other ☐

Level of classifier

Level 2 ☐ Level 3 ☐ Level 4 ☐

Years of national classification experience (practical knowledge, skill, or practice derived from direct observation and participation in WCR)

0-2 years ☐ 3-5 years ☐ 5-10 years ☐

Years of international classification experience (practical knowledge, skill, or practice derived from direct observation and participation in WCR)

0-2 years ☐ 3-5 years ☐ 5-10 years ☐

ANNEXURE H:

VIDEO INSTRUCTIONS AND FORM

INSTRUCTIONS:

1. Please watch the video and answer questions honestly and to the best of your ability.
2. In each video an athlete's hand will be classified by a classifier.
3. Every athlete in each video has stable wrists.
4. Every athlete in each video has full passive range of motion in each joint.
5. Please grade the muscle that you observed in the video in the tick boxes below.
6. Muscle grade can be 0-1, 2, 3 or 4-5. No +/- to be added to scores.

VIDEO 1

Movement tested	**Muscle strength grading**			
	0-1	**2**	**3**	**4-5**
Finger extensors				
Finger flexors				
Interossei				
Lumbricals				
Thumb abduction				
Thumb adductor				
Thumb extensor				
Thumb flexor				
Thumb opponens				

ANNEXURE I:

MUSCLE STRENGTH TESTING SCALE

5.3.1 Muscle Strength Testing Scale[1]

Muscle testing is an important component of the physical assessment. Muscles are graded on a five-point ordinal scale used in manual muscle testing with evidence to support well-established validity and reliability of this testing (Hislop & Montgomery, 2007). The five-point scale is defined as:

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 minimizes 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 full range of motion and maintain end point range position against maximal resistance. The examiner cannot break the athlete’s hold position.

Explanatory note: Plus (+) and minus (-) grades may be utilised where the muscle strength falls between the defined numerical grades. Criteria are defined according to Hislop HJ, Montgomery J. Daniels and Worthingham’s *Muscle Testing: Techniques of Manual Examination. 8th ed*. Philadelphia, Penn: WB Saunders, 2007.

Grades 0 and 1 represent absence or minimal muscle contractile activity, so plus (+) and minus (-) grades should not be used.

Other grades are defined as follows:

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 holds end position against mild resistance

ANNEXURE J:

LETTER FROM STATISTICIAN

Date: 7 / 9 /2015

LETTER OF CLEARANCE FROM THE BIOSTATISTICIAN

This letter is to confirm that the student(s),

with the Name(s) Ms Yvetté van Niekerk

Studying at the University of Pretoria

discussed the Project with the title

with me.

I hereby confirm that I am aware of the project and also undertake to assist with the Statistical analysis of the data generated from the project.

The analytical tool that will be used will be Descriptive statistics, cross-tabulation, Chi-square test, Polytomous regression, Logistic regression. Please also refer attached section from protocol

to achieve the objective(s) of the study.

Name P J Becker Date 7/9/15

Signature Tel: 012 - 319 - 2203

Department or Unit: Research Office, Fac Health Sci, UP

BIOSTATISTICS
Faculty of Health Sciences
Research Office
2015 -09- 07
UNIVERSITY OF PRETORIA

Official Stamp of Biostatistician

ANNEXURE K:

EXAMPLE OF EXCEL SPREAD SHEET

Thumb opposition										
Subject	**Rater 1**	**Rater 2**	**Rater 3**	**Rater 4**	**Rater 5**	**Rater 6**	**Rater 7**	**Rater 8**	**Rater 9**	**Same as the memo**
Thumb opposition Video 1 (and the repeat)										
Reading 1	1	2	1	1	2	1	1	1	1	no
Reading 2	1	2	1	1	2	4	1	1	1	no
Thumb opposition Video 2 (and the repeat)										
Reading 1	1	1	1	1	1	1	1	1	1	yes
Reading 2	1	1	1	1	1	1	1	1	1	yes
Thumb opposition Video 3 (and the repeat)										
Reading 1	1	4	3	3	3	4	2	3	3	no
Reading 2	2	4	3	3	3	3	2	3	3	no

ANNEXURE L:

INFORMED CONSENT: VIDEO PARTICIPANTS

INFORMED CONSENT FOR ANONYMOUS PARTICIPATION IN VIDEO FOOTAGE

Mrs Yvette van Niekerk
23098598
Department of Health
University of Pretoria

Dear Participant

The intra- and inter-rater reliability of manual muscle testing in the new hand classification of wheelchair rugby

I am a master's degree student in Occupational therapy at the University of Pretoria. You are invited to volunteer to participate in the research project on: The intra-and inter-rater reliability of manual muscle testing in the new hand classification of wheelchair rugby.

