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# Promoting independent movers: The effect of the quadriciser on range of motion (rom)

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Promoting Independent Movers: The Effect of the Quadriciser on Range of Motion (ROM)

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An Honors College Project Presented to  
the Faculty of the Undergraduate  
College of Health and Behavior Sciences  
James Madison University

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by Kristen Nicole Frank

April 2017

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Accepted by the faculty of the Department of Health Sciences, James Madison University, in partial fulfillment of the requirements for the Honors College.

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PUBLIC PRESENTATION

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Promoting Independent Movers: The Effect of the Quadriciser on Range of Motion (ROM)

Kristen Frank

James Madison University

Undergraduate Honor's Thesis Proposal

April 2017

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## Abstract

Exercise and movement are pivotal in promoting optimal function for the human body. For individuals with severe orthopedic impairments, attaining the required minimum of 30 minutes of daily exercise is seemingly difficult. The Quadriciser (the “Q”) serves as an alternative method to therapy in attaining daily exercise through promoting passive-active movement of all four limbs. Five middle school and high school subjects with cerebral palsy, severe orthopedic impairments, and multiple disabilities are analyzed to determine if the Q produces increased range of motion (ROM) outcomes for the knee and shoulder joints. A single case AB, pre-post design was utilized where ROM measurements were measured with a goniometer before and after a 30-minute Q intervention. A variety of exercise regimens were utilized including: alternating reciprocal pattern set-up, shoulder flexion set-up, knee flexion set-up, and crossing midline set-up. Group results depicted immediate and cumulative ROM benefits for the knee and shoulder. Incremental weekly change in ROM occurred, as well as leaps from baseline ROM measurements through continued Q use. At the individual level, changes in ROM varied per student. Sustaining ROM results are still yet to be determined following Q intervention.

*Keywords:* Range of motion (ROM), knee extension, shoulder flexion, shoulder extension, Quadriciser, the “Q,” cerebral palsy



## **Chapter 1: Introduction**

In today's society, the prevalence of rehabilitation, physical therapy, and occupational therapy are among many methods in improving strength, mobility, flexibility, and neuro-functioning. Therapy serves as a method that can provide service to an array of ages, disorders, and disabilities. The field of physical and occupational therapy is rapidly growing in an attempt to avoid costly procedures and medications. Rehabilitative techniques aim to restore previous functioning, reduce pain, and prevent disabilities. However, in the event of severe disorders and impairments, achieving therapy goals can be seemingly difficult. In individuals where voluntary/controlled movements are not always possible, engaging in daily physical activity can be a struggle and everyday challenge.

Consequently, the significance and importance of regular exercise is often overlooked. Exercise and movement serve as crucial elements in providing optimal function for the human body (Singh, 2002). Regular exercise has been proven to reduce the risk of premature mortality, while also employing optimal functioning of our muscles, bones, and joints (Singh, 2002). The Mayo Clinic recommends receiving daily exercise for a minimum of 30 minutes a day (Mayo Clinic, 2014). The Mayo Clinic also promotes exercise as it engenders the following benefits: weight control, disease combat, improved sleep, increased energy, and improved mood (Mayo Clinic, 2014). Without exercise and movement, individuals lose bone density, strength, and endurance in addition to failed regulation of weight and blood pressure (Barlowe, 2015). By not engaging in regular physical exercise, exercise tolerance is diminished leading to a possible decreased threshold of physical ability and risk of dependency (Singh, 2002).

Unfortunately, voluntary physical activity is not possible for all, and many of us take for granted the ability to move freely with no restrictions on our activities of daily living. For those

with severe orthopedic impairments, partaking in physical activity, and exercise is impossible without assistance and methods to promote safe movement. Children with severe orthopedic impairments are especially vulnerable, as physical movement is imperative in development of motor skills and functioning. Physical therapists, occupational therapists, and adapted PE teachers provide movement assistance and programs to children with severe orthopedic impairments (Project IDEAL in Action, 2013). The assistance of technology also provides aid such as walkers, canes, wheelchairs, and specialized exercise equipment (Project IDEAL in Action, 2013). Through the implementation of exercise, it is possible that health benefits can extend to severely, orthopedically impaired children and optimize their everyday function.

