# Measuring Trunk Stability and Range of Motion: Two Field Tests for Wheelchair Basketball Classification

by

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Abstract

Adapted sports are sports that enable people with disabilities to participate in sport through modification of traditional sport or new sports designed for people with disabilities. Classification systems are utilized within adapted sports to ensure equitable competition. The focus of this project is the classification system utilized in wheelchair basketball. The primary factor of wheelchair basketball classification is the “volume of action.” This volume of action is related to the ability of the athlete to utilize his/her trunk. Currently, wheelchair basketball systems do not utilize objective measures for classification of athletes. Therefore, the purpose of this project was: 1) to measure the range of motion associated with the volume of action, 2) to determine the influence of trunk stability on force production with the arms, 3) to discover if a relationship exists between these measures. The volume of action was measured as a percentage of height for 20 individuals: 10 with disability, 10 without disability. This was accomplished through a reaching task requiring each participant to reach in 5 directions at 3 heights with each hand. PWOD were found to have significantly higher reach scores. Trunk stability was measured by participants pushing against a wall with a force gauge with and without the aid of support, and in 3 directions. PWOD also demonstrated greater trunk stability according to the strength task. The sum of the reach scores and sum of the trunk stability scores were found to be inversely related, but were not significantly related. The field tests utilized in this project require further development and research to create a comprehensive system of classification for wheelchair basketball.

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## List of Abbreviations

| | |
|---|---|
| NWBA | National Wheelchair Basketball Assocation |
| IWBF | International Wheelchair Basketball Federation |
| ASIS | Anterior superior iliac spine |
| sEMG | surface electromyography |
| SCI | Spinal cord injury |
| CNS | Central nervous system |
| PNS | Peripheral nervous system |
| MMC | Myelomenignocele |
| TCS | Tethered cord syndrome |
| MVIC | Maximum voluntary isometric contraction |
| RF | Rectus femoris |
| ES | Erector spinae |
| RA | Rectus abdominis |
| PEC | Pectoralis major |
| AC | Acromioclavicular |
| PWD | Person with disability |
| PWOD | Person without disability |
| CP | Cerebral palsy |
| UNI | Unilateral |
| CONTRA | Contralateral |
| UNI 45 | Unilateral 45 |

| | |
|---|---|
| CONTRA 45 | Contralateral 45 |

# CHAPTER I

# INTRODUCTION

Adapted sports are versions of traditional sports to which modifications have been made to enable people with disabilities to compete within the sport. Modifications to sport can be made to rules, equipment, and who is eligible to play. These modifications serve to enable athletes with disabilities to compete in sport without changing the goals of the competition (Bressan, 2008; International Paralympic Classification Committee, 2007). For the purposes of this work, the focus is adapted sports for those with mobility impairment, specifically individuals that qualify to play wheelchair basketball.

Wheelchair basketball is a sport for those with an impairment of the lower limbs which prevents them from playing traditional basketball (International Wheelchair Basketball Federation, 2014). Initially, the sport was meant to be a form of rehabilitation for wounded World War II veterans (Strohkendl, 1996). According to Strohkendl (1996), participation was limited to those with paraplegia. People with other mobility impairments became involved in the sport as it grew. This led to the need to create a classification system which would enable fair competition.

The National Wheelchair Basketball Association (NWBA) was founded in 1949. This marked the formalization of wheelchair basketball in the United States. The NWBA became the leader in the wheelchair sport movement. The initial question posed to the NWBA was who should compete in wheelchair basketball. It was determined that to be eligible one must have a lower limb impairment that prevented participation in traditional basketball, such that the person would not be capable of playing basketball if wheelchair basketball did not exist. The allowance of people without spinal cord injury to compete led to the loss of playing time for those with spinal cord injury. Classification systems arose as the means to combat the benching of people with more severe disabilities and to ensure the capability to include all with mobility impairments (Strohkendl, 1996).

Initially, a medical classification system was implemented. The system assigned a point value to each member of the team based upon lesion level. It was believed that the lesion level offered the best measure of what an athlete would be capable of athletically. Each team was then allowed a certain number of points to make up the 5 member team on the floor. The purpose of the classification was to ensure that people with more significant disabilities were not relegated to the sideline as people with less significant disabilities became involved in the sport (Strohkendl, 1996).

As the sport progressed, it became apparent that the effects of lesion and diagnosis were more complicated than the simple system predicted. Therefore, manual muscle testing and watching athletes perform became the standard for classification. Function of the athlete became the main criteria for classification. The first functional system of classification was adopted in 1982 (Strohkendl, 1996).

The system of classification adopted in 1982 has developed into the functional system that is used by the IWBF today. The system relies primarily on watching athletes compete in sports chairs designed to enable better performance (International Wheelchair Basketball Federation, 2014). Ingenuity in adapted sport, especially in the area of chair setup, is one of the greatest ways to gain a competitive edge. Some athletes have discovered methods of seating and strapping that allow them to perform far beyond what the functional system of the IWBF expects. Therefore, these players are given higher classifications. These higher classifications are penalizing the ingenuity that should be praised. A system of classification needs to be established which does not utilize diagnosis as prediction, or performance as the measure of function. Instead, the system should place all athletes in an equal setting, measure their function, and give a classification based upon this.

A major difficulty for a system such as this will be athletes that try to cheat the system. In a round of testing requiring a full effort, an athlete may not give a full effort in order to gain a lower classification. Therefore, a means of confirming classification may be necessary such as gauging functional mobility during competition, but any observations in competition should only be to confirm a classification not to determine it (International Paralympic Classification Committee, 2007). If the observer believes an athlete to be giving less than full effort in the classification process because of in competition capabilities, an appeals process should be made available. The appeals process should include a retesting. The appeals process should include the previous testing, comparisons of previous and latter tests, and an additional functional test. If an athlete’s scores on the original test vary greatly from the new test, it could be that the athlete is trying to cheat the system. In such a case, the other functional test may elicit a more concrete answer to the proper classification. Instituting a rule that penalizes cheating in the manner described, such as suspension from play, could also help deter the attempts to cheat the system.

For such a system to exist, multiple tests must be made available. An initial field test that is inexpensive, measures functional ability, and comprehensive for motor impairments is the first step. Second, a more rigorous test for functional ability would be required for the retest. Therefore, two new tests are proposed to address the deficits within current systems of classification in wheelchair basketball. The first test is a reach test which will be the initial field test. It consists of sitting upon a flat seat and reaching towards a target in five directions and at three different heights. A reach score is obtained from this which can then be used as an athlete's classification for participation. The second test is a strength test. By finding the reduction of force produced when the advantage of support is lost, the strength test is a true measure of trunk stability and function. It is proposed that measuring and comparing these tests yields evidence for these tools to be used in the classification of wheelchair basketball athletes.

## Summary

Athletes participating in wheelchair sports vary in their functional abilities. Classification systems in wheelchair basketball have been created in attempts to ensure fair and equitable classification. Prior systems of classification have not isolated the functional ability of an athlete from his/her performance nor his/her diagnosis. Therefore, this study investigates two novel tests for classifying wheelchair basketball athletes.

## Statement of the Problem

Wheelchair basketball athletes vary in their functional ability due to differences in disability. Classification systems, developed to ensure the sport does not become exclusive to the higher functioning athletes, fail to equitably stratify athletes. The systems either rely on medical diagnosis, which does not ensure proper functional stratification, or are based upon functional assessment during performance, which may be influenced by talent (IPC Handbook). To increase equality of competition, a new system which is sensitive to differences of function despite similar disabilities and not reliant on performance assessment is needed.

## Statement of the Purpose

The purposes of this research are: 1) to determine the range of motion associated with the IWBF's "volume of action"; 2) to determine the influence of trunk stability in the production of force with the arms; and 3) to determine if a relationship exists between the ability to produce force and range of motion associated with the volume of action.

## Hypotheses

*Primary Objective – To determine the relationship between the volume of action and the loss in maximal force produced when the advantage of support is lost.*

1) Evaluate the volume of action during novel sit and reach tasks at sternum, anterior superior iliac spine (ASIS) and basketball height.

H01: Larger ranges of motion in the trunk, shoulder, and elbow associated with lack of disability will result in increased scores during the sit and reach task.

2) Evaluate the peak force with and without support.

H01: The peak force achieved will be greater with support.

3) Compare the scores of the sit and reach task with the difference between the peak forces of the strength task.

H01: The difference in maximal force when support is removed will be inversely related to the scores of the sit and reach task.

*Secondary Objective – To determine the utility of two field tests for classification in wheelchair basketball.*

1) Evaluate the utility of an electronic measurer as a means for measuring the volume of action.

H01: The change in distance measured by the electronic measurer will correlate to the distance reached by the wrist.

2) Evaluate the utility of an electronic muscle test as a means for measuring trunk function.

H01: The peak force resisted as measured by the electronic muscle test will be inversely related to the difference between peak force achieved with and without support.

**Limitations**

The limitations for the proposed study include the following:

1) Medical status is self-reported.
2) All disabilities which qualify for wheelchair basketball are not assessed.

**Delimitations**

The delimitations for the present study include the following:

1) Participants are required to wear compression clothing with retroflective markers bilaterally and sEMG electrodes bilaterally.

2) All participants are between ages 19-50.

3) Participant assessments occur within the Sports Biomechanics Lab.

# CHAPTER II

# LITERATURE REVIEW

The goal of sport competition is to enable competitors to test strength, athleticism, and wit against the opponent within the limits of a game to determine a winner (International Paralympic Classification Committee, 2007). Adapted sport competition has the same goal. To ensure success in adapted sport is determined by the same measures as traditional sport, and not level of disability, adapted sports have adopted classification systems. These systems are designed to encourage people of varying levels of disability to participate in equitable competition (International Paralympic Classification Committee, 2007). For the purposes of this project the focus is the classification systems utilized in wheelchair basketball.

This chapter will present the literature relevant to the classification of wheelchair basketball athletes and is divided into six sections: [1] the purpose of classification systems, [2] the functional losses as a result of spinal cord injury, [3] an examination of how different functional abilities result from similar lesion levels in those with spina bifida, [4] descriptions of the current systems of classification, [5] the deficits of the current systems of classification, [6] a summary of research pertinent to classification.

## Purpose of Classification

Equitable competition is generally created by one of two means in adapted sport: athletes with similar disability types and disability levels competing against each other; or in team sports a system requiring a spectrum of disability levels being represented, which is then classified in such a way that similar levels of disability are present throughout the competition (International Paralympic Classification Committee, 2007). In wheelchair basketball, the primary purpose of classification is to ensure all levels of mobility impairment remain a part of the game. Classification serves to stratify people with different disabilities into groups of different functional levels. Teams cannot field only those who are of the highest functional level, ensuring that the sport is available to those who have lower function as well.

The first step in ensuring equitable competition is determining qualifying disabilities for the sport. Each sport has its own governing body that determines what disabilities qualify to compete. Then, the minimum disability criteria for competition are determined. The minimum criteria designate the lowest level of impairment which necessitates participation in adapted sports. Typically, the minimum disability criteria are associated with an inability or reduced ability to participate in a traditional version of a sport (International Paralympic Classification Committee, 2007). Wheelchair basketball requires a permanent lower limb disability that prevents the athlete from playing traditional stand up basketball (International Wheelchair Basketball Federation, 2014).

At the international level of sport competition, the minimum disability criteria must be met for an athlete to be eligible to compete (International Paralympic Classification Committee, 2007). Smaller competitions at the regional or national level may not include a minimum disability requirement in order to allow more participation and programming which has been demonstrated in Canadian wheelchair basketball (Spencer-Cavaliere & Peers, 2011). Brasile (1990b) has argued that the minimum disability requirement should be dropped especially in local and regional programming in order to allow more people to play wheelchair basketball. It has also been argued that allowing people without disability to play would remove opportunities for people with disabilities in the sport of wheelchair basketball (Smith & Labanowich, 1992). However, Spencer-Cavalier and Peers (2011) demonstrated that participation of people without disability in wheelchair basketball increased positive attitudes towards disabilities and did not have negative effects on people with disabilities. It may also increase opportunity by allowing more players, which results in more teams on which people with disabilities can play (Brasile, 1992; Spencer-Cavaliere & Peers, 2011). After being determined to qualify for an adapted sport, an athlete is classified for participation.

## Spinal Cord Injury

To better understand the process of classification an overview of spinal cord injury (SCI) and spinal cord disorders is needed. SCI produces a variety of effects upon the nervous system. The severity of the injury depends upon the location along the spinal cord and completeness of the injury (Krause & Broderick 2004). With complete spinal cord lesions, a loss of sensory and motor function occurs due to the total severance of the spinal cord. Many factors play a role in this functional loss. The immediate damage to the spinal cord causes death of that nervous tissue, followed by an acute inflammatory response leading to further necrosis. This inflammatory response causes a larger area of injury than just the original site of injury. It begins minutes after the injury, and causes further functional damage to the nervous system (Carlson et al., 1998). Carlson and his associates found that the inflammatory response mainly consisted of neutrophils and macrophages. Oxidative damage could result from the neutrophils which are the first to arrive. The macrophages appear next and extend beyond the site of injury in caudal and rostral directions.

According to Schmidt and Leach, 2003, the macrophages reach the CNS more slowly than the peripheral nervous system (PNS) because of the blood-spine barrier. This slows the removal of debris from the injury site. The CNS also experiences glial scars which prevent the regeneration of tissue because myelin proteins also play an inhibitory role to axonal growth in the spinal cord (Chen et al., 2007). Apoptosis of spinal cord neurons, which are inferior to the injury, while not in direct proximity to the injured tissues, suggests the axons of the injured tissues are incapable of regeneration (Liu et al., 1997). The cell death beyond the injury leads to further loss of function.

In the case of complete SCI, sensation and motor control are lost to levels inferior of the injury. This is due to the injury and secondary effects that were presented above. The complete severance of the spinal cord results in a situation where function can be predicted based upon level of lesion (Moore et al., 2006). The predictability is attributed to the cell death inferior to the lesion and the CNS' inability to regenerate. Table 2 demonstrates the level of injury and predicted functional limits in the cases of complete severance.

Table 1

*Level of Function Based on Site of Complete Spinal Cord Injury*

| Level of Injury | Functional Limits |
|---|---|
| C4-C5 | No function of upper or lower limbs |
| C6-C8 | Limited upper limb function<br>Loss of lower limb function |
| T1-T9 | Loss of lower limb function<br>Trunk control varies depending on injury site |
| T10-L1 | Some thigh muscle control |
| L2-L3 | Most leg function<br>May require assistive devices for walking |

*Note.* Adapted from *Clinically oriented anatomy* (5th ed.).Philadelphia, PA: Lippincott, Williams & Wilkins.

## Spina Bifida

Spina bifida is a birth defect that is divided into three categories based upon the severity of the malformation. Spina bifida occulta is a gap in vertebral arches, but the meninges and spinal cord remain within the vertebral column. Spina bifida meningocele is a similar opening, but a sac forms containing meninges and cerebro-spinal fluid. The most severe form of spina bifida is spina bifida myelomeningocele (MMC). Spinal cord and nerve roots are found in the sac created by a gap in the spinal arches where the spinal cord and nerve roots are without the protection of the spinal column, inevitably leading to injury of the spinal cord (Northup & Volcik 2000).

Those with MMC may demonstrate functional loss similar to those with SCI at the same level of lesion, but the functional loss is less predictable in cases of MMC. There are several factors that could contribute to the variability of functional loss. First, MMC is a developmental disability. The spinal cord is not closed properly leading to the damage to the spinal cord, and structural developmental problems may accompany the abnormality. Also, MMC does not result in a complete lesion of the spinal cord. Therefore, function inferior to the lesion is lost, but the functional results are dependent on the site of the lesion and the nerves affected by the lesion (Northup & Volcik 2000).

Though the exact mechanism for the occurrence of MMC is yet to be found, it has been shown that during the embryonic stages, the spinal column does not close properly resulting in disability from exposing the spinal cord to amniotic fluid and trauma (Adzick & Walsch, 2003). The damage caused prenatally is explained by the "two-hit hypothesis." "The two-hit hypothesis states that primary congenital abnormalities in anatomic development allow a relatively normal spinal cord to become secondarily damaged by amniotic fluid exposure, direct trauma, hydrodynamic pressure, or a combination of these factors" (Adzick, 2010, p. 3). Using a mouse model, Steifel et al., ((2007) found evidence of degeneration of neural tissue exposed to amniotic fluid in utero. The pathology was shown to occur late in gestational development suggesting a degenerative effect of amniotic fluid. Correia-Pinto et al., (2002) also showed the degenerative effect of amniotic fluid on spinal cord tissue in rats. Similar destruction to unprotected nerves and spinal cord were also found in human fetuses with spina bifida in autopsies following "therapeutic abortions" (Meuli et al., 1997). The damage done by fluid creates an injury to the spinal cord that has unpredictable functional results.

People with MMC experience a wide range of functional abilities. Some will be able to walk, while others will not. The location of the lesion will be the best indicator of expected function, but it is less reliable than in the case of SCI. Rintoul et al., (2002) found that in half of the cases of MMC observed, the functional level of disability was associated with two vertebral levels higher than the actual location of lesion. This means that some MMC lesions produced disability associated with lesions more superior in the spinal column than would be predicted by the actual lesion site. Rintoul et al., (2002) postulated that this may be due to the tethering of the spinal cord.

Tethered cord syndrome (TCS) results in sensory and motor deficits in the lower limbs. It can occur as a result of thickening of the filum terminae or some other abnormality resulting in an elongated spinal cord (Tani et al., 1987). The tethering in MMC is a result of the spinal cord becoming affixed to the neural opening and surrounding tissues (Adzick & Walsch, 2003). The tethering causes tension which results in a lessening of oxidative metabolism in the spinal cord which can result in necrosis of the spinal cord. This damage results in “patchy sensation” and differing function loss (Yamada et al., 2004; Yamada et al., 2007). These less predictable functional results are more difficult to classify.

## Systems of Classification

The varying functional abilities as a result of SCI or MMC demand a classification system that is sensitive to these differences. Currently, two methods of classification are utilized: medical and functional. Medical systems of classification base an athlete’s classification on diagnosis (Brasile, 1990b; International Paralympic Classification Committee, 2007; Jones & Howe, 2012). A letter of diagnosis is obtained by the athlete from his/her physician; the diagnosis is verified by trained classifiers; a medical evaluation involving manual muscle tests and range of motion tests is performed by a trained classifier; then, the athlete is given the classification with which he/she will compete. The medical system model for classification is valued because of the objective nature under which it operates. Scores during the manual muscle test and level of lesion generate a quantifiable basis for classification. However, it has drawn criticism because similar diagnoses do not guarantee similar function (Brasile, 1990a; Doyle, et al., 2004). Therefore, classification has moved toward more functional models. These models measure functional abilities that are related to the sport actions that the athlete must be able to complete in order to compete. Preference is given to functional models of classification because these models address the true capabilities of the athlete in order to classify them as having similar or dissimilar abilities (Bressan, 2008; Brasile, 1990a; Doyle, et al., 2004; International Paralympic Classification Committee, 2007; Jones & Howe, 2012). Therefore, they are classified together more appropriately and fair competition is enabled.

Until the 2014-2015 season, the classification system used in the United States by the National Wheelchair Basketball Association (NWBA) was a medical system in which a point value is assigned to the participant based purely on the medical diagnosis. Internationally, wheelchair basketball organizations have utilized a functional system in which a point value is assigned based upon the ability of each athlete to perform wheelchair basketball skills (Doyle et al., 2004; International Wheelchair Basketball Federation, 2010). The NWBA implemented a system based upon the IWBF system for the 2014-2015 season (NWBA, n.d).

In the NWBA medical system, there are three classifications: “Class 1, T7 injuries and above; Class 2, T8 to L2 and some amputees (bi-lateral hip disarticulation); and Class 3, L3 and below and all other amputees” (Doyle et al., 2004). Each classification is assigned the point value to which it is classified (Class 1= 1 point, Class 2=2 points, and Class 3 = 3 points). Teams must field a five member team that does not exceed a certain point total. For the Championship Division of the NWBA, 12 points are allowed on the floor for each team, but no more than three athletes of the Class 3 classification may be in the game at one time for a team. In Division 3, 11 points are allowed on the floor but only two athletes of the Class 3 classification are allowed on the court at the same time. These rules allow for ease of substituting based on whole points, but allows for a great deal of differentiation within classes.

The NWBA system relies on experts to classify each athlete individually. This is done outside of competition and is relatively easy for the athletes. The process begins with a letter from a medical doctor with a statement of the athlete’s diagnosis. The classifier uses the information from the physician or athlete and verifies the location of injury and loss of function. After about 30 minutes of questions and manual muscle test scoring, the classifier can calculate the athlete’s classification. An athlete can be classified quickly and easily due to the nature of the system. This quantitative method for classification leaves fewer questions about the classifications, so athletes and coaches can be more confident that the lineups will be appropriate when it comes time for competition.

The International Wheelchair Basketball Federation (IWBF) makes use of a functional system of classification. The values for this system range from 1-4.5 and the scale has.5 increments. This allows for eight different classifications within wheelchair basketball (Doyle et al., 2004). The increased number of classes allows for better differentiation among classes, but the .5 point system can make substitutions more complicated. In the IWBF, 14 points are allowed on the court at one time without limitation to the number of specific classes.

The process of classification for the IWBF is more cumbersome than the medical classification, but it allows for classification based on the ability of the athlete to perform wheelchair basketball skills. A new athlete is given a proposed classification prior to competition by his/her coach. Upon arrival at the competition, the athlete is observed in practice by trained classifiers and given a preliminary classification to be used for the competition by a committee of classifiers. The committee of classifiers observes the athlete during competition as well and determines a final classification. This will be the athlete’s classification for all further competitions unless an appeal is made by the athlete’s coach or the athlete, or a protest is made by an opponent (IWBF, 2010).