This letter provides information to assist you to decide if you want to take part in this study. Before you agree, you should fully understand what is involved. If you do not understand the information or have any other questions, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy with what is expected from you.

The purpose of the study is to determine the inter-rater reliability of the new hand classification in wheelchair rugby. Inter-rater reliability is concerned with the reproducibility of muscle testing by different classifiers. Intra-rater reliability is concerned with the self-reproducibility of the muscle testing by each individual classifier.

The researcher would like your hands to be filmed during classification. The video will be shown to classifiers to grade muscle strength. No information will be shown in the video footage that can identify you. You will be anonymous. The reason why you have been asked to participate is because your upper limb has been classed as a 2.0, 2.5, 3.0 or you are a classifier. Filming the video may take about 30 minutes. The video will be stored at 114 Monument Avenue, Lyttelton Manor, Centurion, 0157 for 15 years. The researcher will, at all times, be available to assist you with any questions.

The Research Ethics Committee of the University of Pretoria, Faculty of Health Sciences granted written approval for this study (number of protocol: Temp 2016-00115). Your participation in this study is voluntary. You can refuse to participate or stop at any time without giving any reason. As you do not state your name nor show your face on the video footage, you give us the information anonymously. The researcher will keep the information of the participants safe. Therefore, you will also not be identified as a participant in any publication that results from this study.

Note: The implication of completing the video footage is that informed consent has been obtained from you. Thus, any information derived from the video footage (which will be totally anonymous) may be used for publication by the researcher.

The researcher sincerely appreciate your help.

Yours truly,

Yvette van Niekerk
Occupational therapist (South Africa)
Level 3 International Wheelchair Rugby Classifier
yvette.vdwesthuizen@gmail.com

ANNEXURE M:

INFORMED CONSENT: RATERS

INFORMED CONSENT FOR ANONYMOUS QUESTIONNAIRE

Mrs Yvette van Niekerk
23098598
Department of Health
University of Pretoria

Dear Participant

The intra-and inter-rater reliability of manual muscle testing in the new hand classification of wheelchair rugby

I am a master's degree student in Occupational therapy at the University of Pretoria. You are invited to volunteer to participate in the research project on: The intra-and inter-rater reliability of manual muscle testing in the new hand classification of wheelchair rugby.

This letter provides information to assist you to decide if you want to take part in this study. Before you agree you should fully understand what is involved. If you do not understand the information or have any other questions, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy with what is expected from you.

The purpose of the study is to determine the inter-rater reliability of the new hand classification in wheelchair rugby. Inter-rater reliability is concerned with the reproducibility of muscle testing by different classifiers. Intra-rater reliability is concerned with the self-reproducibility of the muscle testing by each individual classifier. Three classifiers on level 2, level 3 and level 4 respectively will randomly be selected for the sample size from all the classifiers who took part in the study.

The researcher would like you to complete a measurement tool consisting of biographic information and a simulated assessment containing video footage (to watch). The video footage will show the hand of a wheelchair rugby athlete being classified. After watching the video, you will be asked to grade the muscle strength of the hand muscles. This may take about 30 minutes. The information will be stored at 114 Monument Avenue, Lyttelton Manor, Centurion, 0157 for 15 years. Please do not write your name on the questionnaire to ensure confidentiality. The researcher will be available at all times to assist you with completion of the questionnaire via email.

The Research Ethics Committee of the University of Pretoria, Faculty of Health Sciences granted written approval for this study (number of protocol: Temp 2016-00115).Your participation in this study is voluntary. You can refuse to participate or stop at any time without giving any reason. As you do not write your name on the questionnaire, you give the information anonymously. Once you have answered the questionnaire, you cannot recall your consent. The researcher will not be able to trace your information. Therefore, you will also not be identified as a participant in any publication that results from this study.

Note: The implication of completing the questionnaire is that informed consent has been obtained from you. Thus, any information derived from your questionnaire (which will be totally anonymous) may be used for publication by the researcher.

The researcher sincerely appreciate your help.