The purpose of this study is to analyze the effects of the Quadriciser (the “Q”) on range of motion (ROM). The Q is a motorized therapy system that promotes the passive-active movement of the arms and legs. This study specifically analyzes the ROM of the shoulder and knee joints in middle school and high school students diagnosed with severe orthopedic impairments, multiple disabilities, and cerebral palsy (Quadriciser Corp., n.d.). The study involves an analysis of incremental speed increase, as well as implementing the following exercise protocols in relation to ROM: shoulder flexion, knee flexion, crossing midline, and the alternating reciprocal pattern Q set-up.

Moreover, this study focuses on two main research questions. The first question studied: (1) Does increasing revolutions per minute (RPM) have ceiling effect in terms of impact on improvements in ROM? (2) Does the Q have a positive impact on the ROM of the Knee and Shoulder? An additional question studied through statistical group analysis was whether the Q produced sustained ROM results overtime. The hypothesis predicts that daily use of the Q will lead to an increase in the students’ range of motion. If the initial hypothesis is found to be true,

future research should investigate whether specific exercises targeting specific joints will lead to greater increases in ROM. This Institutional Review Board (IRB) approved this study as of May 2016 and is under the supervision of Dr. Thomas Moran.

## **Literature Review**

### **The Q**

Initially, the Q was invented with a personal purpose. Larry Bohanan served as a designer for Lockheed Martin for 28 years before creating the Q (Quadriciser Corp., n.d.). In response to his father's diabetes and possible amputation of his leg, Mr. Bohanan invented the Q to promote his father's leg circulation (Quadriciser Corp., n.d.). As a result of its success, Mr. Bohanan established the Quadriciser Corporation to ultimately benefit the medical community and positively impact the health of others (Quadriciser Corp., n.d.). The Q is now found in therapy centers, nursing homes, hospitals and school systems (Quadriciser Corp., n.d.). Many of its avid users claim the Q has encouraged them to achieve "the next level of therapy" (Q Corp., n.d.).

The Q allows continuous passive-active motion of all four limbs, while also providing 20 different types of therapeutic exercises, known as "motorized therapy" (Quadriciser Corp., n.d.). The Q is designed predominantly for individuals who require aid in movement. Some individuals who have utilized the Q include but are not limited to: stroke victims, veterans, traumatic brain injury patients, individuals with cerebral palsy, etc. (Quadriciser Corp., n.d.). The device utilizes a padded seat, hand bars similar to small trapezes (as well as velcro-assisted gloves), and adjustable leg cradles (Inclusive Fitness Coalition, 2015) (Appendix A). There are four variations of the machine including: adults, children, wheelchair-based, and child plus.

Furthermore, varying exercise regimens on the Q can target multiple joints including: the shoulder, knee, ankle, and hip (Quadriciser Corp., n.d.). These exercises allow for joint flexion (a

decrease in angle) and joint extension (an increase in angle). Each exercise involves variance amongst hand bar placement or alternatively, no use of the hand bars (Appendix B). The Q is accompanied by an exercise manual to instruct users on potential exercise regimens and set-ups. Cords can attach to the foot cradles and hand bars to provide resistance (Appendix B). Tension cords can adjust arm extension as a safety precaution, as well as increase overall arm extension (Appendix B). Through research, the Q is known to increase circulation, heart rate, ROM, strength, muscle tone, balance, bowel and bladder function, and psychological health (Quadriciser Corp., n.d.).

### **Background on Cerebral Palsy**

Particularly specific to this study is the presence of cerebral palsy in the students studied. Although the Q is utilized to treat a variety of disorders, cerebral palsy is one of the most common disorders treated by the device. According to the National Institute of Neurological Disorders and Stroke (NINDS), cerebral palsy is a neurological disorder that appears in either infancy or early childhood (NINDS, 2016). Cerebral palsy is typically caused by a brain injury that occurs before cerebral development is completed (Kriggs, 2006). Although a specific etiology is still undetermined, possible causes include: maternal substance abuse, low birth weight, premature birth, and anoxia from traumatic delivery, infections, head trauma during or after birth, and various genetic conditions (Bhutia & Surujlal, 2015). However, 70 to 80 percent of cerebral palsy cases are found to occur prenatally (Kriggs, 2006). Cerebral palsy serves as the most common child physical disability and impacts two to two and a half children per 1000 births (Kriggs, 2006).