The IWBF recognizes four main areas of function that play a role in determining an athlete’s classification: trunk function, hand function, upper limb function, and lower limb function. Trunk function is the centerpiece for the classification system. It includes the “volume of action” which refers to the active range of motion of a player as illustrated by Figure 2 (IWBF, 2010).

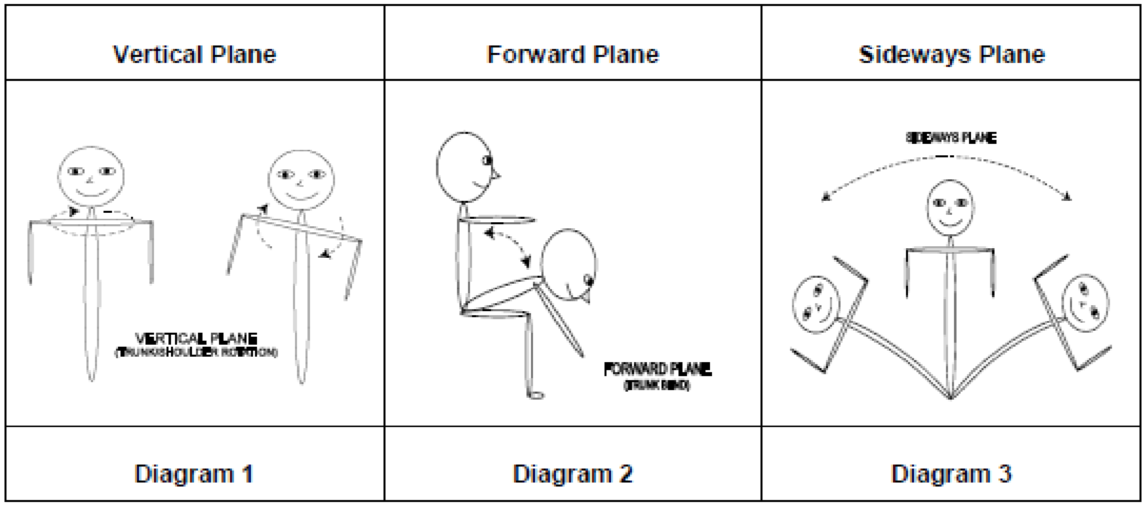


Figure 1. IWBF diagrams of the 3 planes for determining volume of action (*with permission*, IWBF, 2010,).

The volume of action is observed in three planes of motion as shown in Figure-1: vertical plane (frontal plane shoulder elevation and depression), forward plane (sagittal plane), and sideways plane (frontal plane of trunk motions). Table 2 shows a brief synopsis of classifications within the whole point classifications. If an athlete does not belong in one level definitively, a .5 can be added to the classification. Greater detail is found in the *IWBF Player Classification Handbook*. It includes ranges for each plane of motion, rotational factors, and how to incorporate upper limb impairments. The ranges for the planes of motion can be found in Figure-2. At this time, the ranges are not quantified to give recommendations on the measurable range of motion an athlete within a given classification may have. An athlete with upper limb impairment is still required to meet the minimum disability criteria in the lower limbs. The athlete is first classified just as all other athletes, but further consideration is given to what extent the athlete is disadvantaged in the ability to perform sport tasks. The classifiers imagine one-on-one competition between the athlete and someone of the same classification to determine if the athlete should be classified lower (International Wheelchair Basketball Federation, 2014).

Table 2

*IWBF Classification Based Upon Function*

| Classification | Function |
|---|---|
| 1.0 | Little or no controlled trunk movement in the forward plane<br>No active trunk rotation<br>Balance in both forward and sideways directions is significantly impaired<br>Players rely on their arms to return to the upright position when unbalanced |
| 2.0 | Partially controlled trunk movement in the forward plane<br>Active upper trunk rotation but no lower trunk function<br>No controlled sideways movement |
| 3.0 | Good trunk movement in the forward direction<br>Good trunk rotation<br>No controlled trunk movements sideways |
| 4.0 | Normal trunk movements, but usually due to limitations in one lower limb the player has difficulty with controlled movement to one side |
| 4.5 | Normal trunk movement in all directions<br>Able to reach side to side with no limitations |

*Note.* Adapted from IWBF Classification Manual (2014).

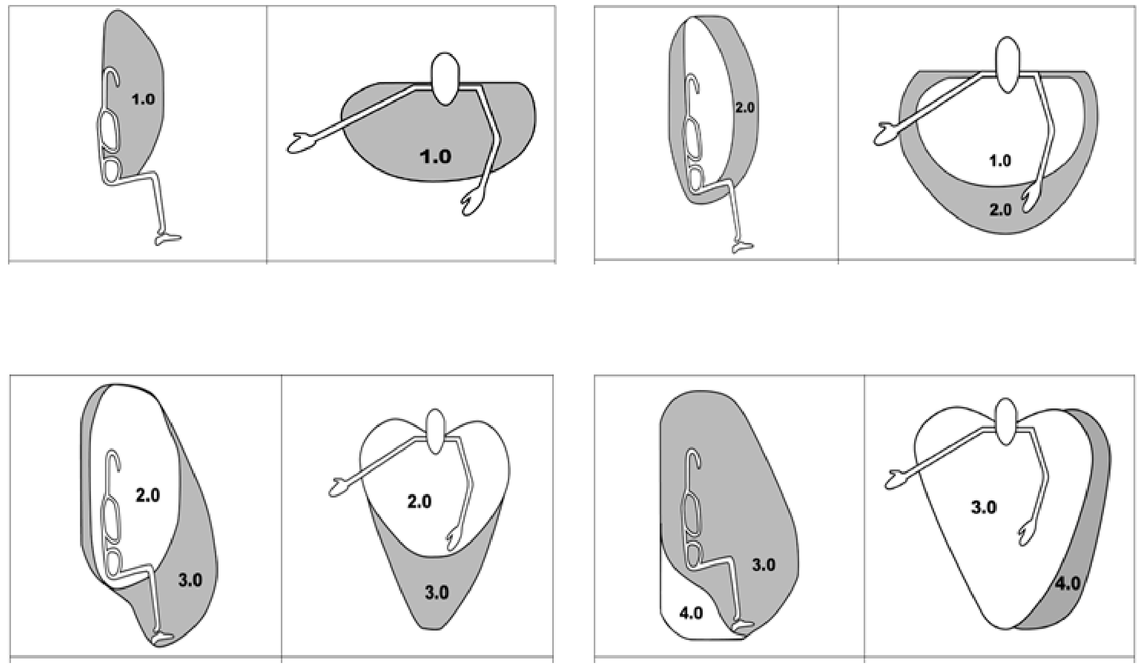


Figure 2. Depiction of the volume of action for each whole point classification (*with permission*, IWBF, 2014).

## Deficits in the Current Systems

The IWBF functional system can lead to a great deal of discrepancy depending on the classifiers. The qualitative measures and classifiers placing different emphasis on importance of different classification factors have created a situation in which athletes and coaches are unsure of classifications before competition. The .5 point values are supposed to address these issues, but there still exists a large potential for subjectivity. The .5 point value also makes lineups more difficult to create. If an athlete is a given a +.5 to his classification, another +.5 will need to be on the lineup to reach the maximum team value of 14 points. Not doing so, leads to having fewer points on the court, and a possible disadvantage for the team since the opposing team could have a greater level of total function on the floor. Classification of an athlete can also be protested (IWBF, 2014) leading to uncertainty of what lineups will even be available to a team at any given competition.

The most important consideration for these classification systems is whether or not they meet the goals of equitable competition and inclusion. Both systems are able to include people with lower limb disabilities. The NWBA medical system is based upon the idea that function is predictable based on the level of the lesion. The belief being that once lesion level is known, the function a person has can be predicted. Therefore, classification can be given based upon those predictions. However, it has been demonstrated that a person's function is not solely dependent upon the location of lesion.

In the case of MMC, the lesion level can lead to greater loss of function than expected in complete SCI. The functional level of MMC is actually associated with the vertebral level two vertebrae above in half the cases (Rintoul et al., 2002). This means that someone with a L3 lesion level would be classified as a 3 though he/she only has the function of someone with a SCI at L1. The athlete would then be classed higher than he/she should be. His/her function would not be equitable to others of the same class. This completely negates the purpose of the classification system. The NWBA medical system also does not address the fact that not all spinal cord disabilities will result in total loss of function based on the lesion site. As seen in cases of TCS, the sensational loss is patchy, and functional loss is incomplete. Therefore, someone with MMC could have better function than predicted by the lesion site because the damage to the spinal cord is not complete. The spinal cord is stretched inhibiting neural signals resulting in loss of some function but not as much as with a complete injury. This can lead to under classifying an athlete which also negates the purpose of equitable competition. An under classed athlete has a distinct advantage over a correctly classed athlete of the same classification.

The IWBF functional system addresses this issue by making function the primary criteria for classification. The issues of differing functional loss are accounted for because the site of injury only plays a role in as much as it reduces the function of the athlete. If an athlete has MMC that affects his/her function as if the lesion were two vertebrae higher, then he/she will be classified as such. The same is true of the case in which an athlete has more function than would be expected because the lesion is not complete.

The important aspect of classifying in this functional manner is that talent, intelligence, and general athletic prowess do not influence classification. An athlete is not given a higher score or placed in a division based on talent as is used in systems like golf handicapping or recreational bowling leagues. Instead, the classification is based on functional limitations due to disability. Therefore, an athlete that trains and overcomes limitations, finding creative ways to be more effective on the court, field, or in the pool, is not punished for this prowess. Instead, the athlete is placed alongside athletes with similar limitations, and the outcome of the event is determined by that prowess. If performance within the sport is the measure of function, then it is not disability that is being matched by the classification system, but rather skill level.

## Ideas of Classification Put into Practice

Trunk motion has long been the key indicator for classification. The ability to utilize the trunk in balance while reaching, propulsion, and rotating during sport movements is the reason for the focus on the trunk. The function of trunk as a measure for classification has been supported in previous research which demonstrated that greater trunk strength is related to greater propulsive strength (Vanlandewijck, Verellen, & Tweedy, 2010). In the Vanlandewijk et al., (2010) project, participants completed a generic test which required pushing bilaterally and maximally against a force plate on a wall, while seated in a stationary chair. This was done with and without the benefit of a backrest. The absence of a backrest resulted in a decreased force production for individuals with lower trunk function. In the sport specific test of propelling, the participants propelled under four conditions. The aid of a backrest and strap were given and removed to create the four conditions. Loss of support of the backrest and strap lead to poorer propulsion performance for the participant with disability. Similar results in which sport performance was indicative of function have been found in acceleration (Vanladewijck, Verellen, & Tweedy, 2011), general performance (Vanlandewijck, et al., 2004), and propulsion (Crespo-Ruiz, Ama-Espinosa, & Gil-Agudo, 2011). In these studies, higher functioning led to better performance. However, these studies did not find cause for as many levels of classification as the current 1-4.5 point system. The lack of stratification could be due to using performance measures to compare classifications. Athletes of similar caliber (international, national, recreational) should produce similar performance in the tests related to sport performance. Also, performance relies on more than just function. It is a result of chair seat setup (Desroches, Aissoui, & Bourbonnais, 2006), wheel camber (Faupin, Campillo, Weissland, Gorce, & Thevenon, 2004), experience (Ergun, Duzgun, & Aslan, 2008) and training.  Therefore, classification systems should not rely on performance testing to determine classification. Instead, it should focus on function as it relates to the sport.

The current IWBF system seeks to measure function as it relates to a volume of motion during athletic competition (International Wheelchair Basketball Federation, 2014). The system is such that a player can be classified differently depending on what chair he/she is using.  This leads to discrepancies and lack of continuity, inevitably resulting in inequality in competition as players may opt to utilize fewer options for stability to be classified lower. Trunk stability and range of motion have been shown to be the best indicators of sport function (Vanlandewijck, Verellen, & Tweedy, 2010). Therefore, trunk stability and range of motion needs to be measured outside of competition and the wheelchair, to determine function of the athletes in an unbiased way. Once classified in this manner, players can utilize technology and training to provide the best athletic competition possible.

The importance of eliminating technology as sources of increased classification scores is growing as advances in equipment is occurring rapidly. Chairs have evolved to lighter and more efficient designs (Ardigo, Goosey-Tolfrey, & Minetti, 2005). Athletes are also taking advantage of multiple strapping configurations and camber settings. Camber optimization has become an important aspect of wheelchair sport as it requires the proper balance for optimal forward speed, lateral balance, and maneuverability (Faupin, Campillo, Weissland, Gorce, & Thevenon, 2004). Athletes should be encouraged to take full advantage of the newest technology to give them the best chance at performance success.

However, the current IWBF classification system may cause athletes to fear optimization resulting in higher classification. In order to maximize trunk stability, athletes incorporate straps and tilted seating configurations. To avoid higher classification, some may elect to not use a strap or place themselves in the absolute best chair configuration. This could be because it is expensive to optimize chair configuration, but it could also be that the athlete wants a lower classification. In the current system, player "A" could have the same functional control as player "B", but "A" does not optimize his/her chair configuration. He/she is given a lower classification than "B". In this case, optimizing and training to have better performance results in being penalized with a higher classification.

Theoretically, in order to avoid being penalized in this way, athletes would not optimize their chairs.The lack of optimization would decrease lower trunk stability and lead to more shoulder instability, placing the athletes at risk of shoulder injury. The link between not choosing optimal settings and potential injury is best understood through understanding wheelchair propulsion, and the injuries related to it.

Within wheelchair sport, the ability to propel a wheelchair is of the utmost importance. Much of the sport related research has focused on performance measures as related to disability level in the hopes to find functional differences. In fact, clinical research has found that different propulsion strategies have been observed in individuals with SCI suggesting performance differences can be reliably predicted by functional differences.

The research on wheelchair propulsion has previously focused on surface electromyography, shoulder forces, and the user-wheelchair interface. The sEMG studies have focused on activation patterns during the propulsion cycle by separating groups based upon lesion above or below a certain level or into ranges of lesion level. Clinically motivated, many of these studies are interested in methods to reduce injury to those utilizing wheelchairs.

Wheelchair propulsion exposes people who use wheelchairs to risk of upper limb impairment. The percentage of people that use wheelchairs with shoulder abnormalities can be found in up to 73% of wheelchair users (Lal, 1998).There are demographic factors that play a role in rates of shoulder injury, but the most telling factor is the number of years of wheelchair use since SCI injury. Those with longer use of wheelchairs are more likely to have some impairment except in the case of childhood onset of disability. Those who have sustained an SCI in childhood do not demonstrate a correlation between number of years using a wheelchair and shoulder abnormalities which is suggested to be a result of adaptation in younger populations (Sawatzky, Slobogean, Reilly, Chambers, & Hol, 2005). Knowledge of the prevalence of shoulder injury in users of wheelchairs is important for wheelchair athletes, coaches, and trainers to since the same mechanisms of injury exist in sport wheelchair propulsion as everyday propulsion.

In order to quantify the experience of upper limb pain experienced in people with disabilities the Wheelchair User's Shoulder Pain Index (WUSPI) was created and validated (Curtis, et al., 1995). The index utilizes self reports of pain during activities as well as the level of difficulty of an activity. The most pain occurred in overhead tasks like reaching to a shelf overhead, uneven transfers, pushing uphill, and washing the back.

The cause of pain and injury in those that use wheelchairs is multifaceted. The development of several models have occurred in an attempt to address the mechanisms of injury. In 1996, Rao et al. created one of the first three dimensional kinematic models of wheelchair propulsion. Using this model, Newsam et al. 1999 found that at initial hand contact the humerus is posterior to the trunk and internally rotated. This places the greater tuberosity and suprispinatus closer to the acromion which could lead to impingement. In this study, differences in propulsion were observed across different levels of SCI. The differences came in force produced during propulsion not in style of push for those with paraplegia. The individuals with quadriplegia demonstrated a different style of push. The group with quadriplegia exhibited a more “pumping motion” in which elbow flexion was greatest during the recovery phase. Instead of the “looping” action demonstrated by the groups with paraplegia in which the elbow undergoes more extension during the recovery. Those with paraplegia were also able to utilize the pectoralis major in order to protect the glenohumeral head during the awkward initiation position but those with quadriplegia were not able to do so.

Further evidence that level of lesion and propulsion technique influence potential for shoulder injury is found in electromyography (Mulroy, Farrokhi, Newsam, & Perry, 2004). Mulroy et al., (2004) utilized sEMG to discover muscle activation patterns during the two phases of the propulsion cycle, namely, push phase and recovery phase.Those with paraplegia demonstrated similar muscle activation patterns despite differences in lesion level. During push phase the anterior deltoid, pectoralis major, supraspinatus, infraspinatus, serratus anterior, and biceps were most active; in recovery, the middle and posterior deltoid, supraspinatus, subscapularis, middle trapezius, and triceps were most active, for those with paraplegia.  In those with quadriplegia, pectoralis major activity was longer in duration, and subscapularis was active during push phase but not recovery.

These findings were supported by Liping, Wakeling, Simon, & Fersuson-Pell, 2012. Liping et al., (2012), noted that the muscles active during the push phase increased as demand increased. However, the recovery muscles did not increase in activity. This may demonstrate how imbalance of the muscles occurs. The push phase muscles are required to generate larger amounts of force due to the increases in resistance. The recovery phase muscles do not have the increased demand. The repeated increased demand could result in increased muscle strength in the push phase muscles but not in the recovery phase muscles creating an imbalance between the push phase muscles and the recovery phase muscles. Burnham et al., (1993) concluded that muscle imbalance, resulting in high ratios of abducter to adductor strength and abductors to internal and external rotators, is a factor in shoulder impingement in wheelchair athletes.

Another avenue explored for discovering the injuries of the shoulder in those who use a wheelchair is magnetic resonance imaging (MRI). In MRI research, age, years of using a chair and gender were found to be predictors of shoulder injury (Boninger et al. 2001; Boninger et al. 2003). Mercer et al. 2006 was able to relate specific stroke patterns to specific shoulder injuries. It was found that higher posterior force, lateral force, or extension moment was related to coracoacromial ligament edema. Increased internal rotation during propulsion was related to higher pathological rates as well.

The studies previously discussed point to muscle imbalance, overuse, and the large moments created at the shoulder as being the cause for shoulder impairment within users of wheelchairs. This creates an image of certain injury to the shoulders of athletes that use a wheelchair. It seems wheelchair athletes would be exposed to frequent large moments at the shoulder, and therefore, would have higher incidents of shoulder injury.

However, an investigation into the incident of soft tissue injury during the 1996 Paralympic games found that while the highest rate of injury for wheelchair athletes was shoulder injuries the rate of incidence was not greater than that of all athletes (Nyland, Snouse, Anderson, Kelly, & Sterling, 2000). This could be due to the findings and implementation of better training to promote strength balance and proper technique in wheelchair athletes (Goosey, Fowler, & Campbell, 1997; Gorce & Louis, 2012; Lenton, Fowler, van der Woude, & Goosey-Tolfrey, 2008; Rodgers, Keyser, Rasch, Gorman, & Russell, 2001). The proper technique involves less pulling on the wheel and more pushing. When forces are directed towards the axle instead of more tangential it leads to larger loads on the shoulder. The most efficient motion found in these studies is a looping or elliptical pattern. The recovery is completed below the handrim. In the “pumping” motion the shoulder is exposed to larger impulses as the forces are applied more abruptly. The pumping motion also demonstrates a higher frequency resulting in more time that the shoulder experiences these forces. In the looping technique, the recovery time is longer which allows for the wheelchair to roll without the hand causing a braking action. Optimizing the time the hand is in contact with the wheel, the position of the shoulder in relation to the hub, and actual technique employed by the user all need further investigation so that training and teaching protocols can be developed for users of wheelchairs.