Yours truly,

Yvette van Niekerk (Occupational therapist - South Africa)
Level 3 International Wheelchair Rugby Classifier
yvette.vdwesthuizen@gmail.com

ANNEXURE N:

PERMISSION LETTER FROM INTERNATIONAL WHEELCHAIR RUGBY FEDERATION

International Wheelchair Rugby Federation

Suite 250, 3820 Cessna Drive
Richmond, British Columbia, V7B 0A2, CANADA
T: 1.604.285.0285 **F:** 1.604.285.0295 **E:** info@iwrf.com

Greg Ungerer
IWRF Head of Classification

19th October 19, 2015

To whom it may concern

This letter confirms that Yvette van Niekerk has permission from the International Wheelchair Rugby Federation to proceed with the research project:

Inter-rater reliability of the manual muscle testing in the new hand classification of wheelchair rugby.

Yours faithfully

Greg Ungerer

IWRF Head of Classification
gungerer@iwrf.com

ANNEXURE O:

DECLARATION OF STORAGE

Protocol No. Temp 2016-00115

Principal Investigator(s) Declaration for the storage of research data and/or documents

I, the Principal Investigator, Mrs Yvette van Niekerk of the following study titled *"The intra- and inter-rater reliability of Manual Muscle Testing in the new hand classification of Wheelchair rugby"* will be storing all the research data and/or documents referring to the above mentioned study at the following address: Monumentlaan 114, Lyttelton Manor, Centurion, 0157

I understand that the storage for the abovementioned data and/or documents must be maintained for a minimum of 15 years from the commencement of this study.

START DATE OF STUDY: January 2015

END DATE OF STUDY: December 2017

UNTIL WHICH YEAR WILL DATA WILL BE STORED: 2030

Name: **Yvette van Niekerk**

Signature: Yvette van Niekerk

Date: **01-01-2017**

ANNEXURE P:

DECLARATION REGARDING PLAGIARISM

DECLARATION OF ORIGINALITY
UNIVERSITY OF PRETORIA[3]

The Department of Health places great emphasis upon integrity and ethical conduct in the preparation of all written work submitted for academic evaluation.

While academic staff teaches you about referencing techniques and how to avoid plagiarism, you too have a responsibility in this regard. If you are at any stage uncertain as to what is required, you should speak to your lecturer before any written work is submitted.

You are guilty of plagiarism if you copy something from another author's work (eg a book, an article or a website) without acknowledging the source and pass it off as your own. In effect you are stealing something that belongs to someone else. This is not only the case when you copy work word-for-word (verbatim), but also when you submit someone else's work in a slightly altered form (paraphrase) or use a line of argument without acknowledging it. You are not allowed to use work previously produced by another student. You are also not allowed to let anybody copy your work with the intention of passing if off as his/her work.

Students who commit plagiarism will not be given any credit for plagiarised work. The matter may also be referred to the Disciplinary Committee (Students) for a ruling. Plagiarism is regarded as a serious contravention of the University's rules and can lead to expulsion from the University.

The declaration which follows must accompany all written work submitted while you are a student of the Department of Health. No written work will be accepted unless the declaration has been completed and attached.

Full names of student: **Yvette van Niekerk**

Student number: **23098598**

Topic of work: **Masters degree of Occupational Therapy**

Declaration

1. I understand what plagiarism is and am aware of the University's policy in this regard.
2. I declare that this **protocol** is my own original work. Where other people's work has been used (either from a printed source, Internet or any other source), this has been properly acknowledged and referenced in accordance with departmental requirements.
3. I have not used work previously produced by another student or any other person to hand in as my own.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

SIGNATURE: Yvette van Niekerk **DATE:** **20-10-2015**

ANNEXURE Q:

ETHICS APPROVAL CERTIFICATE

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
- FWA 00002567, Approved dd 22 May 2002 and Expires 20 Oct 2016.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 22/04/2017.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

14/04/2016

Approval Certificate
New Application

Ethics Reference No.: 67/2016

Title: The intra- and inter-rater reliability of manual muscle testing in the new hand classification of wheelchair rugby

Dear Yvette van Niekerk

The **New Application** as supported by documents specified in your cover letter dated 26/02/2016 for your research received on the 29/02/2016, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 13/04/2016.

Please note the following about your ethics approval:
- Ethics Approval is valid for 1 year
- Please remember to use your protocol number (**67/2016**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:
- The ethics approval is conditional on the receipt of 6 monthly written Progress Reports, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Professor Werdie (CW) Van Staden
MBChB MMed(Psych) MD FCPsych FTCL UPLM
Chairperson: Faculty of Health Sciences Research Ethics Committee

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

☎ 012 354 1677 🖷 0866516047 deepeka.behari@up.ac.za http://www.up.ac.za/healthethics
✉ Private Bag X323, Arcadia, 0007 - 31 Bophelo Road, HW Snyman South Building, Level 2, Room 2.33, Gezina, Pretoria