The common indicators of cerebral palsy include slowed motor development, abnormal muscle tone, and unusual posture (Kriggs, 2006). Generally, overall symptoms of cerebral palsy

include: ataxia (lack of muscle coordination), tight muscles, spasticity, crouched gait, and either floppy or stiff muscle tone (NINDS, 2016). Additionally, those with cerebral palsy may also experience seizures, hearing loss, impaired vision, inability to control bladder/bowels, and abnormal sensations (NINDS, 2016). Intellectual impairment occurs in two thirds of cerebral palsy patients (Kriggs, 2006). Due to the destruction of brain cells, there is a high prevalence of diminished cognitive functioning (Bhutia & Surujlal, 2015). Seventy to eighty percent of those with cerebral palsy experience spastic reflexes, and 10 to 20 percent of individuals have athetoid/dyskinetic cerebral palsy (Kriggs, 2006). Ninety percent of cerebral palsy cases are non-ambulatory (Bhutia & Surujlal, 2015).

Furthermore, the severity and functioning of each individual case of cerebral palsy varies extensively (Bhutia & Surujlal, 2015). The four main types of cerebral palsy include: spastic, dyskinetic, ataxic, and mixed (CDC, 2015). Spastic cerebral palsy involves tight muscles, dyskinetic engenders uncontrolled movements, and ataxia leads to poor balance and coordination (CDC, 2015). Individuals with cerebral palsy exhibit five possible motor functions including: spasticity, athetosis, ataxia, rigidity, and tremor. Disturbances in sensation, perception, communication, behavior, and epilepsy also often accompany cerebral palsy (Bhutia & Surujlal, 2015). Although there is no cure or concrete treatment in regards to cerebral palsy, physical and occupational therapy are utilized to maximize potential (CDC, 2015).

In relation to therapeutic measures, the Q is being considered as an alternative to traditional therapy as it employs continuous passive-active movement and is particularly suited for individuals with severe orthopedic impairments. As majority of individuals with cerebral palsy are often sedentary, their risk for muscle weakness, decreased endurance, impaired circulation, limited functional strength, multiple system problems, lower bone density, increased

fractures, lower self-esteem, and reduced independence increases (Bhutia & Surujlal, 2015). By incorporating regular exercise, individuals with cerebral benefit emotionally and physically. Some of these benefits include but are not limited to: increased bone density, increased muscular strength, improved endurance, increased mobility, increased self-esteem, and decreased risk of anxiety and depression (Bhutia & Surujlal, 2015).

### **Previous Studies**

In analyzing previous studies that correlated ROM measures in children with cerebral palsy through the implementation of exercise regimens, it is evident that exercise exhibits a positive effect on ROM measures. Particularly, one 2015 study indicated that physical activity incorporation results in gross motor function improvement in children with cerebral palsy (Bhutia & Surujlal, 2015). Results also demonstrated that physical activity may reduce the degree of motor disability (Bhutia & Surujlal, 2015). Training sessions that proved to be successful included strengthening, flexibility, balance, endurance, and coordination exercises (Bhutia & Surujlal, 2015). Some of the exercises would involve tossing/kicking a ball, slow walking, calisthenics, stretching/rotating of the joints, etc. (Bhutia & Surujlal, 2015). In all of these training sessions, the children are contracting their muscles, alongside with working and stretching their joints and tendons.

Another study demonstrated the efficiency of swimming and aquatics exercise in improving ROM for children with cerebral palsy. The applied swimming program lasted for 12 weeks, occurring three times per week for one hour (Jorgic, Aleksandrovic, Dimitrijevic, Radovanovic, Zivkovic, Ozsari & Arslan, 2014). Exercises such as the backstroke, breaststroke, and crawl were implemented (Jorgic, Aleksandrovic, Dimitrijevic, Radovanovic, Zivkovic, Ozsari & Arslan, 2014). However, swimming and aquatics improved flexibility and ROM at the

shoulder joint, but requires modification to improve the ROM of the lower leg joints (Jorgic, Aleksandrovic, Dimitrijevic, Radovanovic, Zivkovic, Ozsari & Arslan, 2014).