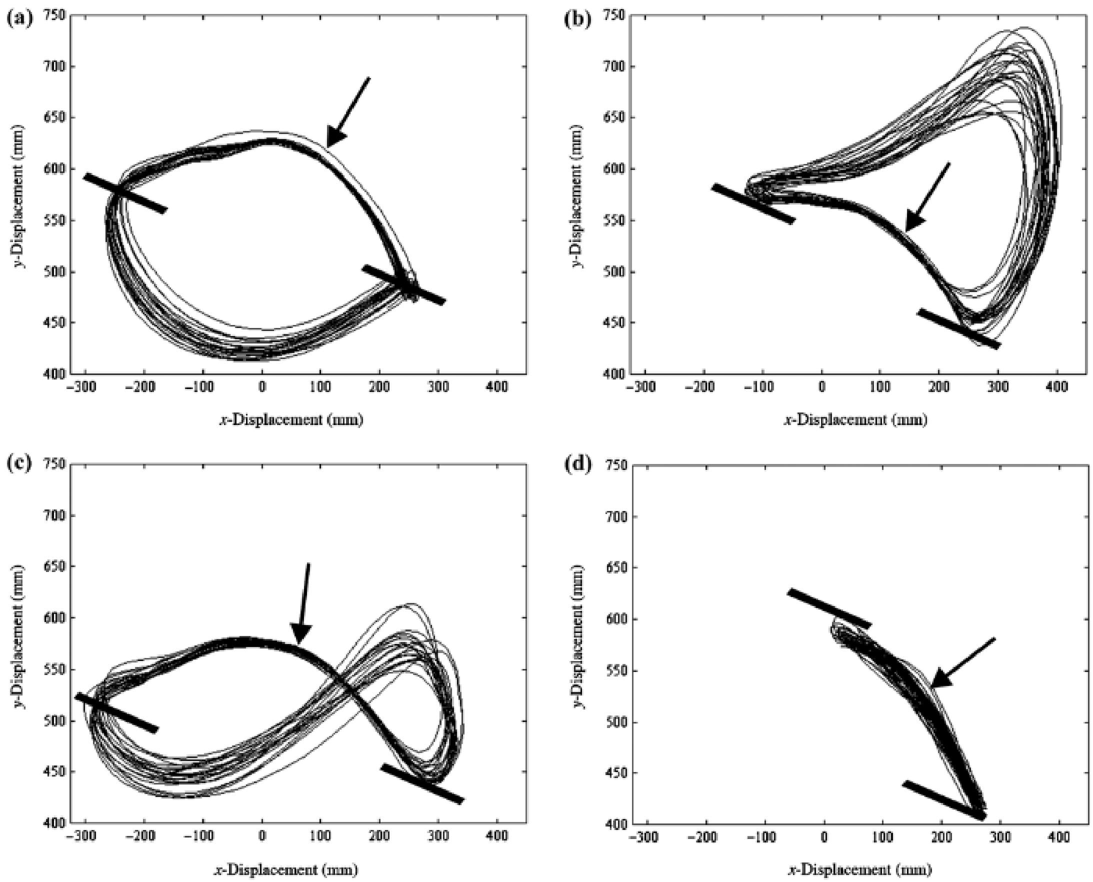

Figure 3. Patterns of propulsion found by Boninger et al., (2005). (a) elyptical most efficient, (b) single-loop, (c) double-loop, and (d) arcing/pumping. The images demonstrate common patterns of motion realized at the wrist during wheelchair propulsion. The arrows reflect the hand being in contact with the handrim (*used with permission).*

The benefits of training on shoulder pathology have also been demonstrated. In a sample of people with quadriplegia, it was found that those who trained for a wheelchair rugby team for two years demonstrated improvements in general functionality and efficiency of propulsion (Furmaniuk, Cywinska-Wasilewska, & Kaczmarek, 2010). Furthermore, an eight week training study demonstrated how even small amounts of training inside a person’s home can positively affect shoulder stability (Keyser, Rasch, Finley, & Rodgers, 2003).

Looking even broader at ways to manage the forces experienced at the shoulder also adds insight into how to prevent shoulder injury in wheelchair athletes. For example, training the trunk could lead to better shoulder outcomes. In a 2006 study, Yang et al.,found that as participants fatigued during wheelchair propulsion, more trunk motion was seen though it was not as effective. In a similar study, loss of trunk stability led to loss of shoulder stability (Yildirim, Comert, & Ozengin, 2010). Therefore, increasing the endurance of the trunk could lead to less shoulder injury.

Another factor that has shown great benefit to the loads placed upon the shoulder is chair configuration. Axle position in relation to the shoulder is one of the largest factors in the creation of the load at the shoulder (Desroches, Aissoui, & Bourbonnais, 2006; Dubowsky, Rasmussen, Sisto, & Langrana, 2008; Gorce & Louis, 2012). A higher seat allows for a less flexed elbow at contact and places the shoulder slightly behind the axle which permits for the most efficient propulsion pattern and the least amount of force exerted at the shoulder. New designs of chairs have also lightened the load on users of wheelchairs making propulsion easier (Ardigo, Goosey-Tolfrey, & Minetti, 2005).

Prevalence of shoulder injury in wheelchair athletes is a topic with conflicting in research. Though athletes may train to prevent muscle imbalance and to use proper technique there still exists injuries related to overuse in similar prevalence to non-athletic users of wheelchairs (Finley & Rodgers, 2004). This could, in part, be due to the lack of support given to wheelchair athletes. Large numbers of wheelchair athletes train on their own without properly trained coaches (Liow & Hopkins, 1996). In contrast to these studies, others have found that athletes, who have competed in wheelchairs sports longer, have better muscle balance (Nyland, Robinson, Caborn, Knapp, & Brosky, 1997; Denier, Gremeaux, Fattal, Codine, & Bernard, 2007) and propelled themselves most efficiently (Ergun, Duzgun, & Aslan, 2008). The disagreeing results in the current body of literature could be the result of small sample sizes in the studies, certain samples having lesser quality in training, or a combination of those factors. In any case, it is important that wheelchair athletes be given every opportunity to protect their shoulders from injury since in many cases their shoulders provide the main mode of their locomotion and activies of daily living ( Ergun et al., 2008; Samuelsson, K., Tropp, H., & Gerdle, B., 2004). Therefore, every attempt to preserve the health of the shoulders of people that use wheelchairs should be made, including a classification system which encourages athlete safety by not penalizing chair optimization.

Potential injury may not be enough to ensure athletes optimize their chairs. Currently, some may be more inclined to take the immediate benefit of playing time as a result of lower classification, rather than properly optimizing their chair. This leads to more likelihood of injury because of the factors previously described. To combat the desire to not optimize chair settings in order to achieve a more favorable classification, it would be best to create a system of classification that is based on function without sport performance as the metric of function. Optimal performance should be encouraged by classification. In the current system, it is discouraged in some cases so as to achieve a lower classification. Tests should be developed that give functional measures related to sport. Athletes should not be penalized with higher classifications because they train and optimize their performance. The classification system should be such that it encourages optimization of all the athletes. This will lead to better training and hopefully less injury in wheelchair basketball players.

A body of research regarding the effectiveness of wheelchair sport classification has been created. In this line of research, classification is utilized as a tool for separating groups to determine differences in function or performance (Nyland, Robinson, Caborn, Knapp, & Brosky, 1997). It has not been determined that the right number of classifications exists within the individual sports, and it is not clear that the systems are accomplishing the goal of placing athletes with similar function in competition with each other. Therefore, the International Paralympic Committee (IPC) has pushed for research that demonstrates how fair competition can be established through evidence based classification.

Nyland, Robinson, Caborn, Knapp, and Brosky (1997) examined the relationship of shoulder torque, wheelchair use, and classification. The study utilized the National Wheelchair Basketball Association's medical classification system. The system consists of 3 classifications based upon medical diagnosis and presumed function. It was found that the group in the lowest classification demonstrated less symmetry in the ability to produce torque when externally rotating at the shoulder. The nondominant shoulder was found to produce less torque in external rotation for these individuals. The lowest classified players also exhibitied higher dependence on a wheelchair for daily mobility. The study served as evidence that the system did differentiate functional abilities. However, it did not address how those differences came to be, how those related to the level of lesion, or how those affect function on the court.

Success and mechanical strategy of free throw shooting is an area where researchers have aimed to show the effective differences among those classified in wheelchair basketball (Goosey-Tolfrey & Butterworth, 2002; Malone, Gervais, & Stedward, 2002). Goosey-Tolfrey and Butterworth 2002 utilized the IWBF's functional classification system to create groups to find differences in free throw shooting technique among members of differing classes. Two groups were established:  1) 2's and 2.5's and 2) 4's and 4.5's. Group 2 demonstrated a more upright seating position based upon trunk kinematic data, a higher release point, and a significantly greater success percentage. The higher release point could be due, in part, to sitting higher. Similar results were found by Malone et al., (2002) but the range of classifications within the participant pool was 1-4.5. These studies point to the need to identify classifications properly since performance of a fundamental skill can be related to functional classifications.

Athletes with differing classification demonstrate different capabilities in performance and functional tests (Molik, et al., 2010). Utilizing the IWBF functional system, it was found that Class 1 athletes showed the greatest differences from the others; Class 2 athletes were different from the 3's and 4's; however, the Class 3 athletes did not signficantly differ from the Class 4 or 4.5 athletes. The most interesting element of this project was the differentiation of the athletes with cerebral palsy from other motor impairments. The athletes with cerebral palsy performed the worst in all the tests.

The differences found for those with cerebral palsy begs the question of how should the testing for classification be done. Typically, manual muscle testing is performed by a classifier. However, there is not uniformity in the system across sports and sometimes not within a sport (Tweedy, Williams, & Bourke, 2010). Tweedy et al.,(2010) found that of the 20 Summer Sports, 15 use some form of manual muscle testing in classification. Of those 15, only 5 utilize a standard test procedure. The others are unspecified and up to the individual classifiers (Tweedy, Williams, & Bourke, 2010). This suggests a need to standardize testing procedures.

The research showing the value and faults within the classification systems is built upon the relationship between disability level and functional outcomes. Research has shown the relationship between level of spinal cord lesion and trunk function in reaching tasks. Other measures of function demonstrated to be related to lesion level are activities of daily living such as changing clothes, reaching above one's head, and transfers. While these may not be sport related, the differences in functional ability highlight the potential effectiveness of this approach for classification in adapted sports.

The most important difference between people of differing functional levels comes in the ability to stabilize the trunk. The ability to stabilize the trunk is crucial for movement in everyday life, but in sport it is also even more essential for balance (Chen, et al., 2003) (Janssen-Potten, Seelem, Drukker, & Reulen, 2000) (Vanlandewijck, Verellen, & Tweedy, Towards evidence based classification - the impact of impaired trunk strength on wheelchair propulsion, 2010). The research in this area has demonstrated that trunk function is measurable by reaching tasks (Field-Fote & Ray, 2010; Janssen-Potten, Seelem, Drukker, & Reulen, 2000; Janssen-Potten, Seelen, Drukler, Huson, & Drost, 2001). For example, Field-Fote and Ray (2010) showed that measures of reach and trunk excursion are related to dynamic stability of people with SCI, for the ability to move one's center of gravity closer to the edge of the base of support is at the center of understanding differences between capability based on lesion level versus function (Janssen-Potten, Seelem, Drukker, & Reulen, 2000). People with spinal cord injuries are less capable of moving their center of gravity outside of their base of support than those without spinal cord injury (Janssen-Potten, Seelem, Drukker, & Reulen, 2000). The lessened ability to move one's center of gravity out of the base of support diminishes the ability for one to complete sports tasks such as rebounding, catching an errant pass, or picking a ball up off the floor. People with spinal cord injuries also adopt a posture with more posterior tilt of the pelvis in order to gain and maintain balance (Chen, et al., 2003; Alm, Gutierrerz, Hultling, & Saraste, 2003). The posteriorly tilted pelvis leads to more curvature in the three major curves of the spinal column. The increased curvature prevents the ability to actively move through the full range of motion which also limits one's ability to perform sport actions.

Recognizing the importance of trunk stability and trunk range of motion, the IWBF created its functional system of classification. The classification is an excellent attempt and has had success in the creation of equitable competition. However, it is not able to keep up with the rate of technology change since the classifications are dependent on how someone performs in a particular chair. As the chairs advance, the IWBF system falls behind. Players are able to do more as the technology is made better. Some athletes also have more experience resulting in what appears to be higher function, but it is actually a result of better training. Therefore, to encourage optimization of athletes in all aspects, a new system for classifying is needed. The system should be done outside of competition, be reliant upon functional measures (especially those related to trunk function), and still done in a way that is not a burden on athletes, coaches, or classifiers.

# CHAPTER III

# METHODOLOGY

The purpose of this project is to determine the efficacy of two field tests in the classification of wheelchair basketball athletes.  In order to evaluate the efficacy of the novel classification system, participants were recruited to perform two sets tasks. The first set were reaching tasks which include measurements to quantify the "volume of action" within the IWBF classification system as well as development of a novel field test for measuring the volume of action. The second set of tasks includes strength measurement tasks which are utilized to relate functional ability to the reaching task. The strength task of the study focuses on the percentage of force output lost when the advantage of support is removed.

The following chapter will present the methodology in four sections. The first section will present the requirements of participation. The second and third sections will present the instrumentation and procedures for the reaching task and strength task. The fourth section will detail the statistical analyses to be utilized.

## Participants

Twenty participants volunteered for this project. Specifically, 10 individuals with mobility impairments which meet the IWBF's minimum criteria to compete in wheelchair basketball and 10 individuals without mobility impairment were recruited.

The participants without mobility impairment demonstrate the volume of action for a person without functional limitations. The individuals with mobility impairments have varying motor impairments which allows for the stratification of differing functional abilities.

## Reaching Task

### Instrumentation

**Classification Tool**.

A novel tool for classifying wheelchair athletes was constructed for this project.The tool consists of a 46 cm x 46 cm x 46 cm box with an adjustable footrest and a target towards which the participants reach. The target height adjusts to be level with: the sternum; ASIS level of all participants; and to 24 centimeters from the ground, which is the equivalent of the diameter of a men's basketball. The target was placed 1.5 m from the box and so that the participants reach in the five directions as shown in Figure-8. In order to measure distance reached, the participants held a laser distance measurer.

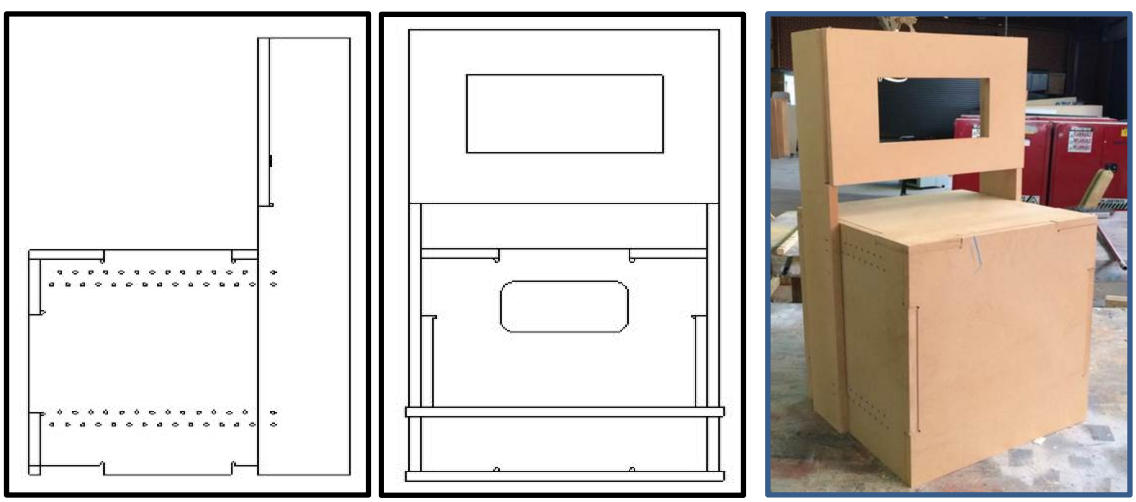

Figure 4. Classification seat design schematics (left, center) and seat used for testing (right).

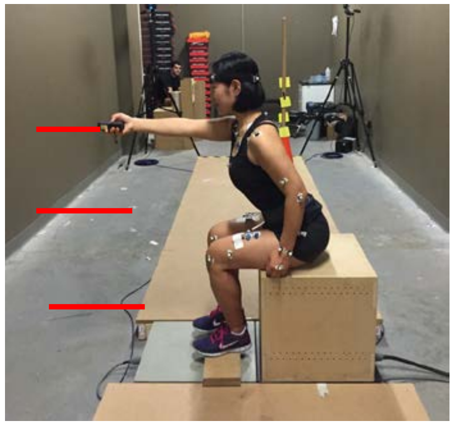

Figure 5. Participant trial of reaching task. Three heights demonstrated by red lines.

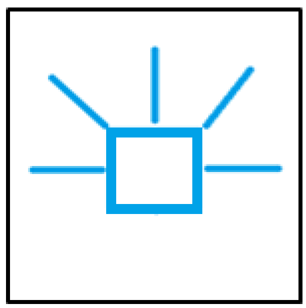

Figure 6. Directions of reach while using classification tool.

**Force Plate.**

Center of pressure during sitting was found utilizing an AMTI OR-6-1000 Force Platform (Advanced Medical Technology Inc., Watertown, Massachusetts). The classification seat rested flush upon the force plate. The ability to move the center of pressure on a force plate is related to the ability to move one's center of gravity closer to the edge of the base of support while seated. Therefore, this measurement demonstrates the functional ability lost as a result of mobility impairment (Field-Fote & Ray, 2010; Janssen-Potten, Seelem, Drukker, & Reulen, 2000

**Surface Electromyography.**

Surface electromyography (sEMG) was utilized to collect muscle activation data during the trials. Muscles of interest were the erector spinae, rectus abdominis, sternal portion of the pectoralis major, and rectus femoris. Particularly, the author is interested in the level of muscle activation during the final posture of the reach. Primarily, discovery of different patterns of muscle activation utilized by individuals with motor impairments will be sought. The utilization of different activation patterns will indicate where functional deficits occur. These deficits would be of immense importance to creating a proper classification system as they would reflect the very functional differences the classification system model of adapted sport are based.

Muscle activity was collected by using eight pairs of bipolar Ag-AgCL surface electrodes (Blue Sensor M, Ambu, Copenhagen, Denmark). The sEMG leads were connected to a Noraxon® Telemyo 2400R-World Wide Telemetry receiver (Noraxon® U.S.A. Inc., Scottsdale, AZ, USA). The Telemetry receiver will be connected to a Noraxon® Telemyo 2400T V2 wireless transmitter (Noraxon® U.S.A. Inc., Scottsdale, AZ, USA) to collect the data using the procedures described by Basmajian and Deluca (1985).

**Kinematics.**

A 10 camera Vicon® MX motion analysis system (Vicon®, Los Angeles, CA, USA) with a sampling frequency of 200 Hz was used to collect three-dimensional kinematic data of the pelvis, trunk, shoulders, elbows, and wrists during the reaching task. Thirty-one, 14 mm, spherical retro-reflective markers (MKR-6.4, B & L Engineering, Tustin, California, USA) were placed upon each participant by means of double sided tape in a modified Plug-In-Gait model as shown in Figure-9 and Table 3. The 10 Vicon® MX cameras captured the kinematic data, and Visual 3D (C-Motion Research Biomechanics, Germantown, Maryland, USA) was utilized to calculate wrist translation during the reaching tasks.

Table 3

*Marker Positions for Motion Capture*

| Marker Name | Position | Segment |
| --- | --- | --- |
| RFHD | Right Front Head | Head |
| LFHD | Left Front Head | Head |
| RBHD | Right Back Head | Head |
| LBHD | Left Back Head | Head |
| CLAV | Sternoclavicular Joint | Chest |
| STRN | Sternum | Chest |
| C7 | 7th Cervical Vertebrae | Spine |
| T10 | 10th Thoracic Vertebrae | Spine |
| ROFF | Right Midtorso | Assymmetry Identification |
| RSHO | Right Acromioclavicular Joint | Shoulder |
| LSHO | Left Acromioclavicular Joint | Shoulder |
| RLEL | Right Lateral Aspect of Humeroulnar Joint | Elbow |
| LLEL | Left Lateral Aspect of Humeroulnar Joint | Elbow |
| RMEL | Right Medial Aspect of Humeroulnar Joint | Elbow |
| LMEL | Left Medial Aspect of Humeroulnar Joint | Elbow |
| RRAD | Right Distal End of Radius | Wrist |
| LRAD | Left Distal End of Radius | Wrist |
| RULN | Right Distal End of Ulna | Wrist |
| LULN | Left Distal End of Ulna | Wrist |
| RFIN | Right 3rd Metacarpophalangeal Joint | Knuckle/Finger |
| LFIN | Left 3rd Metacarpophalangeal Joint | Knuckle/Finger |
| RIC | Right Iliac Crest | Pelvis |
| LIC | Left Iliac Crest | Pelvis |
| RASIS | Right Anterior Superior Iliac Spine | Pelvis |
| LASIS | Left Anterior Superior Iliac Spine | Pelvis |
| RTHI | Right Lateral Aspect of Femur | Upper Leg |
| LTHI | Left Later Aspect of Femur | Upper Leg |
| RLKN | Right Tibiofemoral Joint | Knee |
| LLKN | Left Tibiofemoral Joint | Knee |
| RMKN | Right Femoral Medial Epicondyle | Knee |
| LMKN | Left Femoral Medial Epicondlye | Knee |

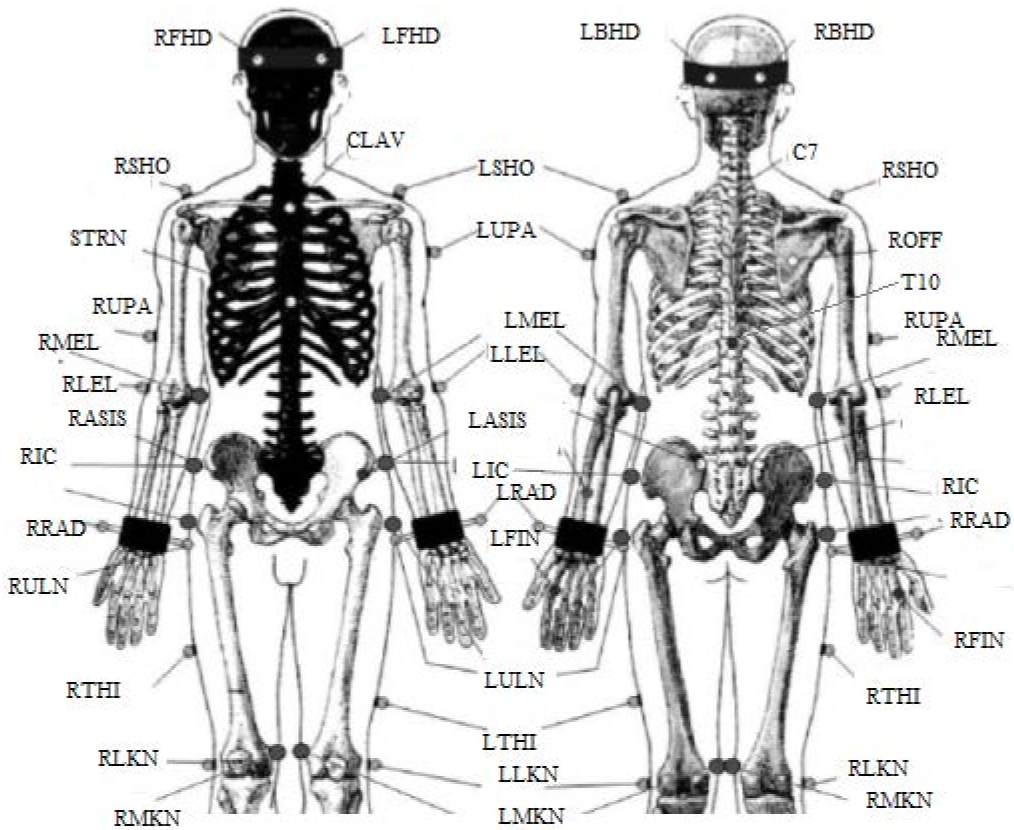


Figure 7. Modified Plug-in-Gait model retroflective marker locations.

## Procedure

### Preparation.

Participants were given compression clothing to wear. Using the techniques illustrated by Basmajian and Deluca (1985), the participant will be prepared for sEMG recordings. The areas of skin above the muscles of interest were prepared as follows: shaving the hair from the site, abrading the area, and cleaning the area with alcohol wipes. The electrodes were placed on the skin above the muscles of interest along the midline of the muscle and parallel to the muscle fibers with an inter-electrode distance of 2cm. A maximum voluntary isometric contraction (MVIC) was conducted using the manual muscle testing techniques by Kendall et al.,(2005) for the muscles of interest.

The pectoralis major were tested by having the participant sit on the classification seat with the backrest in place. A researcher stood behind the participant, placed one hand on the contralateral shoulder of the participant, and other hand on the medial side of the participants elbow. The researcher instructed the participant to maintain a “straight arm” and try to pull his/her arm across his/her body (Kendall et al, 2005). The participant will remained seated to measure the rectus abdominis. The participant was asked to curl his/her trunk as if to do a sit-up (Kendall et al, 2005). One researcher provided resistance by pulling both shoulders posteriorly. The MVIC for the erector spinae was completed by having the participant remove pressure from the back rest while seated. One researcher held the participant’s shoulders. The participant was instructed to attempt to extend his/her back (Kendall et al, 2005).  To measure the rectus femoris MVIC, a researcher will position the participant’s knee at 90 degrees. The researcher will place the participant’s ankle for the leg to be measured giving resistance against the participant’s attempt to extend his/her knee (Kendall et al, 2005). The MVIC provides baseline data for sEMG measurements to be converted to and compared as a percentage. Upon completion of the MVIC collections, 26 retroflective markers will be placed upon the participant using double-sided tape.

**Volume of Action.**

To determine the volume of action for each participant, a series of reaches were completed. The novel classification tool was utilized for conducting the reach tests. Under three conditions, (sternum height, ASIS height, and ball height), the participants completed 10 reaches, 5 with each hand:  1) directly in front, 2) directly right, 3) directly left, 4) 45 degrees transverse rotation from front to right, and 5) 45 degrees transverse rotation from front to left.

The distance the participant is able to reach at each height was measured by calculating the difference of the starting distance between the laser and target from the final distance between the laser and target. All distances were compared as a percentage of trunk torso height.

***Reach Sternum Height***.

Participants sat upon the constructed seat with hips and knees at 90 degrees. The target height was set level with the sternum. The initial target distance was the distance between the laser and target with the participant maintaining an upright posture and holding the laser level with the target. The participants were instructed to reach towards the target as far as possible, with the laser level at the height of the target and hold for 5 seconds. This procedure was conducted with each hand and in each direction. Participants were instructed to not utilize the non-reaching hand for support, but any other strategy for further reach was encouraged. Participants were directed to attempt to make use of trunk rotation, elbow extension, and shoulder flexion/abduction to maximize reach distance.

***Reach ASIS Height.***

Participants sat upon the constructed seat with hips and knees at 90 degrees. The target height was set level with the ASIS. The initial target distance was the distance between the laser and target with the participant maintaining an upright posture, fully extended elbow, and holding the laser level with the target. The participants were instructed to reach towards the target as far as possible, with the laser level at the height of the target and hold for 5 seconds. This procedure was conducted with each hand and in each direction. Participants were instructed to not utilize the non-reaching hand for support, but any other strategy for further reach was encouraged. Participants were directed to attempt to make use of trunk rotation, elbow extension, and shoulder flexion/abduction to maximize reach distance.

#### *Reach Ball Height.*

Participants sat upon the constructed seat with hips and knees at 90 degrees. The target height was set at 24 cm, the equivalent to the diameter of a men's basketball. The initial target distance was the distance between the laser and target when the participant holds the laser at ball height as close to the seat as possible. The participants were instructed to reach towards the target as far as possible, with the laser level at the height of the target and hold for 5 seconds. This procedure was conducted with each hand and in each direction. Participants were instructed to not utilize the non-reaching hand for support, but any other strategy for further reach was encouraged. Participants were directed to attempt to make use of trunk rotation, elbow extension, and shoulder flexion/abduction to maximize reach distance.

## Strength Task

### Instrumentation

#### Testing Seat.

A seat was constructed for this project. The seat consisted of a 46 cm x 46 cm x 46 cm long box with an adjustable footrest and a removable support. The seat was placed with the support side on away from the wall.

**Force Gauge.**

Force measurements during the strength task were acquired utilizing a SHIMPO FGV-PT 500 Force Gauge (NIDEC-SHIMPO, Chicago, Illinois, USA). Concentric force measures were found by the participant pushing the force gauge against a wall. Eccentric force measures were found by pushing against the participant with the force gauge.

**Surface Electromyography.**

Surface electromyography (sEMG) was utilized to collect muscle activation data during the trials. Muscles of interest were the erector spinae, rectus abdominis, sternal portion of the pectoralis major, and rectus femoris. Primarily, discovery of peak muscle activation utilized by individuals was sought. The utilization of different activation patterns indicates where functional deficits occur. These deficits are of immense importance to creating a proper classification system as they would reflect the very functional differences on which the functional model of adapted sport is based.

Muscle activity was collected by using eight pairs of bipolar Ag-AgCL surface electrodes (Blue Sensor M, Ambu, Copenhagen, Denmark). The sEMG leads were connected to a Noraxon® Telemyo 2400R-World Wide Telemetry receiver (Noraxon® U.S.A. Inc., Scottsdale, AZ, USA). The Telemetry receiver was connected to a Noraxon® Telemyo 2400T V2 wireless transmitter (Noraxon® U.S.A. Inc., Scottsdale, AZ, USA) to collect the data.

**Kinematics.**

Motion of the trunk was collected utilizing a 10 camera Vicon® MX motion analysis system (Vicon®, Los Angeles, CA, USA) with a sampling frequency of 200 Hz. Thirty-one, 14 mm, spherical retro-reflective markers (MKR-6.4, B & L Engineering, Tustin, California, USA) were placed upon each participant by means of double sided tape in a modified Plug-In-Gait model as shown in Figure-7 and Table 3.

## Procedure

### Preparation.

Participants were given compression clothing to wear or wore their own compression clothing. Using the techniques illustrated by Basmajian and Deluca (1985), the participant were prepared for sEMG recordings. The areas of skin above the muscles of interest was prepared as follows: shaving the hair from the site, abrading the area, and cleaning the area with alcohol wipes. The electrodes were placed on the skin above the muscles of interest along the midline of the muscle and parallel to the muscle fibers with an inter-electrode distance of 2cm.

### Concentric Strength Measure.

Participants sat upon the classification tool with hips and knees at 90 degrees. Each participant completed 6 maximal effort pushes 3 times each: front with support, front without support, right with support, right without support, left with support, left without support. For the front condition, the participants held the SHIMPO force gauge with both hands with the shoulder positioned at 90 degrees shoulder abduction, 45 degrees horizontal adduction and 0 degrees rotation; and 90 degrees elbow flexion (Vanlandewijck, Verellen, & Tweedy, Towards evidence based classification - the impact of impaired trunk strength on wheelchair propulsion, 2010). The participants were instructed to push against the force gauge against the wall with maximum force for three seconds. For the right and left conditions, the participants held the force gauge in the appropriate hand with the shoulders positioned at 45 degrees of shoulder abduction and

90 degrees of elbow flexion. The participants were instructed to push the force gauge against the wall with maximum force for three seconds. Support was provided by means of a removable chair backrest in the appropriate conditions (front with support, right with support, left with support). A trunk stability score was found for each direction. The score was calculated by subtracting the without support peak force from the supported peak force. This difference was then converted to a percentage of the support peak force. The percentage found for each direction served as the score.

**Eccentric Force Measure.**

Participants will sit on the classification box with hips and knees at 90 degrees of flexion. A researcher will push against the participant in three different conditions (front, left and right) with a SHIMPO FGV-PT 500 Force Gauge. For the front condition, the researcher applied the force gauge to the sternum of the participant. The participant was instructed to resist motion against the pressure applied by the researcher. The researcher pushed the force gauge against the participant until the participant could no longer resist motion. The test was conducted in the left and right condition by applying the portable muscle tester to 2 inches below the AC joint. Again, the participant was instructed to resist motion. Then, the researcher will applied pressure to the portable force gauge until the participant could no longer resist motion. The peak force achieved while resisting motion was utilized for analysis.

## Statistical Analysis

Statistical analysis will be completed utilizing SPSS software (version 17.0; SPSS Inc., Chicago, IL, USA). Simple regression was utilized to discover the relationship between the wrist translation according to the VICON 3D motion capture system and the change in distance according to the laser distance measurer. The effects of disability on the reach score was analyzed by utilizing 2 (group) x 2 (hand) x 3 (height) x 5 (direction) repeated measures analysis of variance (ANOVA). Hand conditions were combined to remove redundancies within the data and a 2 (group) x 3 (height) x 5 (direction) repeated measures ANOVA was utilized to compare disability effects on reach scores not as left and right, but forward, unilateral, unilateral 45, contralateral, and contralateral 45. The influence of disability on peak PEC and RF muscle activation during the reaching task was analyzed utilizing separate 2 (group) x 2 (hand_muscle) x 3 (height) x 5 (direction) factorial repeated measures ANOVAs. A 2 (group) x 2 (hand_muscle) x 3 (height) x 5 (direction) multivariate analysis of variance was utilized to analyze the effects of group on the peak activation of RA and ES during the reaching task.

The influence of support on peak force production was analyzed a 2 (group) x 2 (support) x 3 (direction) repeated measures ANOVAs. The effect of disability on difference in force production based on support was analyzed utilizing a 2 (group) x 3 (direction) repeated measures ANOVA. The effects of disability on RF and PEC peak activation with and without support were sought through the use of separate (group) x 2 (support) x 3 (direction) repeated measures ANOVAs. The differences in peak activation of RA and ES were sought through the use of a 2 (group) x 2 (support) x 3 (direction) repeated measures MANOVA. The relationship between the strength field test measure and the resistance test was sought utilizing simple regression as was the relationship between the sum of the reach scores and the sum of the trunk stability scores.

# CHAPTER IV

# RESULTS

The purpose of the project was to evaluate the potential of a new classification system for wheelchair basketball athletes. Specifically, the study aimed to 1) measure the "volume of action" associated with the IWBF classification system, 2) determine the influence of trunk stability on the production of force with the arms, and 3) determine if a relationship between the volume of action and the ability to produce force exists. The following chapter presents the results of the study including: 1) participant demographics, 2) reach task evaluation, 3) strength task evaluation, and the 4) comparison of the volume of action and ability to produce force.

## Participant Demographics

Twenty participants volunteered for the study. Ten participants were affected by a form of motor impairment which would qualify them to participate in wheelchair basketball (PWD), and ten were without motor impairment (PWOD). All participants completed a medical questionnaire to establish their ability to safely participate. All volunteers qualified and freely signed an informed consent document approved by the Auburn University Office of Research Compliance Institutional Review Board. Table 4 summarizes the demographic data of all participants. Table 5 summarizes information regarding disability and wheelchair basketball participation for the PWD.

Table 4

| *Demographic Data of Participants* | | |
|---|---|---|
| All Participants | Mean | Standard Deviation |
| Age (yrs) | 29.65 | 9.19 |
| Height (m) | 1.74 | 0.47 |
| Trunk Height (m) | 0.67 | 2.81 |
| Mass (kg) | 75.43 | 15.44 |
| PWD | Mean | Standard Deviation |
| Age (yrs) | 32.8 | 10.94 |
| Height (m) | 1.73 | 0.42 |
| Trunk Height (m) | 0.67 | 2.96 |
| Mass (kg) | 77.09 | 19.37 |
| PWOD | Mean | Standard Deviation |
| Age | 26.5 | 6.04 |
| Height (m) | 1.76 | 0.52 |
| Trunk Height (m) | 0.67 | 2.8 |
| Mass (kg) | 73.77 | 11.05 |

Table 5

| *Disability Related Information for PWD Group* | | | | |
|---|---|---|---|---|
| Participant | Disability | Level | Classification | Years Competed |
| PWD 01 | CP | Spastic | 2 | 10 |
| PWD 02 | SCI/Amputee | T9 Incomplete / RBK | 2.5 | 10 |
| PWD 03 | SCI | T12 INC | 3.5 | 3 |
| PWD 04 | Amputee | DBK | 4.5 | 5 |
| PWD 05 | Amputee | LBK | 4.5 | 4 |
| PWD 06 | Amputee | RBK | 3 | 5 |
| PWD 07 | Transient Osteoporosis | Minimum Disability | 4.5 | 1 |
| PWD 08 | SCI | T12 | 2 | 1 |
| PWD 09 | Multiple Sclerosis | | 3 | 1 |
| PWD 10 | SCI | L3 INC | 3 | 0 |
| Mean | | | 3.25 | 4 |

## Reaching Task

To measure the range of motion associated with the volume of action, participants reached with each hand (left and right), at 3 heights (sternum, ASIS, and ball), and in 5 directions (forward, right, left, right 45, and left 45). The distance reached was determined by 3D motion capture as the translation of the wrist as well as a laser distance measure. Distances were measured in meters (m) and converted to a percentage of trunk height giving a reach score (reach score= $\frac{distance}{trunk\ height}\ x\ 100$) to be utilized in statistical analysis. A score of 0 was given in conditions in which the participant was unable to complete the action either because they were unable to lower themselves or rotate their trunk in order to direct the laser onto the target. Of the possible 300 reaches for the PWD, 278 were completed. A score of zero was given to the trials not completed. The PWOD completed all trials. A simple linear regression was calculated to predict laser distance based on wrist translation. The results indicated that the data collected with the VICON motion capture system are related to the more basic laser distance measurer ($R^2$=0.658, F (1,536) = 1029.56, $p < 0.001$).

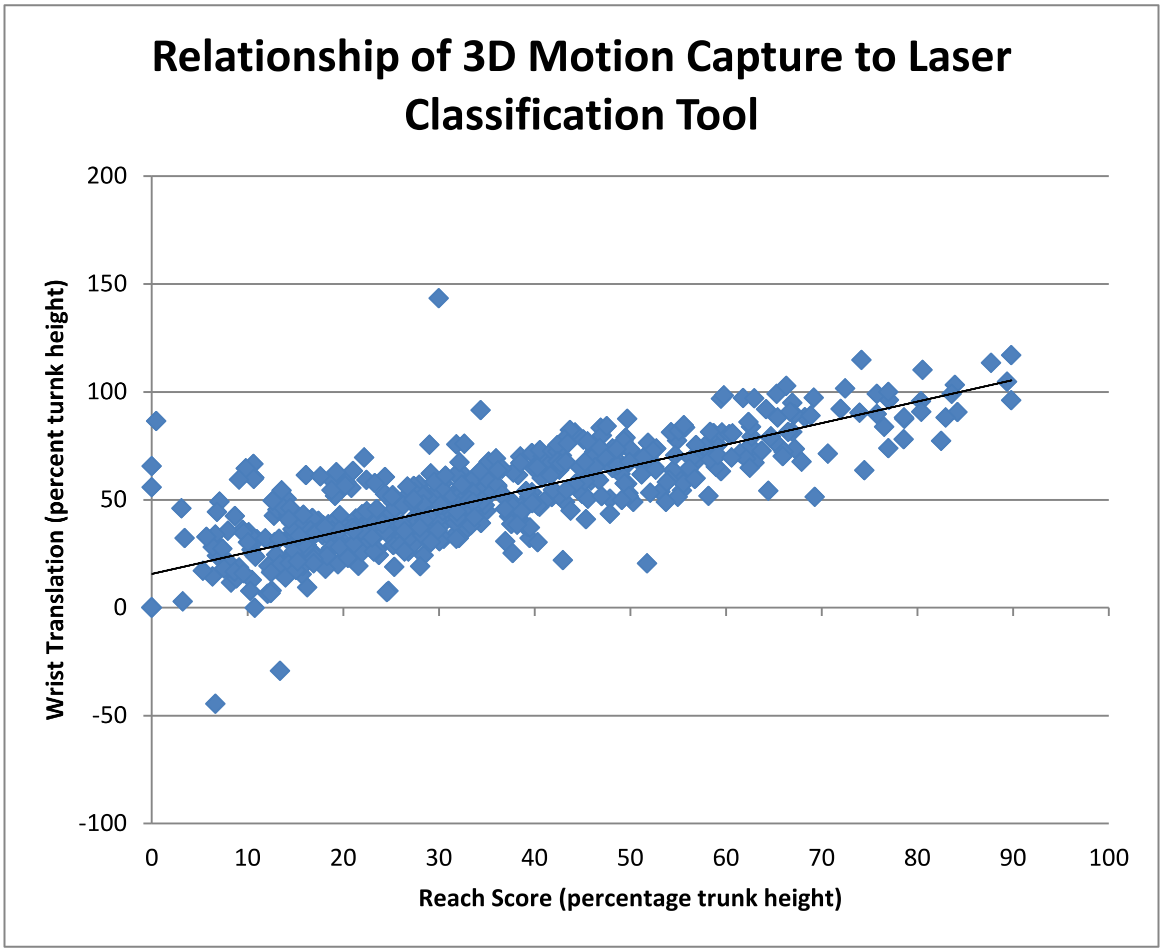


Figure 8: The relationship of the distance of wrist translation according to 3D motion capture to reach score obtained by the laser distance measurer (F (1,536)= 1029.56, $p < 0.001$, $R^2$=0.658).

A 2 (hand) x 3 (height) x 5 (direction) x 2 (disability) mixed methods repeated measures analysis of variance (ANOVA) was utilized to determine if differences in the reach scores existed. Hand, height and direction were within-subject factors, and disability was a between-subjects factor. The multivariate test results are summarized in Table 6. With this initial analysis, the Box's M was not able to be calculated due to similar hand condition data causing redundancies within the analysis so Pilai's Trace is reported. No significant differences (p>.05) were found between groups on reach score when considering hand used so post hoc analysis was not completed; PWOD tended to reach further than the PWD.

Table 6

*Summary of the Initial Reach Repeated Measures ANOVA*

| Effect | Measure | Pilai's Trace | F | Degrees of Freedom | $\eta^2$ | p | Power |
|---|---|---|---|---|---|---|---|
| Hand | Reach Score | 0.044 | .832 | 1,18 | 0.044 | .374 | 0.139 |
| Height* | Reach Score | 0.699 | 19.694 | 2,17 | 0.699 | <0.001 | 1 |
| Direction* | Reach Score | 0.894 | 31.544 | 4,15 | .894 | <0.001 | 1 |
| Group | Reach Score | | 2.716 | 1,18 | 0.131 | 0.117 | 0.345 |

*Note.* Significant values (p<0.05) are denoted with *.

No significant difference (p<0.05) was found between hand usage, but PWOD reached further with both hands. A significant difference was shown among each of the heights at which the reaches were measured. At the ASIS height, participants performed the furthest reaches and at the ball height the shortest reaches. This was true for both groups of disability (PWOD, PWD), but the PWOD reached further at all heights. Reach scores were significantly affected by direction of reach. Participants reached the furthest in the F direction followed by L 45, R 45, L and R respectively.

In order to remove the redundancy which affected the original statistical analysis, the hand and direction variables were combined into a single variable with five levels (forward, unilateral, unilateral 45, contralateral, and contralateral 45). A separate 3 (height) x 5 (direction) x 2 (disability) repeated measures factorial ANOVA was utilized to investigate the differences of reaching across the body or on the same side of the body during the reaching tasks. Box's M revealed that the assumption of equality variance was not violated; therefore, Wilk's Lambda is reported. Multivariate results are summarized in Table 7.

Table 7

*Summary of the Reach ANOVA with Combined Hand Conditions*

| Effect | Measure | Wilk's Lambda | F | Degrees of Freedom | $\eta^2$ | p | Power |
|---|---|---|---|---|---|---|---|
| Height* | Reach Score | 0.358 | 33.165 | 2,37 | .642 | <0.001 | 1 |
| Direction* | Reach Score | 0.152 | 48.944 | 4,35 | .848 | <0.001 | 1 |
| Group* | Reach Score | - | 5.598 | 1,38 | .128 | 0.023 | 0.635 |
| Height x Group* | Reach Score | 0.814 | 4.234 | 2,37 | .186 | 0.022 | 0.706 |
| Direction x Group | Reach Score | 0.966 | .305 | 4,35 | .034 | 0.873 | 0.11 |
| Height x Direction* | Reach Score | 0.209 | 14.676 | 8,31 | .791 | <0.001 | 1 |
| Height x Direction Group | Reach Score | 0.862 | 0.622 | 8,31 | .138 | 0.752 | 0.235 |

*Note*. Significant values (p<0.05) are denoted with *.