Similarly, a six-week gymnastics study proved overall ROM and functional motor performance improvement in all participants (Cook, Frost, Twose, Wallman, Falk, Galea, Adkin, & Klentrou, 2015). Participants were children with cerebral palsy (Cook, Frost, Twose, Wallman, Falk, Galea, Adkin, & Klentrou, 2015). The gymnastics training program improved ROM, muscle strength, neuromuscular activation, balance, and functional motor performance by 10 percent or more (Cook, Frost, Twose, Wallman, Falk, Galea, Adkin, & Klentrou, 2015). Quality functional motor performance scores expressed an overall improvement of 15%, and improvements may engender a large, beneficial impact on everyday life (Cook, Frost, Twose, Wallman, Falk, Galea, Adkin, & Klentrou, 2015). Thus, exercise and muscle contraction continue to produce positive effects on not only ROM, but also muscle strength and overall motor performance and abilities.

Alternatively, one study illustrated insignificant results in measuring the ROM outcomes of certain interventions in children with cerebral palsy. In a 2016 study, stretching children with cerebral palsy demonstrated some positive outcomes, while other evidence demonstrated little or no positive changes (Eldridge & Lavin, 2016). This possibly indicates that ROM is promoted through active movement such as muscular contraction, rather than static movements such as stretching.

In May of 2014, a Q pilot study was performed by Dr. Moran that analyzed ROM and motor planning (fluidity of movement) in relation to high or low muscle tone (Moran, 2014). Individuals with high muscle tone exhibited tightness and high muscle spasticity while individuals with low muscle tone exhibited no tightness and loose limbs (Moran, 2014). Q

intervention involved a session of a hour, with alternating reciprocal pattern set-up implemented for the first 15 minutes. Individuals were placed into one of four groups based on a high or low tone diagnosis, and the number of intervention days/weeks. Goniometer measurements of shoulder flexion, elbow extension, hip flexion, knee extension, and plantar flexion analyzed ROM outcomes. Motor planning was studied through gait analysis. Gait analysis involved participants walking 30 ft before and after Q implementation. The number of heel strikes were counted in comparison to dragging feet and stubbing toes.

Ultimately, Dr. Moran's study demonstrated that the Q produced significant changes in ROM and number of heel strikes following Q implementation. ROM improvements were also demonstrated from beginning of Q intervention to the end. Pre-post ROM measurements illustrated improvement, indicating that Q intervention causes ROM improvement following exercise. The main question that is still yet to be determined is whether the Q produces sustained ROM results overtime. The study produced sustained and improved results for the number of heel strikes, as well as the ROM of right shoulder flexion and both right and left hip flexion. Further research is required to determine sustained ROM results across all five joints. Lastly, 10 of the 12 participants stated that they noticed physical benefits up to two days post Q usage. Overall, the results in this study indicate that the Q yields potential in terms of improving joint ROM as well as motor planning, particularly in participants with severe orthopedic impairments.

## **Chapter 2: Methods**

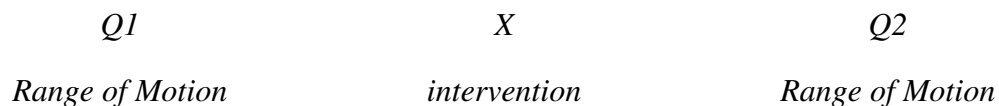
### **Subject Design**

This study employs a single subject AB/ pre-post design, and the participants serve as both the treatment and control. ROM measurements are measured with a goniometer before Q intervention and immediately following Q intervention. ROM measurements were measured



three times per joint, and the highest measurement was recorded. This procedure was implemented as measurements were taken in morning where students may initially feel stiffer. Data collection occurred at two different schools. The study was first conducted at Montevideo Middle School with three students. Data collection began on January 27th, 2016, ceasing on April 29<sup>th</sup>, 2016. The study was again replicated at a high school with three participants. Data collection began on September 7th, 2016 at Spotswood High School and terminated on October 19th. A total of five subjects across the two schools were studied; one subject was utilized in both data collections as the student graduated to the high school in the fall. This subject's data was treated as a separate participant given the amount of time between the last post measurement in April 2016 and baseline measurement in September 2016. This study design was utilized to analyze in-depth, the effect of the Q on knee and shoulder ROM.

#### *Experimental Design*



#### **Sample Population**

The study focuses on three Montevideo Middle School students with severe orthopedic impairments and multiple disabilities. Similarly, the study also involves three Spotswood High School students, one of which was also studied at Montevideo (student A). All three Spotswood students exhibit cerebral palsy among multiple disabilities. Due to physical limitations, the Q allows students to fulfill the daily requirement of physical activity, while also allowing students to participate in exercises they would be unable to normally. All students utilize a wheelchair and wear orthotic devices.