Significant main effects were found for the height, direction, and group. PWOD reached further than PWD in all conditions (Figure 14, Figure 15). A post hoc 2 (disability) x 3 (height) ANOVA was utilized to analyze the effects of disability and height. PWOD reached significantly further at the ASIS ($p=0.005$) and ball ($p<0.001$) heights, and a nonsignificant difference ($p=0.097$) was found at the sternum height (Table 6, Figure 14). The forward direction yielded the highest reach score followed by Unilateral 45, Contralateral 45, Unilateral, and Contralateral (Table 8, Figure 15). A post hoc 2 (disability) x 5 (direction) ANOVA was utilized to analyze the effects of disability and direction. PWOD reached significantly further in all directions. At the ball height, individuals reached the furthest forward followed by Unilateral 45, Contralateral 45, Unilateral, and Contralateral (Table 8, Figure 15). The Sternum and ASIS heights resulted in a different order of scores (from longest reach to shortest): Forward, Contralateral 45, Unilateral 45, Contralateral, and Unilateral (Figure 19). Post hoc analyses are summarized in Table 8.

Table 8

*Results of Post Hoc Repeated Measures Analysis of Variance for Reaching Task*

| Effect | Level | F | Degrees of Freedom | $\eta^2$ | p | Power |
|---|---|---|---|---|---|---|
| Group x Height* | ASIS | 8.132 | 1,198 | 0.039 | 0.005 | 1 |
| Group x Height* | Ball | 19.805 | 1,198 | 0.091 | <0.001 | 1 |
| Group x Height | Sternum | 2.777 | 1,198 | 0.014 | 0.097 | 0.635 |
| Group x Direction* | Forward | 6.018 | 1,118 | 0.049 | 0.016 | 0.682 |
| Group x Direction* | Unilateral | 8.212 | 1,118 | 0.065 | 0.005 | 0.811 |
| Group x Direction* | Unilateral 45 | 4.698 | 1,118 | 0.038 | 0.032 | 0.575 |
| Group x Direction* | Contralateral | 9.337 | 1,118 | 0.073 | 0.003 | 0.858 |
| Group x Direction* | Contralateral 45 | 9.418 | 1,118 | 0.074 | 0.003 | 0.861 |

*Note*. Significant effects denoted by *.

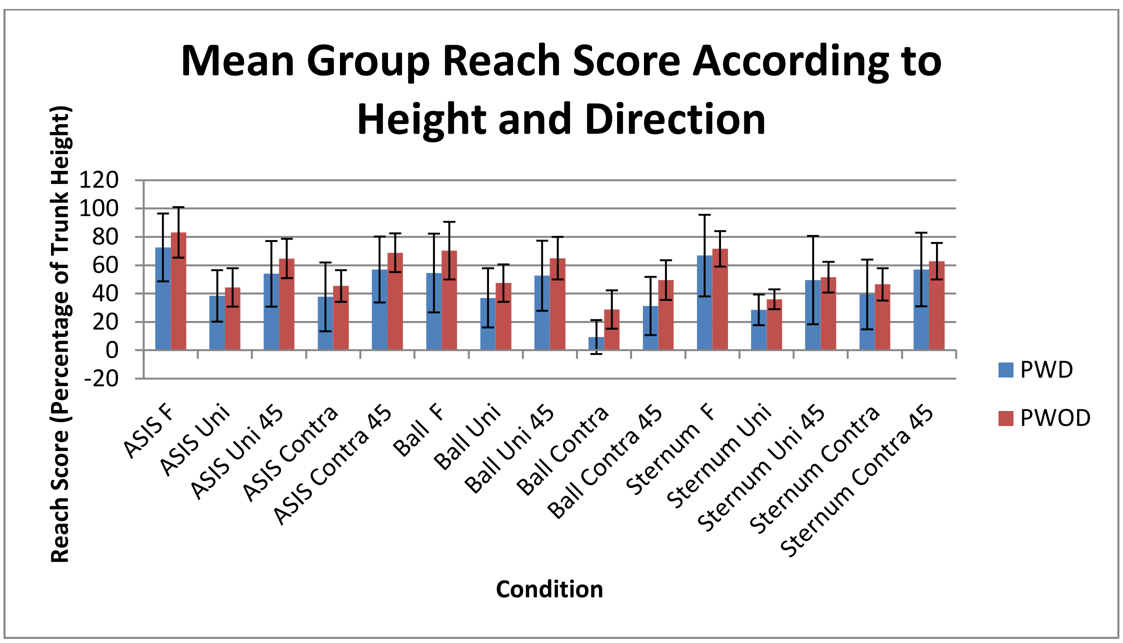


Figure 9. Effects of disability, direction and height on reach score .

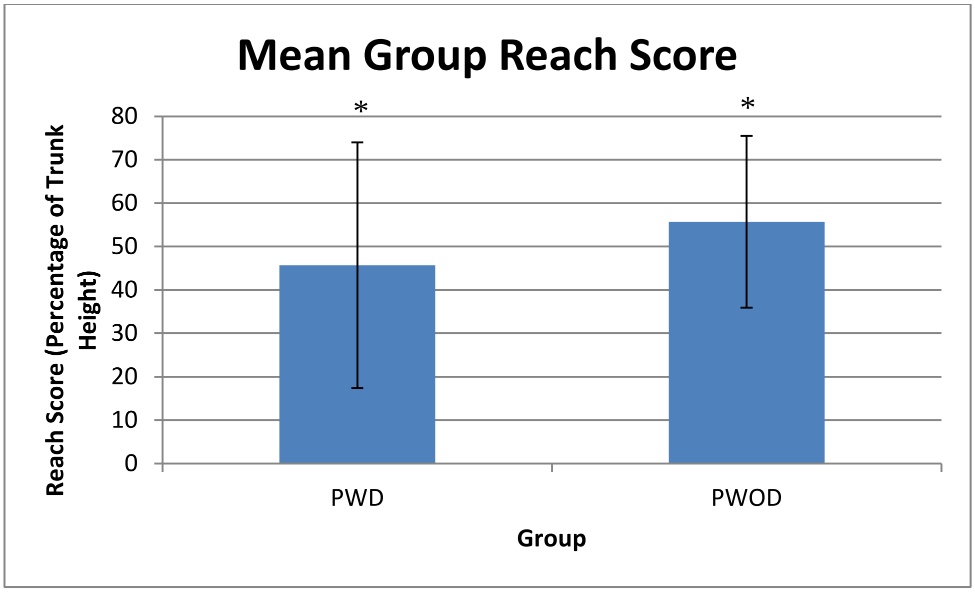


Figure 10. Effects of group on mean reach score. Significant difference indicated by * (p=0.023).

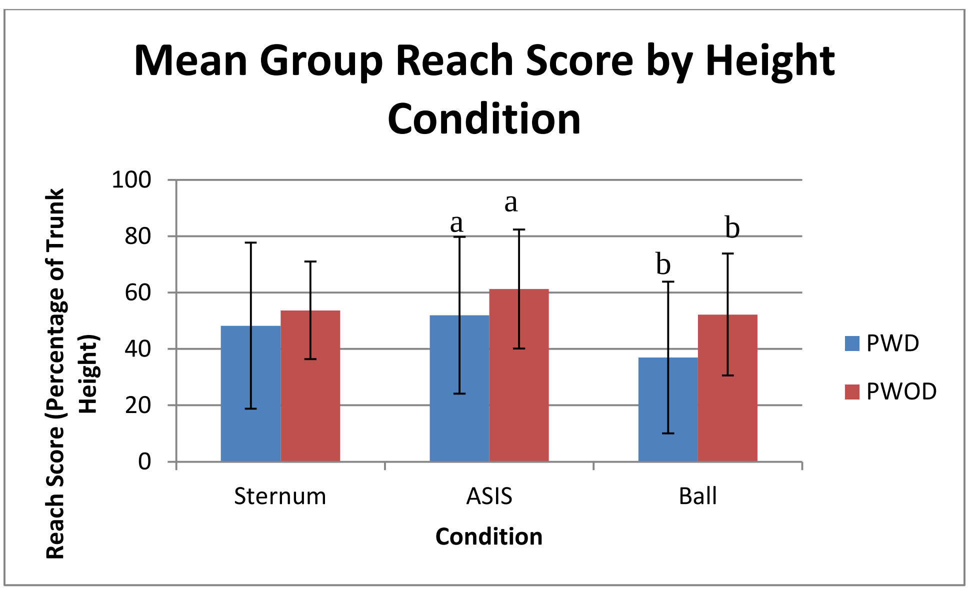


Figure 11. The effects of height on mean group reach score. Significant differences indicated by "a" (p=0.005), "b" (p<0.001).

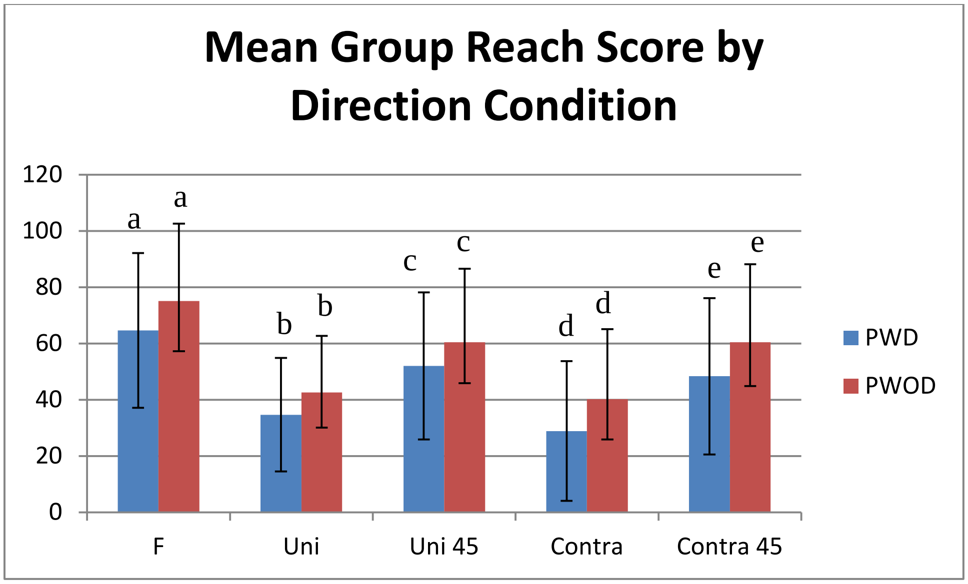


Figure 12. Effects of direction on mean group reach score. Significant differences indicated by “a” (p=0.016), “b” (p=0.005), “c” (p=0.032), d and e (p=0.003).

Significant height*group and height*direction interactions were found. The height*group interaction was due to the ability of the PWOD to reach further to a greater extent than other directions in the Contralateral and Contralateral 45 directions. The height*direction interaction was due to the scores at the ball height of the Unilateral and Unilateral 45 scores being higher than the sternum height. The ball height scores were lowest in all other directions (Figure 16).

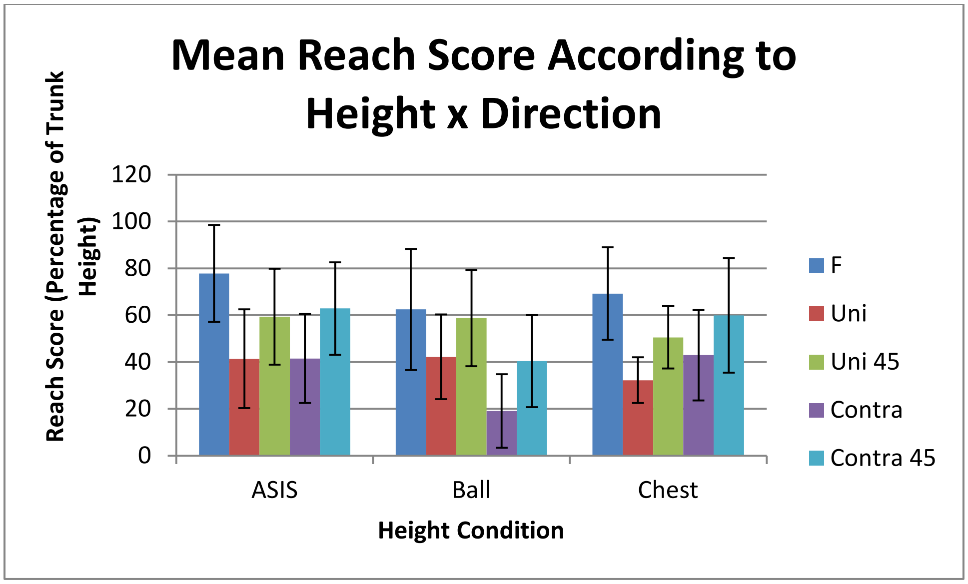


Figure 13. Effects of height and direction on mean reach score.

Surface electromyography (sEMG) was utilized to collect the peak activation of 8 muscles (bilateral rectus femoris, bilateral rectus abdominis, bilateral erector spinae, and bilateral pectoralis major) during the reaching tasks. Statistical analysis was performed to compare activation according to:  1) the hand used and muscled investigated being unilateral (HMS) or contralateral (HMO), 2) the height at which the reach was performed, 3) the direction being unilateral or contralateral to the hand used, and 4) disability status. Therefore, for the rectus femoris (RF) and pectoralis major (PEC) 2 separate 2 (hand-muscle) x 3 (height) x 5 (direction) x 2 (group) repeated measures factorial ANOVAs were utilized to assess differences in the mean peak activation. Because of the related nature of the ES and RA measures, a 2 (hand-muscle) x 3 (height) x 5 (direction) x 2 (group) repeated measures MANOVA was utilized with the Peak RA and Peak ES as the dependent variables. The participants who could not complete trials were removed from the analysis, as were those with values greater than 3 standard deviations from the mean:  RF (n=30, PWD=12, PWOD=18), PEC (n=26, PWD=12, PWOD=14), and ES/RA (n=26, PWD=11, PWOD=15). The relevant results of the reach sEMG multivariate tests are summarized in Table 9. For each of the sEMG multivariate analyses, Box's M could not be computed due to the colinearity of the data. Therefore, Pilai's Trace and Wilk's Lambda are reported.

Table 9

*Results of Repeated Measures Analysis of Variance for Muscle Activity During Reaching Task*

| Effect | Measure | Pilai's Trace | Wilk's Lambda | F | Degrees of Freedom | p | Power |
|---|---|---|---|---|---|---|---|
| Hand-Muscle | RF | 0.093 | 0.907 | 2.863 | 1,28 | 0.102 | 0.372 |
| Height* | RF | 0.159 | 0.841 | 2.557 | 2,27 | 0.096 | 0.467 |
| Direction | RF | 0.428 | 0.572 | 4.669 | 4,25 | 0.006 | 0.901 |
| Group | RF | - | - | 1.452 | 1,28 | 0.238 | 0.214 |
| Hand-muscle x Direction x Group* | RF | 0.352 | 0.648 | 3.398 | 4,25 | 0.024 | 0.773 |
| Hand-Muscle* | PEC | 0.569 | 0.431 | 31.647 | 1,24 | <0.001 | 1 |
| Height* | PEC | 0.328 | 0.672 | 5.617 | 2,23 | 0.01 | 0.808 |
| Direction* | PEC | 0.654 | 0.346 | 9.928 | 4,21 | <0.001 | 0.998 |
| Group | PEC | - | - | 0.563 | 1,24 | 0.456 | 0.112 |
| Group | ES/RA | 0.046 | | 0.559 | 2,23 | 0.580 | 0.131 |

*Note*. Significant effects denoted by "*".

A nonsignificant difference was found between the groups; PWOD demonstrated a higher RF peak activation (Figure 17). The mean peak activation of the RF was higher when the hand being used to reach was unilateral to the muscle investigated (Figure 18).

The mean peak RF activation was similar across all heights, and PWOD demonstrated higher peak activation across all heights (Figure 19) and directions (Figure 20). Peak RF activation was highest in the Contralateral 45 followed by the Contralateral, Unilateral 45, Forward, and Unilateral for the PWOD. Specifically, the peak RF activation was highest when using the unilateral hand of the muscle while reaching to the Contralateral 45 direction. However, the PWD demonstrated the highest peak RF activation in the Contralateral, Contralateral 45, Unilateral, Forward and Unilateral 45. This held true for all heights.

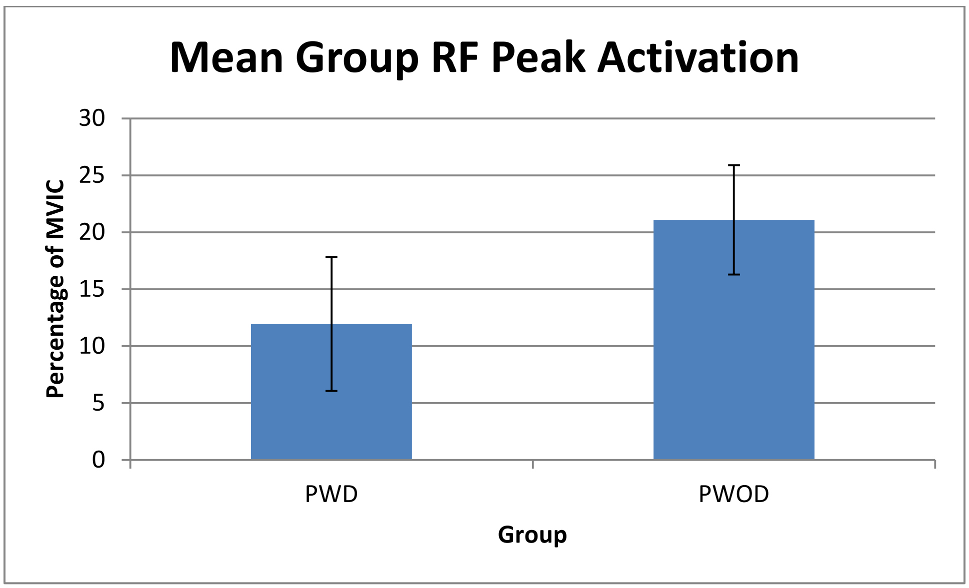


Figure 14. Effects of disability on mean RF peak activation.

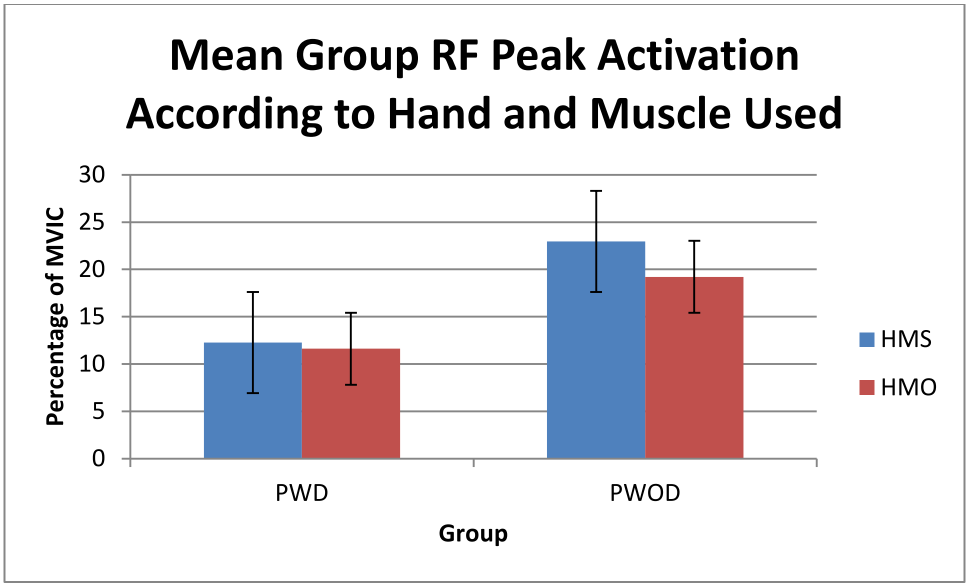


Figure 15. Effects of hand and muscle used on mean group RF peak activation.

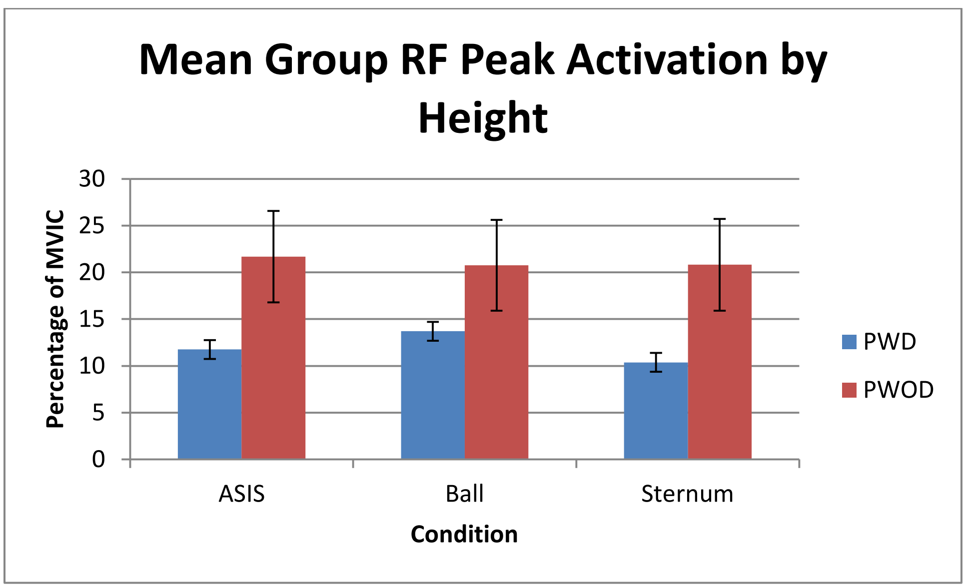


Figure 16. Effects of height on mean group RF peak activation.