Student A is a female that exhibits severe spastic cerebral palsy, as well as severe

athetoid movements. Athetosis is typically characterized by slow, involuntary, convoluted movements of the hands, fingers, feet, and toes (Cerebral Palsy Alliance, 2015). Athetoid movements can also affect the arms, legs, neck, and tongue (Cerebral Palsy Alliance, 2015). In turn, Student A also expresses impaired gross and fine motor strength, planning, and coordination. Student A also expresses hypotonia, a struggle to gain weight, and a suppressed immune system. Additionally, student A exhibits limited head control, utilizes ankle-foot orthotics (AFOs), and is dependent for activities of daily living. Student A sometimes wears knee immobilizers. Lastly, student A demonstrates global delays, low cognitive functioning and delayed response time. However, student A will make vocalizations, laugh and turn her head in response to their name. Student A was studied in both school settings. At Montevideo Middle School, student A was 14 and turned 15 during data collection at Spotswood High School.

Student B is a 14-year-old female that demonstrates hypotonia (low muscle tone) due to cerebral palsy, mild conductive hearing loss, exotropia, global delays, and seizures (last seizure was April 2012). Exotropia is a common form of strabismus where the eyes deviate outward. At 6 months, student B was diagnosed with subtelomeric deletion. Subtelomeres contain segments of DNA between chromosome caps and chromatin, and subtelomeric changes account for a significant amount of individuals with intellectual disabilities (Lee, Cho, & Hallford, 2011). Global development delay involves lower than normal intellectual functioning, diagnosed between birth and 18 years of age (Douglas Silas Solicitors, 2015). Student B also exhibits poor trunk control, requiring the need for a thoracic-lumbar-sacral orthotic (TLSO). Although student B has low motivation to walk, student B is able to ambulate with a gait trainer. Student B is dependent for transfers and communicates nonverbally through facial expressions and occasional vocalizations.

Student C is a 14-year-old male and exhibits cerebral palsy and frequent seizure episodes. Student C also expresses athetoid movements, poor strength, inhibited motor planning and coordination, and poor trunk balance. Student C needs constant motivation in regards to walking and transfers. Gait trainer aids student C in maintaining posture and gait. Student C is dependent for activities of daily living and uses a G tube to fulfill nutritional needs. Additionally, student C requires the aid of AFOs.

Student D is a 15-year-old female and expresses multiple disabilities, speech impairments and cerebral palsy. Student D was studied at Spotswood High School. Student D currently takes medication for a seizure disorder. Student D favors their left side and will do grabbing and reaching predominantly with the left hand. Student D is unable to keep head up in an upright position and requires the assistance of a TLSO and AFO's. Student D is wheelchair bound, and a trough arm was added to student D's wheelchair for proper position of their right arm. Student D is able to make some verbal requests, exhibits a variety of sayings, and will vocalize/socially interact with others. Student D is able to utilize a gait trainer and a three-wheeled bike with assistance. Lastly, student D requires assistance for all activities of daily living.

Student E is a 15-year-old female that demonstrates cerebral palsy, hypertonia, and multiple disabilities. Student E utilizes a self-manipulated motorized wheelchair that can be powered with a joystick and requires the assistance of AFO's. Student E lacks fine motor abilities to complete delicate tasks and just began utilizing a walker and bike in 2016. In May of 2013, student E received back surgery. Student E is ultimately socially engaged and can communicate with gestures and verbal approximations. Ultimately, student E requires assistance in all forms of activities of daily living.

## **Procedure**

The Q has been incorporated into the students' daily routine, and students utilize a small adult Q machine. Upon arrival, student A utilizes the Q first typically around eight am Monday through Friday. Students B and C, as well as students D and E follow student A in no particular order. Each student attempts to exercise on the Q for 30 minutes each school day. Student A is transferred from their wheelchair device into the Q. At times, student B or C, may be transferred from either their stander or wheelchair device into the Q. Students D and E are transferred to the Q directly from their wheelchair.