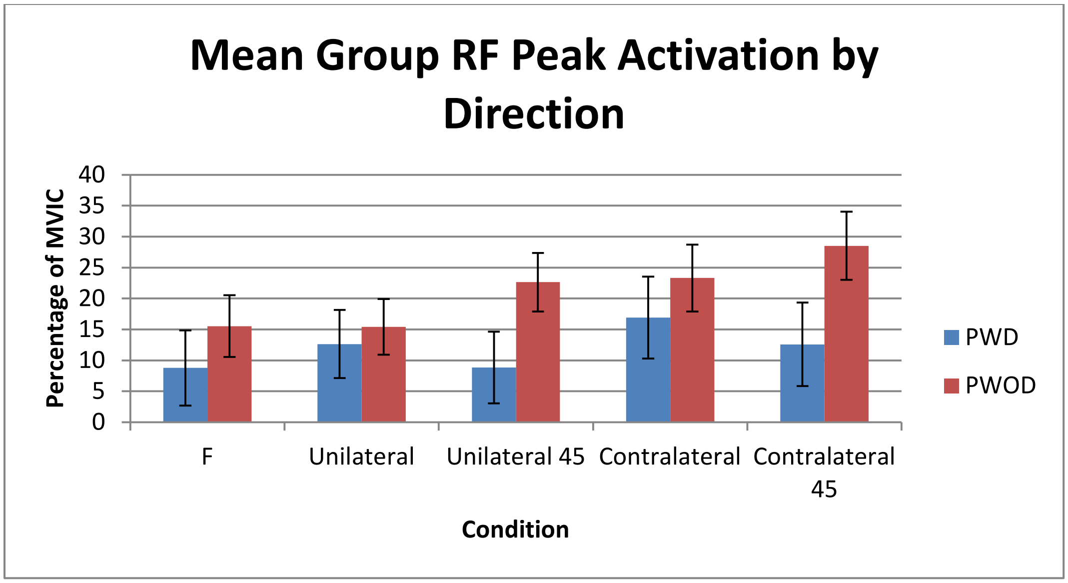


Figure 17. Effects of direction on mean group RF peak activation.

Peak PEC was similar for both groups (Figure 21). Peak PEC activation was highest when the hand and muscle were unilateral (Figure 22). The trend continued at all heights (Figure 23) and in all directions (Figure 24). The greatest peak activations were found during the when the unilateral hand and muscle were measured during the contralateral reach.

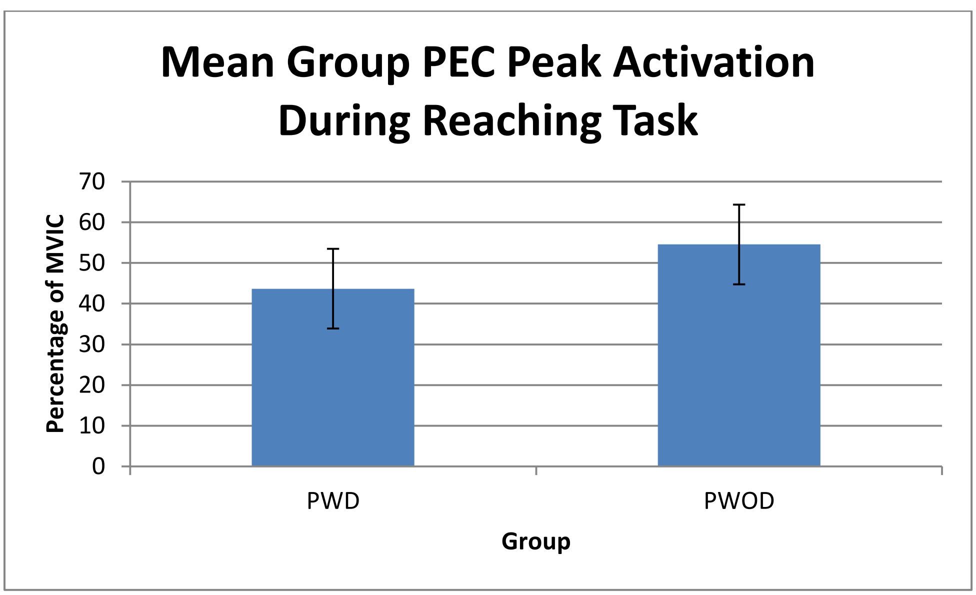


Figure 18. The mean group PEC peak activation during the reaching task.

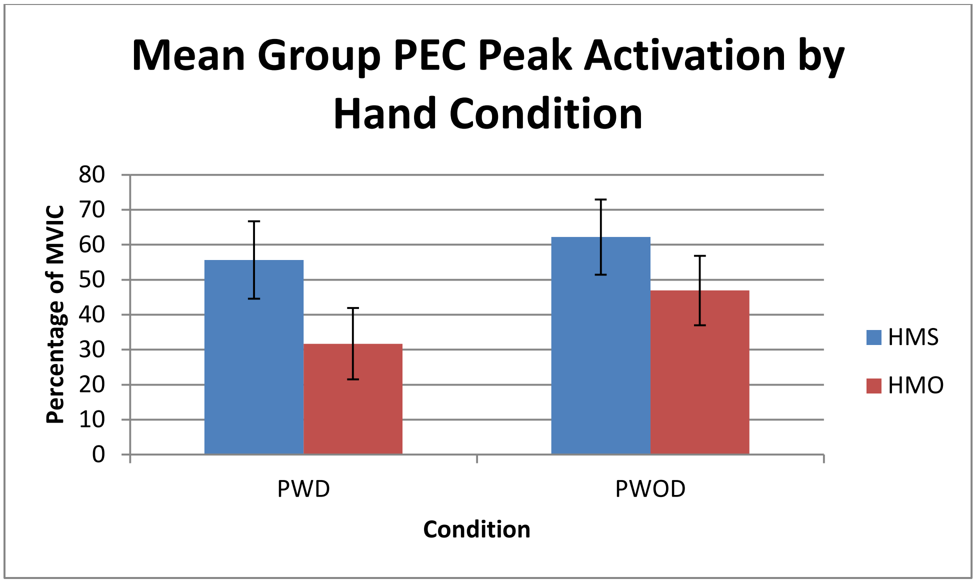


Figure 19. Effects of hand condition on mean group PEC peak activation.

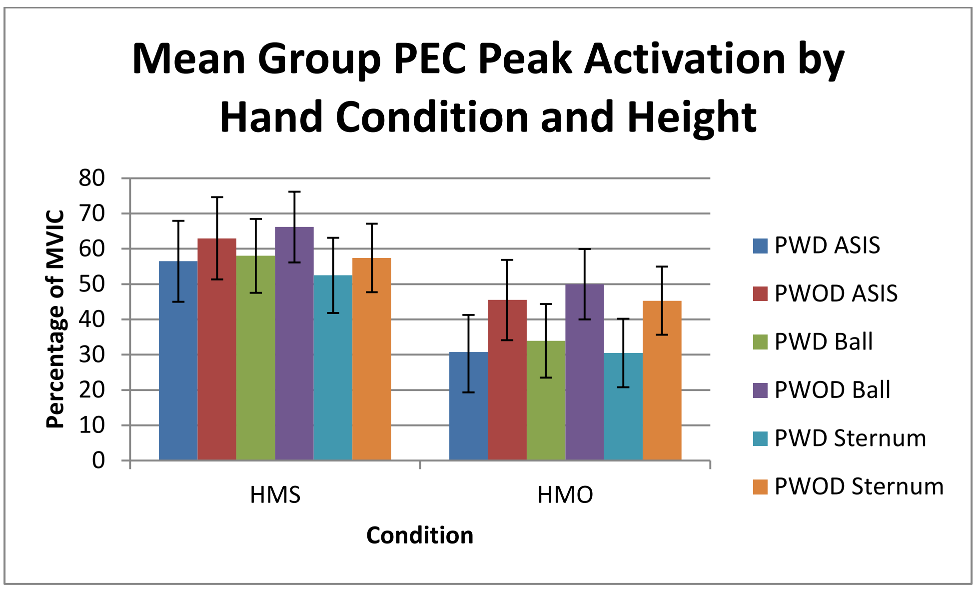


Figure 20. Effects of hand and height condition on mean group PEC peak activation.

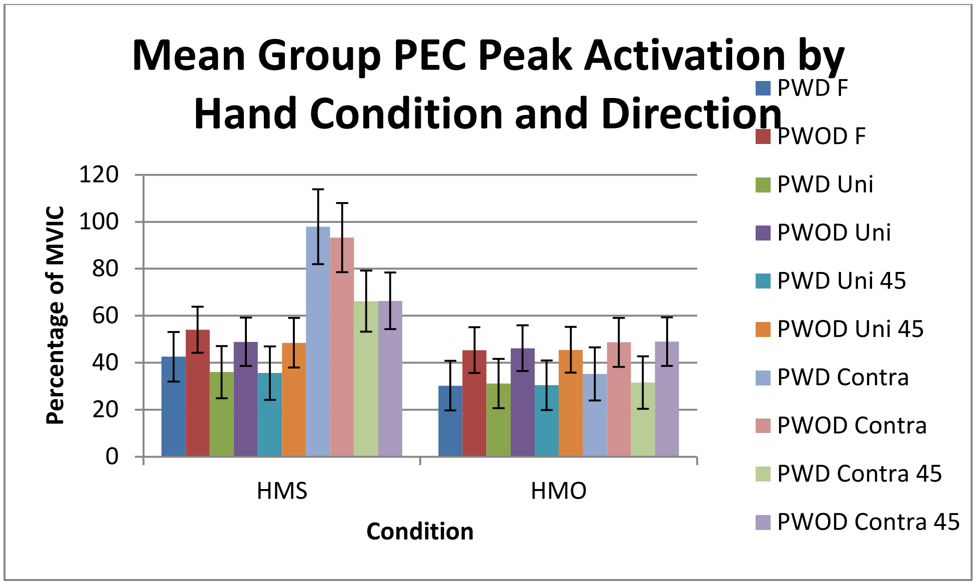


Figure 21. Effects of hand condition and direction on mean group PEC peak activation.

The peak activation of the trunk muscles was analyzed using a 2 (hand-muscle) x 3 (height) x 5 (direction) x 2 (group) MANOVA with the ES and RA as the dependent variables. No significant differences between the groups were found. PWD demonstrated higher levels of ES activity than RA activity (Figure 25). PWOD demonstrated higher levels of RA peak activity than the PWD, but both groups produced similar ES outcomes (Figure 25). Higher peak ES activation was found for both groups when the muscle and hand used were contralateral to one another (Figure 26). The ES peak activation was higher for the PWD at the ASIS and ball heights, but not different at the sternum height (Figure 27). The RA peak activation for PWD was lower at all heights when compared to the PWOD (Figure 27). The peak activation of the ES was highest in the forward reaching conditions for both the PWD and PWOD (Figure 28). PWOD showed higher peak RA activation in all directions (Figure 28).

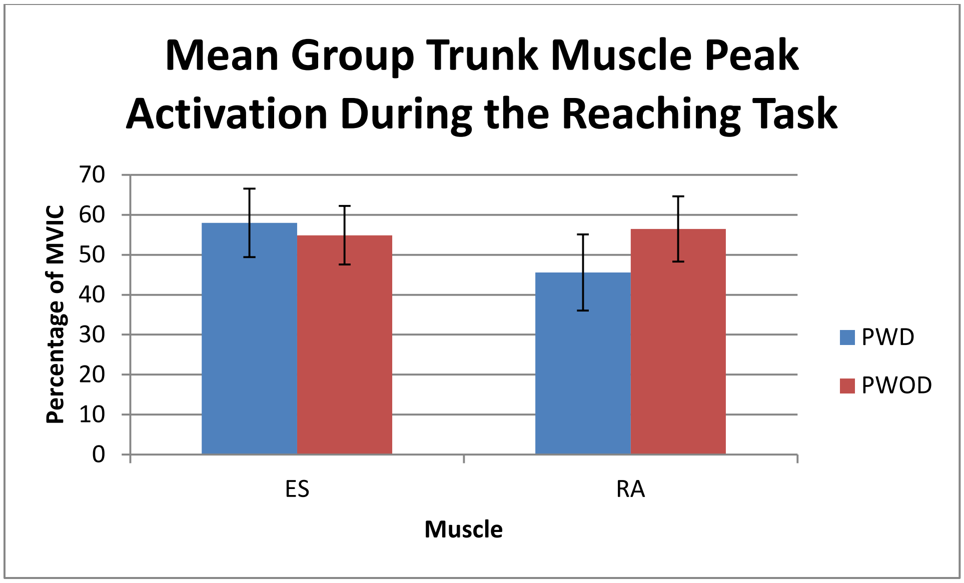


Figure 22. The mean group trunk muscles' peak activations during the reaching task.

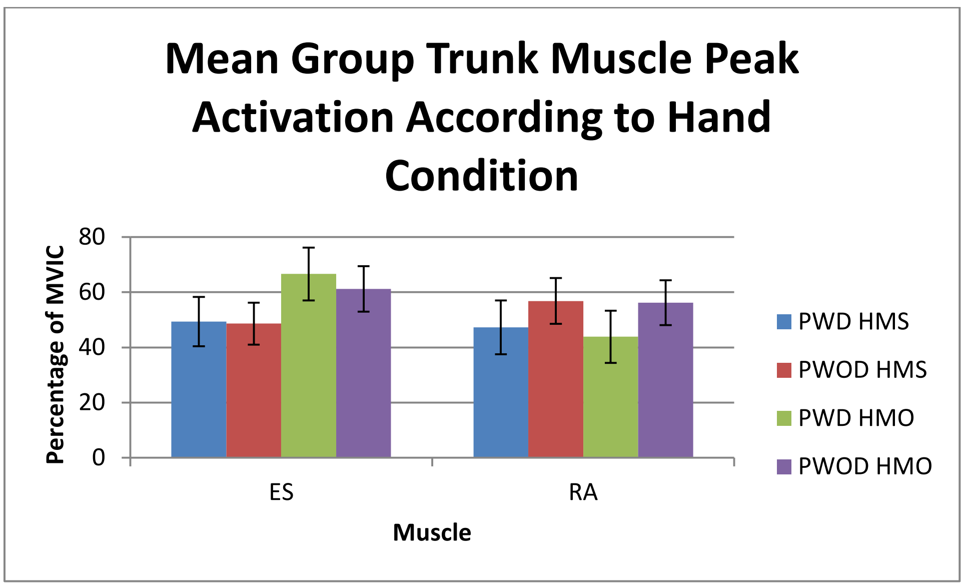


Figure 23. Effects of hand condition on the group mean trunk muscle peak activation.

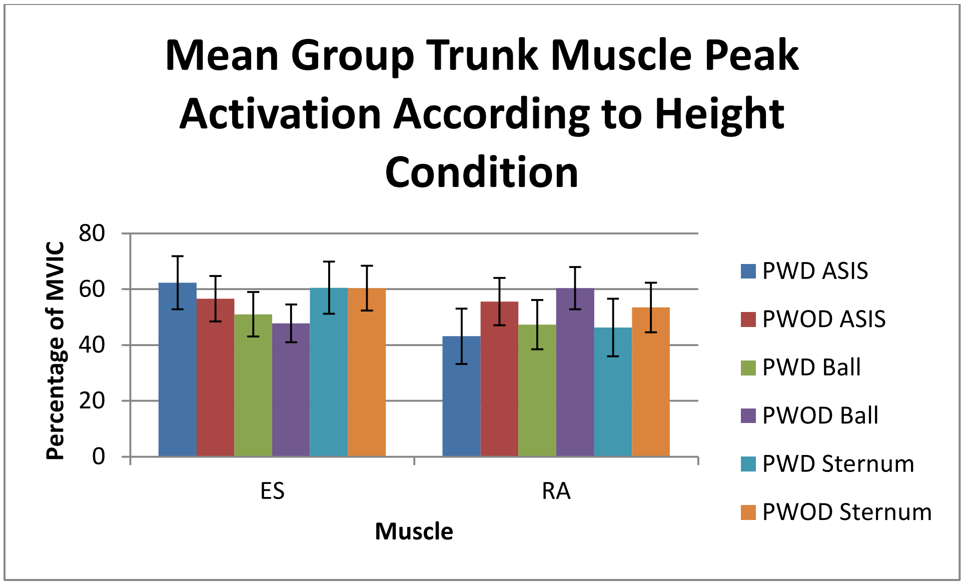


Figure 24. Effects of height condition on the group mean trunk muscle peak activation.

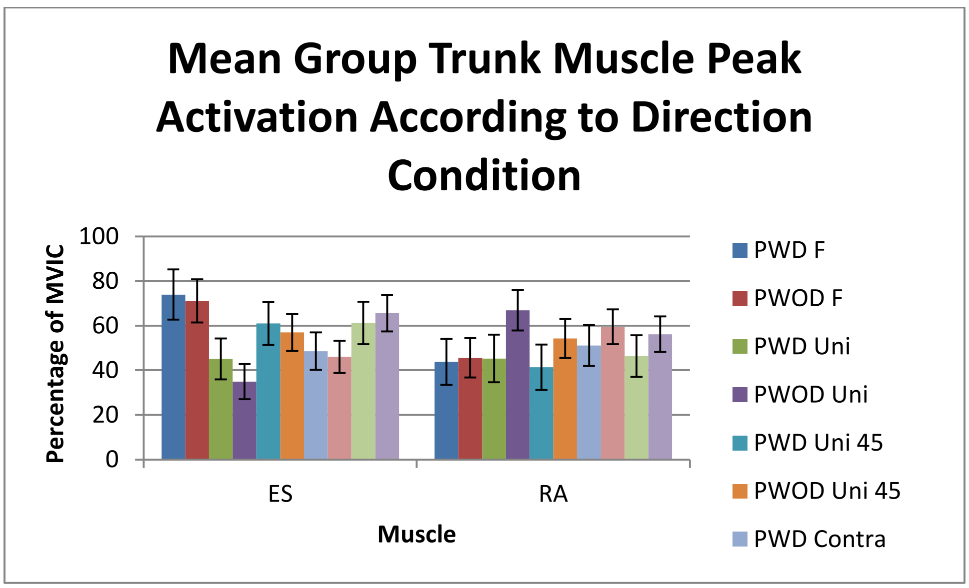


Figure 25. Effects of direction condition on the group mean trunk muscle peak activation.

## Strength Task

To assess trunk stability, participants completed 3 pushing tasks (front, left, right) with and without support. A 2 (disability) x 2 (support) x 3 (direction) repeated measures factorial ANOVA was utilized to find differences between the groups. No significant difference between the groups was found. PWD demonstrated greater force production than PWOD in the forward direction with support, and similar force to the left and right as PWOD (Figure 29). It is possible that PWD have adapted to be able to utilize the support more effectively than PWOD, although it should be noted that, though not significant, the PWOD were able to match the force production with less PEC sEMG activity. PWOD demonstrated greater force production without support. A significant support main effect was found (Wilk's $\Lambda$ =0.130, F (1,18)=119.990, p<0.0001, Power =1).

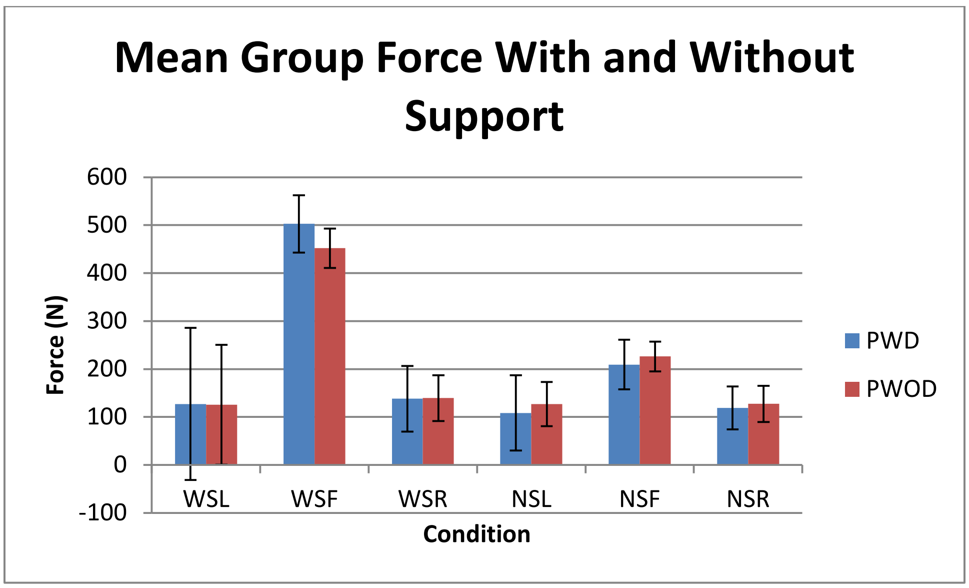


Figure 26. Effects of support and direction on mean group force scores.

The difference in force production between the with support and without support conditions was normalized by means of converting the difference to a percentage of the with support condition. A 2 (disability) x 3 (direction) repeated measures ANOVA was utilized to compare differences in the percentage of with support scores. A significant multivariate effect was found for direction (Figure 30) (Wilk's $\Lambda$=.127, F (2,17)=58.29, p<0.001, Power=1). A post hoc ANOVA revealed a significant group difference (F(1,18)=6.812, p=0.018, Power=.695).

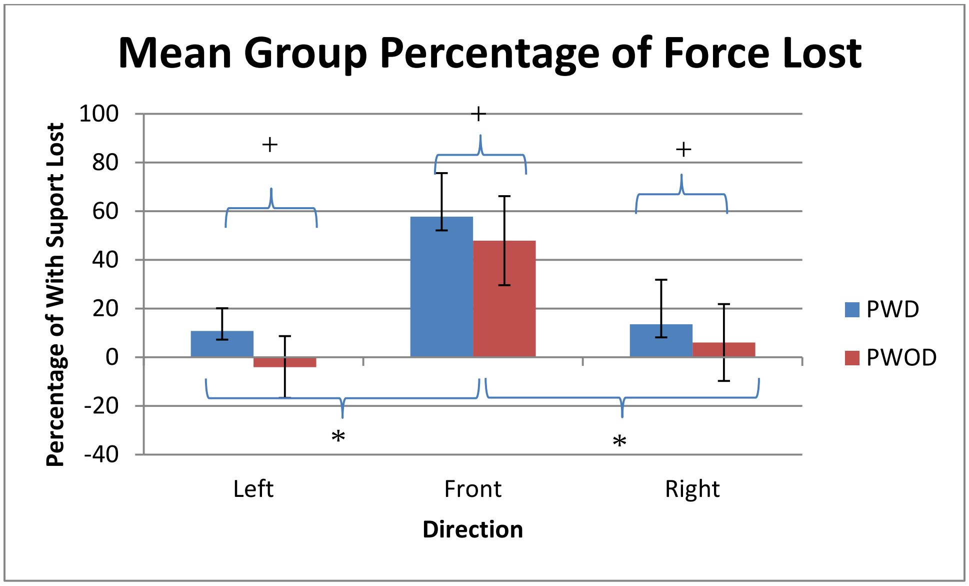


Figure 27. Effects of direction on percentage of force lost when support is removed. Significant results for direction indicated by "*" (p<0.001) and disability indicated by "+" (p=0.018).

A second trunk stability task was used to measure the participants' ability to resist force. A researcher pushed upon the participants from the front, right, and left. The force resisted was converted to a percentage of the participants' weight. A 2 (disability) x 3 (direction) repeated measures ANOVA was utilized to analyze differences in the ability to resist force. Nonsignificant (p=0.379) differences were found with the PWOD resisted greater amounts of force from each direction (Figure 31).

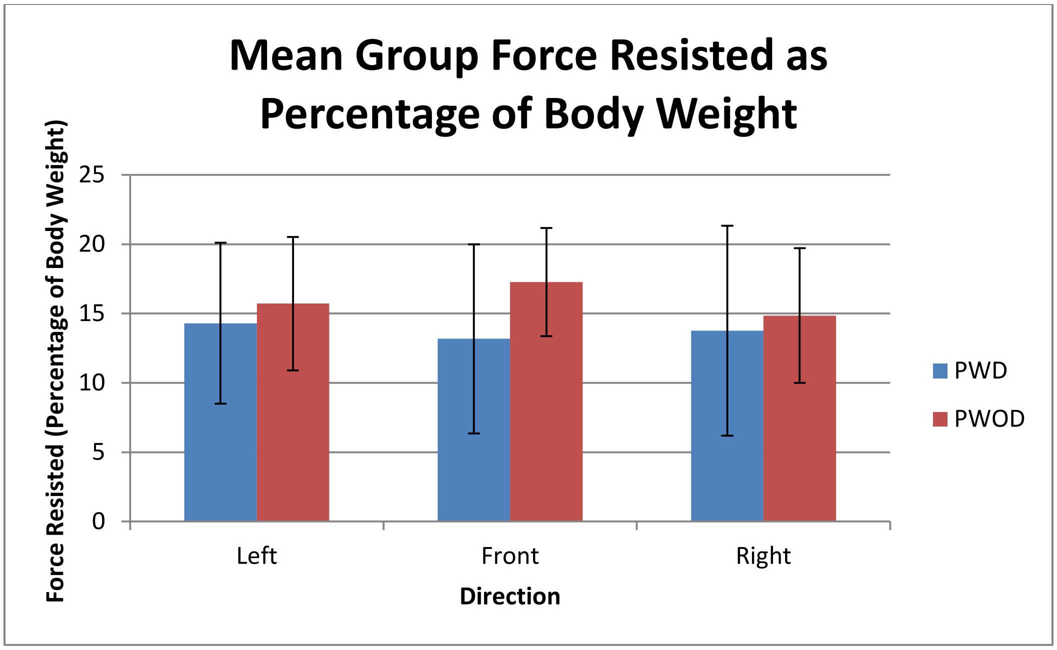


Figure 28. Effects of disability and direction on the ability to resist force.

Surface electromyography (sEMG) was utilized to collect the peak activation of 8 muscles (bilateral rectus femoris, bilateral rectus abdominis, bilateral erector spinae, and bilateral pectoralis major) during the strength tasks. Statistical analysis was performed to compare activation according to support and direction. Direction was analyzed as the muscle being unilateral or contralateral to the direction of the push. For the RF and PEC separate 2 (disability) x 2 (support) x 2 (direction) repeated measures ANOVAs were utilized to analyze differences in peak activation. Those with values greater than 3 standard deviations from the mean were removed from the analysis RF (n=33, PWD=17, PWOD=16), PEC (n=31, PWD=17, PWOD=14), and ES/RA (n=26, PWD=16, PWOD=10). Box's M showed that the assumption of sphericity was violated. Therefore, Pilai's Trace was used. A significant support effect was found (Pilai's Trace=0.205, $F(1,31) = 8.000$, $\eta^2$=0.205, p=0.008, Power=0.782). A significant support*group interaction was found (Pilai's Trace=0.165, F (1,31)=6.135, $\eta^2$=0.165, p=0.019, Power=0.670). No significant main effect was found for direction or group.

PWOD demonstrated greater RF peak activation than PWD (Figure 32). The PWOD RF peak activations were highest without support (Figure 32). No difference was found in the activation of the RF for PWD when separated by support condition. PWOD exhibited the greatest RF peak activation in the front direction and least in the unilateral (Figure 33).

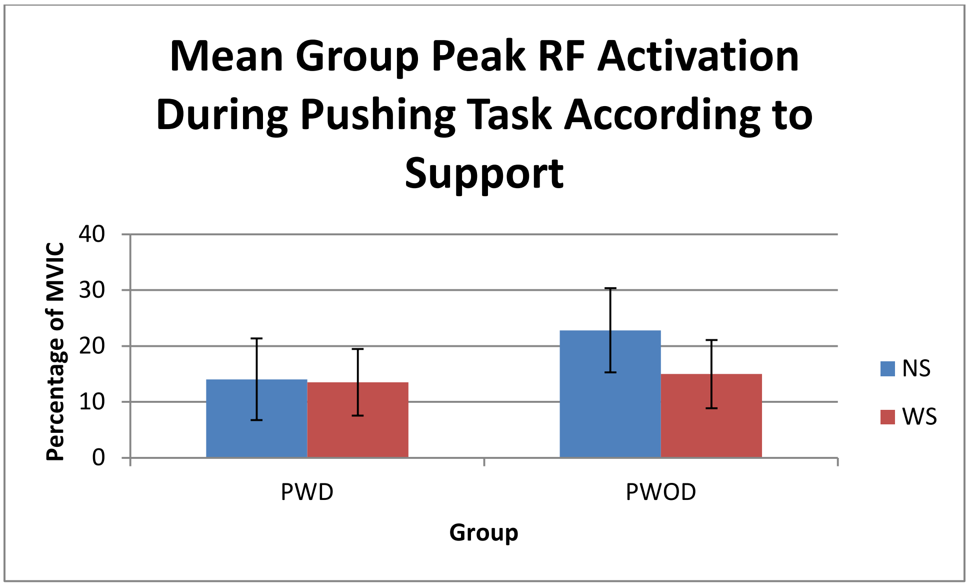


Figure 29. Effects of group and support on mean RF peak activation.

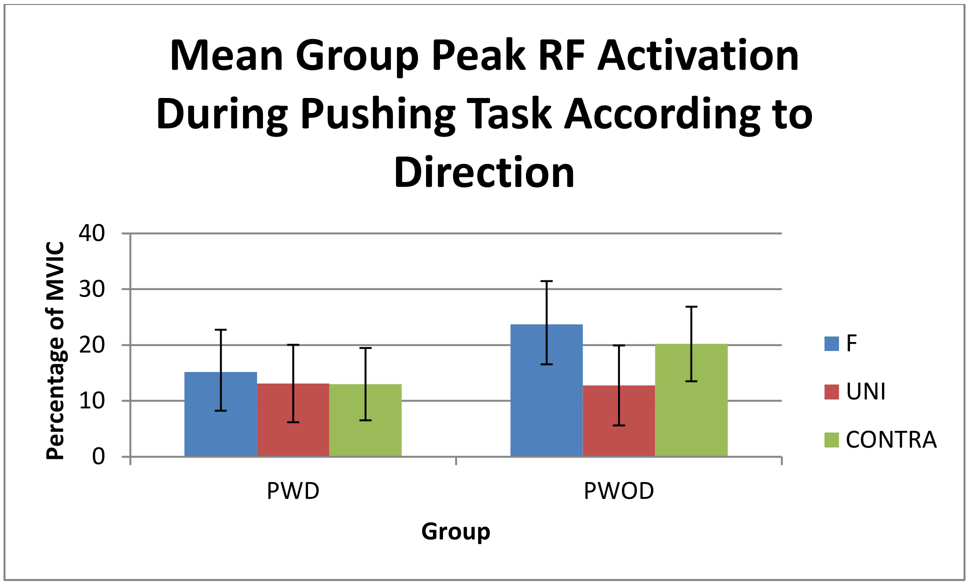


Figure 30. Effects of group and direction on mean RF peak activation.

Significant support (Pilai's Trace=0.417, $F(1,29)=20.762, \eta^2=0.417$, $p<0.001$, Power=0.993) and direction (Pilai's Trace=0.589, $F(2,28)=20.041$, $\eta^2=0.589$, $p<0.001$, Power=1.000) main effects were found for the PEC peak activation. Box's M indicated a violation of the sphericity assumption indicating the need to use Pilai's Trace. No difference was found between the groups. Higher PEC peak activation was found with support. The forward direction elicited the highest PEC peak activation, and the contralateral direction the lowest.

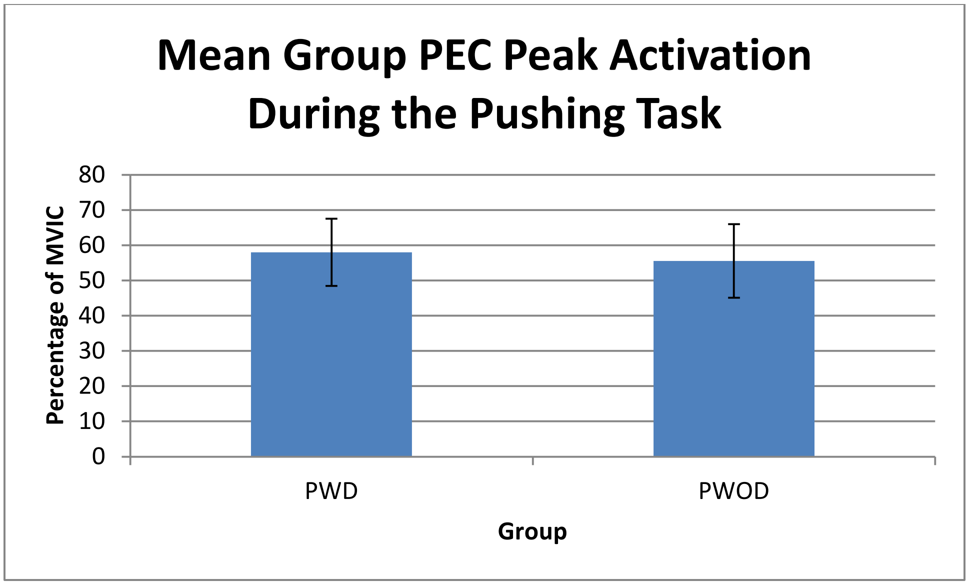


Figure 31. Effects of disability on the mean PEC peak activation.

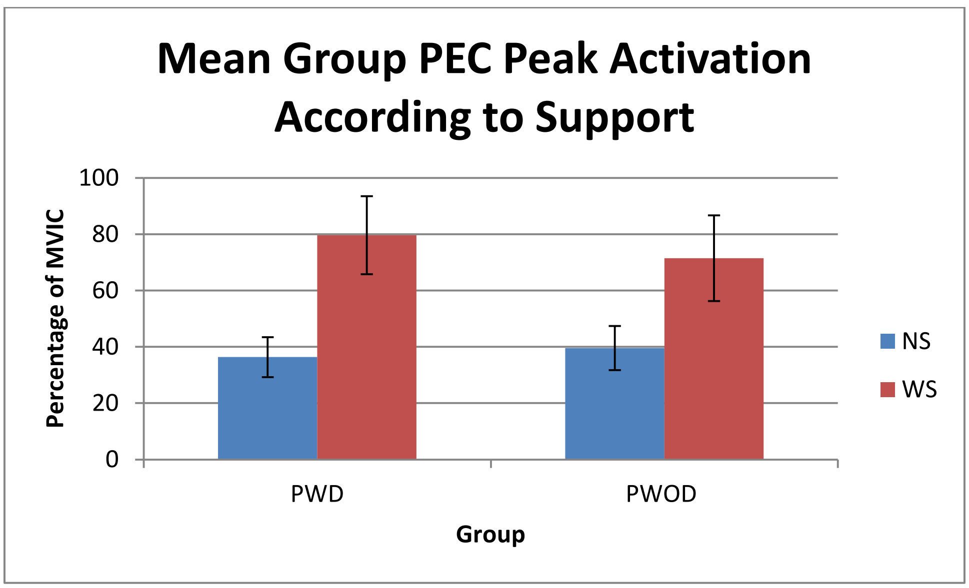


Figure 32. Effects of disability and support on the mean PEC peak activation during the strength task.

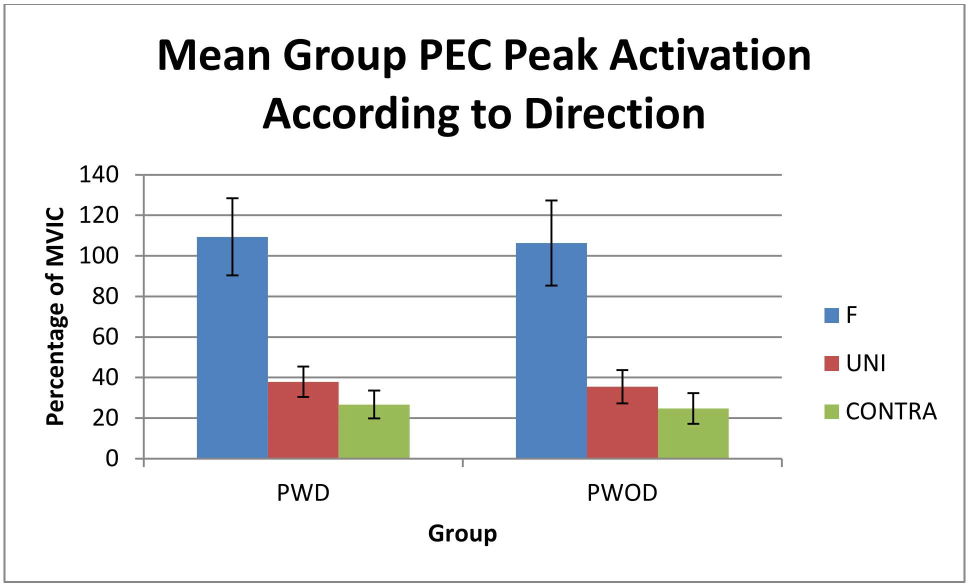


Figure 33. Effects of disability and direction on the mean PEC peak activation during the strength task.

The peak activation of the trunk muscles was analyzed using a 2 separate 2 (hand-muscle) x 3 (height) x 5 (direction) x 2 (group) MANOVA with the ES and RA as the dependent variables. Box's M was unable to be calculated indicating the need to use Pilai's Trace. Significant main effects were found for support (Pilai's Trace=0.374, F(2,23)=6.860, $\eta^2$=0.374,p=0.005, Power=0.883) (Figure 37) and direction (Pilai's Trace=0.611, F(4,21)=8.234, $\eta^2$=0.611,p=0.0004, Power=0.992) (Figure 38), but not for disability. PWD demonstrated lower RA peak activation with support, while PWOD show no difference. PWD had slightly lower ES peak activation without support. PWOD had higher ES peak activation with support. Both groups demonstrated the highest RA peak activation during front without support, and the greatest ES peak activation during front with support.

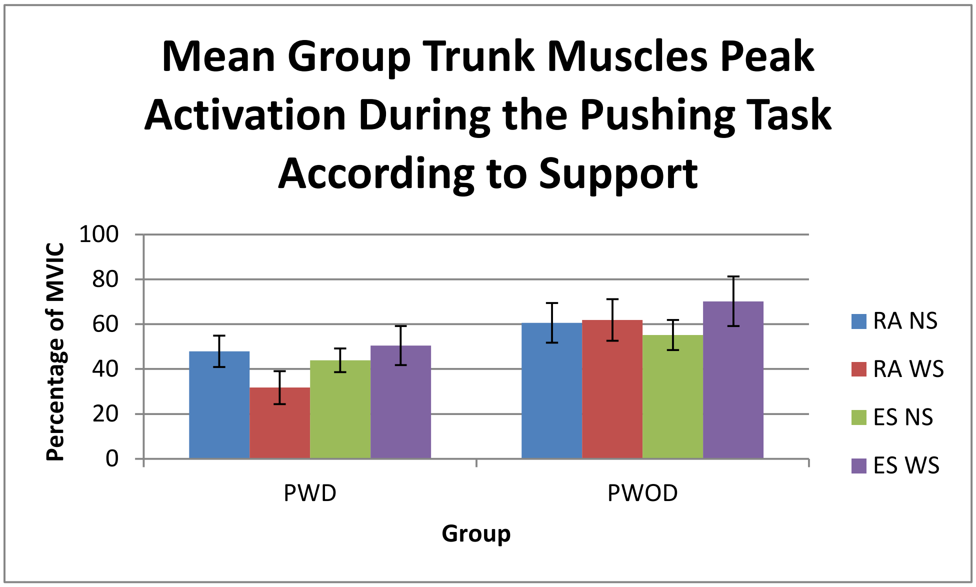


Figure 34. Effects of disability and support on trunk muscles peak activation during the strength task.

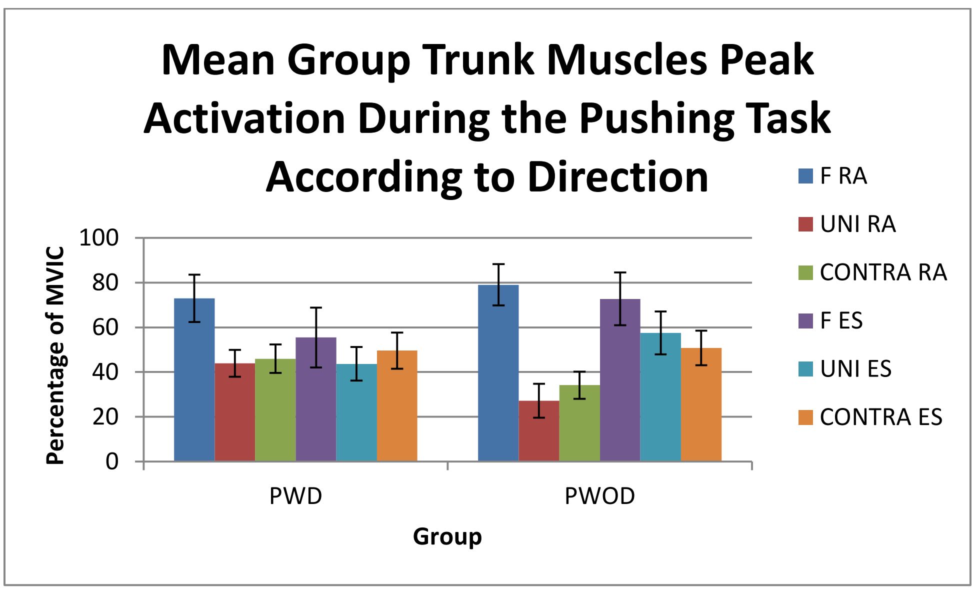


Figure 35. Effects of disability and direction on trunk muscles peak activation during the strength task.

## Reach Score and Trunk Stability Comparison

The relationship between the reach scores and trunk stability scores was investigated by summing the scores of both for each participant (Figure 39). A simple regression was utilized to predict reach score total based upon trunk stability score. Trunk stability was not a significant predictor of reach score total ($R^2$=0.018, F(1,18)=0.329, p=0.573).

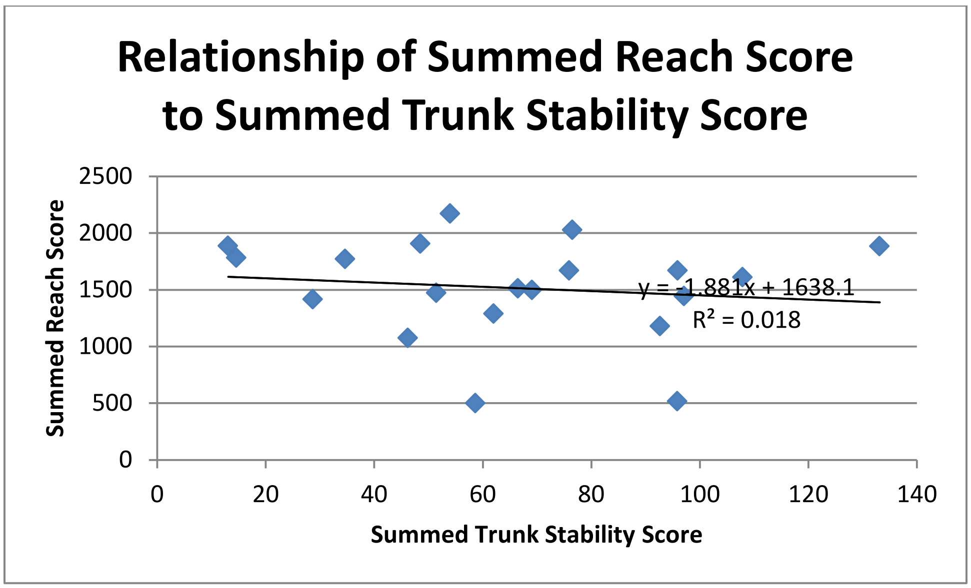


Figure 36. The relationship of the summed trunk stability score to the summed reach score ($R^2$=0.018, F(1,18)=0.329, p=0.573).

# CHAPTER V

# DISCUSSION

The purpose of this project was to: 1) evaluate the “volume of action” that is utilized in wheelchair basketball classification, 2) determine the influence of trunk stability on the ability to produce force with the arms, and 3) investigate if a relationship exists between the volume of action and stability of the trunk. These were investigated through two novel field tests (reaching task and strength task) which may be useful in wheelchair basketball classification. The following chapter is divided into six sections. The first section discusses the importance of classification to adapted sports, and what is necessary for a proper classification system. The second section discusses measurement of the volume of action via the reaching task. The third section discusses the measurement of trunk stability via the strength task. The fourth section discusses the potential relationship between the two tasks. The fifth section discusses the potential for utilizing the reaching task and strength task in classification. The final section gives a summary of the discussion and proposals for future research.

## Classification

Sport outcomes are meant to be determined by strength, athleticism, and wit of the athletes that compete within the sport (International Paralympic Classification Committee, 2007). In sports in which athletes with disabilities compete, the athleticism and talent can sometimes be distorted due to functional limitations. A means for addressing this is the use of classification systems (Bressan, 2008; International Paralympic Classification Committee, 2007). Classification systems are utilized in two manners (individual and team sports) to ensure fair and equitable competition. Athletes can be separated in to categories of competition for individual sports. Therefore, athletes would only compete against those of similar function. In team sports, athletes are given a classification that is associated with a point value, and a team may only field up to a certain point value at any given time within the competition (International Paralympic Classification Committee, 2007). Wheelchair basketball uses the team based system. Athletes are given a point value (1-4.5) and each team may only field a total of 14 points (International Wheelchair Basketball Federation, 2014).

The systems of classification commonly rely on one of two criteria: medical diagnosis or functional capabilities. The functional model is preferred over the medical model, as the medical model relies on the assumption that injury level predicts function (Brasile, 1990a; Doyle, et al., 2004). A person with a SCI at some level may have different functional abilities from a person with SB at the same level. Functional model assessments go beyond this problematic assumption and actually assess function to determine classification (Bressan, 2008; Brasile, 1990a; Doyle, et al., 2004; International Paralympic Classification Committee, 2007; Jones & Howe, 2012). The IWBF and NWBA currently use a functional model approach (International Wheelchair Basketball Federation, 2014). A drawback to these current systems is the actual method of classification.

These systems require a panel of trained classifiers to watch teams play and rate the athletes during competition (International Wheelchair Basketball Federation, 2010). Several things cause this to be problematic: 1) there is no actual measurement of functional movement; 2) the settings of a sports chair affect the range of motion of athletes (Desroches, Aissoui, & Bourbonnais, 2006), perhaps giving the appearance of different function; 3) it may not always be possible to give a full evaluation of an athlete depending on time played during the observed competition; and 4) athletes and coaches are unsure of classification going into a competition as they must wait at least one game to have the classification certified.

To address these concerns, an objective system of measuring functional abilities of wheelchair basketball athletes is necessary. The system needs to be such that the athletes can objectively be assessed outside of competition. The author supports the use of the "volume of action" as a criteria of classification, but believes that it should be evaluated through objective measurement not subjective observations. The classification system also requires a means to verify classification, on the chance that an athlete might not give a full effort during the measurement of the volume of action. Therefore, a second test should be utilized to verify proper classification. Classification could be accomplished in an objective manner that would ensure equitable competition that is decided by talent, strategy, and aptitude for the sport with two objective field tests; This project focuses on two potential field tests which were developed and tested; the first is the reaching task which is an assessment of the volume of action; the second in the force development task which is a test of trunk stability.

## Reaching Task

This section discusses the findings of the reaching task completed during this project as it relates to the volume of action in the classification of wheelchair basketball. The volume of action is the primary attribute of athletes assessed for wheelchair basketball classification. It is the volume in which an athlete can reach and perform athletic tasks. Currently, it is assessed by a panel of classifiers watching an athlete compete in a sanctioned wheelchair basketball game (IWBF, 2014). A goal of this project was to assess the effectiveness of a reaching task, which utilizes a hand-held laser distance measurer, to measure the volume of action. It is possible that such a task could be utilized as a field test in wheelchair basketball classification.

Twenty participants (10 PWD, 10 PWOD) completed the reaching task. They pointed the laser distance measurer at a target and reached towards the target. The target was set to 3 heights (ASIS, ball, sternum) and 5 directions (forward, unilateral, unilateral 45, contralateral, contralateral 45); the participants reached with each hand at each height and direction for a total of 30 reaches. Measurements of the initial distance and final distance of the reach were recorded. The participants were also recorded by a 3D motion capture system. The results of a regression analysis indicate that the reach scores found by measuring with the laser distance measurer are predicted by the movement of the wrist according to the VICON 3D motion capture system ($R^2$=0.658). This means that the laser distance measurer was reflecting a measurement of the actual movement of the participant. Therefore, further examination of the reaching task was indicated. The repeated measures ANOVA utilized to investigate differences in the reaching task yielded significant main effects. A significant group effect ($p$=0.023) indicated that this reaching task differentiates people based on having a disability. As hypothesized, the PWOD were able to reach further in all directions and at all heights. This indicates that PWOD have a greater volume of action than PWD. Therefore, it is the functional limitations caused by disability that creates the differences in the volume of action. While not specifically assessed in the current project, it is believed that these differences exist and are measurable by this system within the broad spectrum of disability.

Significant main effects were also found for height and direction. The distance reached at the ASIS height were found to be the furthest and the distance reached at the ball height were the lowest. It is hypothesized that the ability to move the shoulder closer to the target at the ASIS level through trunk flexion allowed for greater translation of the laser distance measurer. At the ball height, it is believed that trunk motion was limited by the starting position. More investigation is needed to determine the cause in differences. The forward direction yielded the highest reach scores. Again, the ability to utilize the trunk in this direction is believed to be the most influential factor. A significant height*group interaction was found. This was due to the great difference between the groups at the ball height level. This would suggest that the ball height reaching task was the most discerning of the reaching tasks. PWOD are able to lean down and reach farther because they have capability to control their trunk and maintain balance. Specifically, they can move the center of gravity of the trunk and upper body beyond their lap, because of the contribution of trunk extensors. The PWD, however, must rely on their lap to support their trunk and the center of mass of the upper body cannot move beyond the lap.

A significant height*direction interaction was found. The UNI and UNI 45 reaches were shortest at the sternum height, but all other reaches were shortest at ball height. It is believed that the unilateral nature of this task caused an asymmetrical translation of the center of mass of the trunk and upper body. This created a more demanding moment about the pelvis and thus prevented the participants from reaching at this height. At the ball height, the participants could use their lap to support the asymmetrical loading pattern and thus reach further in the unilateral conditions then they could at the sternum height where the support of the lap was not present.

An understanding of why PWOD reached further was sought through sEMG. Peak activation of 8 muscles was measured during each of the reaching trials. The peak activation of the muscles involved was converted to a percentage of the MVIC and analyzed by utilizing a series of repeated measures ANOVAs. No significant group main effects were found for peak activation of any of the muscles, indicating that the PWOD were able to reach further without significantly larger percentages of MVICs. An interesting significant hand*direction*group interaction was found for the RF. The interaction was between the following two measures: (1) the PWD demonstrated the highest peak activation in the muscle contralateral to the hand reaching, in the contralateral direction (for example, when the right hand reached to the left, the RF demonstrated a greater percent MVIC in the left leg), and (2) the PWOD demonstrated the highest RF peak activation in the unilateral leg to the hand reaching to the Contralateral 45 direction (for example, the muscle activity of right RF during the reaching of the right hand reaching to the left). The group component of the interaction was due to the low level of RF activation by the PWD. Furthermore, a current limitation of the present study is that it does not discriminate between disabilities, only between those with a disability and those without. Specifically, the results of the peak activation could be confounded by the different types of disability (neurological versus amputation); those with amputations may have utilized higher muscle activations and therefore increased the mean of the PWD group. This higher muscle activation may have been cancelled out by those with SCI using less muscle activation since the mean peak was investigated. Therefore, future study must be conducted on a larger population of PWD so that more distinction among the groups can be investigated.

For the PEC, significant main effects for height and direction were found as well as a significant hand-muscle*direction*group interaction. The highest PEC peak activations were found when reaching to the contralateral side where the PEC was used to rotate the shoulder into horizontal adduction. The highest peak activation for the PEC was found during the ball height condition, as the PEC had the additional demand of shoulder flexion. Specifically, the PEC contributes to shoulder flexion up to $60^o$, and when the participant was leaning forward to position the hand at ball height the shoulder is within this shoulder flexion range. The hand-muscle*direction*group interaction was found as the PWD demonstrated a larger increase than the PWOD from the contralateral hand to the unilateral hand. It is thought that the increased demand for the PWD was due to the requirement of the task to stabilize the laser while pushing the button down. The pushing of the button down increased the extension moment during the isometric portion of the reach and the PWD utilized more shoulder stabilization to counteract this larger moment. Further study is needed to be able to definitely indicate if this hypothesis is correct.

Though the group reach score differences cannot currently be explained by the muscle activation, it is clear that the reaching task does stratify people according to disability status. The reaches were done in five directions and at three heights, thus creating a measured volume. These volumes could be associated with the IWBF's volume of action, and therefore as a means to classify wheelchair athletes in a manner more objectively than mere observation. Therefore, it is recommended that the sport governing bodies, which utilize a volume of action as a method of classification, should consider adopting the reaching task field test as a method to classify wheelchair athletes within their competitions. While the reaching task does discriminate between PWD and PWOD future research is insure that this task will discriminate across motor impairments. In addition, more research is also needed to more completely explain the reason why this task discriminates.

## Strength Task

Wheelchair basketball classification is based upon the premise that people with more trunk control will have higher function to complete athletic tasks. Specifically, individuals with a lower spinal cord lesion are classified higher than individuals with a higher lesion, without any measure of trunk control. Athlete's performing a strength task with and without the aid of support has been utilized to show differences in trunk stability in previous research (Vanlandewijk 2010). The strength task of the current project required participants to hold a force gauge and press it against the wall with and without a support in three directions (forward, left, right). The PWD demonstrated greater force production to the PWOD with support forward, and similar force production to the PWOD in the with support lateral conditions. The PWD had lower force production than the PWOD in all of the without support conditions. The group differences were not significant when analyzing the force measurements. This means that the groups did not significantly differ in any one particular condition. However, a significant difference was found for the percentage of force lost when support was removed (Figure 30). This indicates that the test is able to discern differences in the lack of trunk stability. Specifically, PWD rely more heavily on support for force development than PWOD.

Measuring force production with the force gauge was uncomfortable for some participants, especially in the lateral conditions. This may have prevented maximum force production. Utilizing a forceplate or digital scale on the wall, may allow for a more comfortable testing protocol. However, as this project was attempting to develop a portable field test, utilizing a hand held gauge was more appropriate than the use of a force transducer mounted to a wall.

A limitation of the present study is that support was moved to always be opposite the direction of the applied force. Though valuable in attempting to answer the question regarding the use of support, it is not realistic. Individuals in wheelchairs generally do not have side trunk support during sporting activities. Future research should consider completing the tasks with only posterior support. This would be more like the support found during wheelchair basketball competition.

Significant sEMG group main effects were not found. However, the sEMG enlighten the strategies participants utilized for this test. The RF was significantly higher during the without support conditions. It is believed that through co-contraction, it was being utilized to created stability for the pelvis. The significant group*support interaction is due to the low level of PWD peak activation across the support conditions. PWD did not engage their RF at a high level, presumably due to their impairments.

Peak PEC activation demonstrated a main effect for support. The PEC was activated at a higher degree when support was present. It is believed the participants utilized the PEC more with support to produce the greater force. This is most likely due to the participants overcoming their ability to support themselves in the without support condition. Therefore, they utilized less PEC activation to produce less force so they could remain stable. A significant direction main effect was also found for the PEC. The PEC was most active in the forward direction and the unilateral side. This is to be expected as during the contralateral direction the PEC is not involved in moving the arm. The forward direction demonstrated the highest peak activation as the motion put the most demand on the PEC and is consistent with the reaching findings.

Significant main effects for the trunk muscles were found for support and direction. The RA had greater peak activation without support, while the ES had greater peak activation with support. This is most likely due to the utilization of the RA to stabilize when support is lost. In the with support condition, it seems the ES is being used to press the trunk against the backrest. It is believed that this prevention of trunk motions posteriorly allows for greater force production as the equal and opposite reaction force from the wall to the person is overcome by the resistance of the support. In the without support condition, trunk stabilization could have been overcome by the reaction force and resulted in lower force production by the participant.

A second part of the stability testing in the current project utilized the force gauge in a novel manner. A member of the research team pushed against the participant with the force gauge to measure the ability to resist force. No differences were found in this test. Difficulty in determining the point at which stability is lost, and the inability to control the rate of force production being resisted, may have contributed to the lack of a significant finding. A measurement of impulse resisted may prove to be a more appropriate measure as more gradually applied forces are easier to withstand than rapidly applied force.

## Relationship of Field Tests

If the two tasks of this project are to be utilized as field tests for a single classification of an athlete, then a relationship between the two tests would prove beneficial. As hypothesized, the sums of the reach task are inversely related to the sum of the strength task. However, the correlation is very weak. It seems that the trunk stability score and reach score are not related as hypothesized. However, a larger number of participants and a means of relating the directional aspects of the tests may be needed to find a relationship between the tasks. In order to relate the directional aspects, it could be useful to seek the relationship through multiple regression as opposed to the singular regression used in the current study. Further, it may be beneficial to identify if the lateral directions of trunk stability predict lateral directions of reach score while seeing if the forward trunk stability score predicts the forward reach score. Specifically, when reaching to the right, the participant would use the right trunk muscles concentrically to get into position, but the left trunk muscles to eccentrically prevent falling over. So, when reaching to the right, the right RA/ES would get the participant into position, but the left RA/ES would hold the participant in that position. However, when resisting the push from the researcher, from the right side, the resistance is with the right RA/ES in an eccentric/isometric contraction.

It may also be of value to measure the trunk stability and reach score separately without relating the two. Originally, it was hoped that the scores could be related so that one test would be necessary in the field with the other being there to reinforce the outcomes in the case of appeals. However, trunk stability and volume of action seem to provide different information regarding function. Therefore, both tests being used always may be of more value to classification, however system of combining the two tests should be continued to be sought.

## Utility of Reaching Task and Strength Task for Classification

In order to discuss the utility of the field tests to be applied in classification, an understanding of the practical matters involved in classification is necessary. Classification is completed at competitions as it is not feasible for classifiers to travel to each team and perform classification. Because classification is done at competition venues, it is important that the process take minimal time, require a small space to conduct the evaluation, and the equipment must be easily transported. The equipment and testing must meet these requirements while stratifying athletes according to their level of function.

The equipment utilized for the reaching task requires some design development to make the seat and target more portable so that classifiers would be able to easily pack them for air travel; the reaching task components utilized in the present study are reasonably portable for transportation by automobile. The reaching test does meet the requirement of differentiating based upon function. However, the use of the laser distance measurer does not make the test accessible to all athletes. If an athlete had an upper limb amputation or low hand dexterity, then he/she would not be able to complete the test. The hand dexterity or amputation would need to be considered as to how it affects the athlete’s function, but the volume of action still needs to be evaluated. Therefore, the laser measuring device would need to be modified to accommodate hand limitations. However, the three heights and five directions protocol used in this project should be adopted.

The strength test also indicated differences based upon disability. The average classification of the wheelchair basketball players in the present study was 3.25, indicating a group that was relatively high functioning. Therefore, the test is able to discern functional differences, even between high function PWD and PWOD. The equipment utilized for the strength test is portable, but as in the reach test, the seat requires modification to ensure classifiers could travel with it on airplanes. The use of the force gauge may also limit the athletes that are able to complete the classification task. A different device which could be utilized by those with upper limb amputations or low hand dexterity should be evaluated.

A benefit of both of these tests is the removal of the in competition aspects of classification. The athletes being given an equal sitting platform eliminates an advantage or disadvantage chair settings may give. Concerns about the needed amount of time to evaluate each athlete are also eliminated by the use of tests outside of competition. By testing each athlete with the same test, there are no differences in emphasis of what is being observed by the classifiers. These objective methods of testing should be pursued to establish a more equal form of classification.

## Conclusions and Future Research

The purpose of this study was to discover if two field tests (reaching task, Strength task) could be utilized in the classification of wheelchair basketball athletes. It was a first step in determining whether the tests could discern between PWD and PWOD. The results indicate that both the reaching and strength tasks differentiate between those with and without disability. Further investigation is required for determining if a relationship between the two tests exists or how to combine the scores for fair classification. Last, further research is needed to see if scores from either test stratify across various levels of disability.

The sEMG results of this project did not give insight into any differences in muscle activation according to group. This could be because of the chosen method for analyzing the sEMG. Future study may benefit from investigating different timing of muscle activation or the overall mean activations of muscle, instead of the peak activation. In addition, it is possible that while no significant differences were noted between the PWD vs PWOD groups, differences may be apparent between those with neurological impairments (SCI) versus those without (amputees). A different choice of muscle may also be appropriate for future sEMG research related to these tasks. The author believes that study of a hip extensor may reveal differences in activation based upon disability.

Overall, future study is needed to determine to what degree these tests stratify based upon disability. Larger samples of PWD are required, and a sample of greater functional loss is required. The participants in this project tended to be higher functioning (Mean Classification =3.25). The high function of the PWD indicates that the tests are able to discern differences in function even if the groups are close in function. Changes to the equipment used in the tasks, so that people with upper limb impairment could participate, would be of benefit to future research in that more people would be able to complete the tasks, and a greater understanding of the differences in function could be measured. A much larger pool of data is required to formalize and normalize any classification system, but the results of this study are encouraging in that objective systems of classification are feasible.

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Appendix A

# Participant Screening Questionnaire

**Please read each question carefully and answer honestly. If you do not understand the question, please ask the investigator for clarification. Check the appropriate answer.**

**Participant Number:___________**

**Yes** **No**

___ ___ 1. Are you 19-50 years of age?

___ ___ 2. Do you currently have an injury that prevents you from performing upper extremity exercise?

___ ___ 3. Do you currently have an illness that prevents you from performing upper extremity exercise?

___ ___ 4. Do you have any reason to believe that your participation in this investigation may put your health or well-being at risk?

___ ___ 5. Are you capable of performing wheelchair propulsion with no pain or range of motion issues?

___ ___6. Do you have an allergy to adhesives?

Signature of participant _______________________________

Date__________________

Appendix B

**INFORMED CONSENT FOR**

"Measuring trunk stability and range of motion:
Two field tests for wheelchair basketball classification"

You are invited to participate in a research study to investigate two new field tests for wheelchair basketball classification. The study is being conducted by Jared Rehm, Doctoral Candidate, under the direction of Dr. Wendi Weimar, Professor, in the Auburn University School of Kinesiology. With your help it is hoped that two field tests will be evaluated for use in measuring trunk stability for wheelchair basketball classification. You were selected as a potential participant because you are of at least 19 years of age, and your health condition and mobility might, through pre-screening health questionnaire to follow, permit you to perform the test safely and successfully.

*Purpose*: The purposes of this study are: 1) to determine the range of motion associated with the International Wheelchair Basketball Federation's "volume of action"; 2) to determine the influence of trunk stability in the production of force with the arms; and 3) to determine if a relationship exists between the ability to produce force and range of motion associated with the volume of action. The results will aid in the development of new classification methods for wheelchair sports.

*Methodology*: The testing session will last approximately 60 minutes. This time will be used for the filling out of forms, the practice of the tests as well as the actual data collection and brief wait time between tests and warm-up. You will be asked to perform 3 tests. A reach test will consist of 15 maximum length reaches with each hand. The reaches will be in 5 directions at 3 heights. The second test will be a push test in which you will push a force gauge against a wall with maximum effort. This will be done in 3 directions. In the third test, a member of the research team will press against you with the force gauge in three directions until you are not able to resist.

*Risk*: It is possible that you may sustain muscle soreness or a muscle injury. However, the risks associated with this study should not be any more than normally encountered in normal activities of daily living and wheelchair sport training. In the unlikely event that you sustain an injury from participation in this study, you will be required to assume full financial responsibility for your own medical care. Participants are responsible for any and all medical cost resulting from injury during the study. Further, you may discontinue participation at any time without penalty.

*Benefits*: There is no direct benefit to you.

*Confidentiality*: Any information obtained in connection with this study that can be identified with you will remain confidential. Your decision whether or not to participate will not jeopardize your future relations with Auburn University and the School of Kinesiology. If you decide later to withdraw from the study you may also withdraw any identifiable information, which has been collected about you, in this study. A copy of this form is for you to keep for your records.

Participant's Initials_________

If you have questions about this study, please ask them now or contact Jared Rehm at jmr0020@tigermail.auburn.edu or Dr. Wendi Weimar at weimawh@auburn.edu. Both can be contacted at 334-844-1468.

If you have questions about your rights as a research participant, you may contact the Auburn University of Human Subject Research of the Institutional Review Board by phone (334) 844-5966 or email at hsubjec@auburn.edu or IRBChair@auburn.edu.

**HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATED YOUR WILLINGNESS TO PARTICIPATE.**

________________________________ __________
Name Date

________________________________
Participant's signature

________________________________ __________

Signature of Investigator: Jared Rehm Date