Upon starting exercise on the Q, all of the student's AFO's are removed, and sneakers are placed back on. TLSO's remain on for students B and D. The first step due to safety precautions is to snugly secure the waist and chest belt to prevent falling out of the machine. It is imperative that all straps are securely tightened so each student is safely set up in the Q. Typically, a pillow is placed behind students for comfort and adjustment, as well as underarm foam pieces to avoid irritation with the chest strap. Students A and D predominantly require a pillow to support their heads and necks. Following this step, students' feet are then placed and secured in the feet compartments such that during exercise, their feet do not kick out during exercise. Student B continually released her left foot from the Q and required the use of water shoes to provide enough friction to complete the full 30 minute duration. Depending on the exercise, if the hand bars are utilized, Velcro-assisted gloves are used and students' hands are then attached to the hand bars. This assists the students in not only providing secure gripping, but also preventing the release of their hands during exercise.

Depending on the exercise intervention, the position of the hand bars and implementation of resistant cords varies. Additionally, tension cords are adjusted specifically for each individual

depending on the height and comfort level of arm extension (Appendix B). The tension cords are adjusted so that arm extension is fluid, typically with elbows raising to around eye-level. To monitor the students' comfort-level, palpating the posterior shoulder and tricep indicates whether tension cords need to loosen or tighten. If the shoulder feels loose and fluid versus tight, this indicates a comfortable level. Additionally, facial expressions and verbal/nonverbal cues are also monitored to indicate distress or discomfort.

Lastly, in setting up the Q for each specific exercise intervention, there are a variety of bar positions for the hand bars, as well as bars on the base to adjust resistance cords (Appendix C). Positions vary from one in the front, to eight in the back. Additionally, bars placed behind the individual can adjust height of the hand bars (Appendix A). Typically, the Q is set on position B in this case for all students. Two modes exist for leg motion: forward and reverse. The speed dial is controlled at the front of the Q, and an emergency halt button exists in between the forward and reverse switch in case of emergency.

### **Alternating Reciprocal Pattern Set-up**

The alternating reciprocal pattern set-up of the Q was utilized in this study, as well as was alternated with other exercise set-ups (Appendix D). The machine is set in the "forward setting" where legs and feet cycle forwards, similar to a biking pattern. The bars behind the individual are set to letter B, and cords attach to the sides of the hand bars, which ultimately connect to the front and back of the machine to ensure stable position of the arms (Appendix A). Hand bars are slid to position five on the top bar (Appendix C). Velcro gloves are utilized to aid students in gripping the handles, and feet are placed and strapped in boot compartments (Appendix B). Waist and chest straps are always secured and utilized to ensure safety. Tension cords (LC2 and RC2) are attached to metal hooks located above the speed dial (Appendix C).

### **Knee Flexion Set-up**

A knee flexion protocol was implemented in response to improving knee ROM amongst wheelchair-bound participants (Appendix E). This set-up involved passive arm movement at position five located on the top bar for a duration of 30 minutes, allowing students to continue exercise on their upper extremities (Appendix C). Tension cords (LC2 and RC2) are attached to metal hooks located above the speed dial (Appendix C). The first ten minutes serve as a warm-up, with the lower extremities moving in a forward cycling motion with no present restrictions. The following ten minutes involved attaching 20 inch bungee cords to the bottom of the feet capsules, providing resistance. Finally, the last ten minutes involved the feet and knees moving in a reverse cycling motion with the bungee cords still attached.

### **Shoulder Flexion Set-up**

In setting the Q up for the shoulder flexion exercise, three different set ups were implemented in regards to the machine (Appendix F). The placement of the hand bars can be adjusted through sliding and tightening their position along the top bar (Appendix A). Positions range from one (front most end) to eight (back most end). Tension cords (LC2 and RC2) are attached to metal hooks located above the speed dial (Appendix C). For the first ten minutes of exercise, the hand bars are placed in a neutral position at position five. The following ten minutes, the hand bars are adjusted to position one, and the last ten minutes are adjusted to position eight. No alterations to the feet were made, and the lower extremities cycled in a forward motion during the 30 minutes of exercise.

### **Crossing Midline Set-up**

To set-up Crossing Midline properly, the hand bars must be alternated and switched to the opposite hand. This allows for an alternative, crossing pattern for the arms. The left hand bar

is placed on position two located on the top bar, while the right hand bar is placed on position six (Appendix C). The bars behind the individual are set to B (Appendix A). The hand bars are attached to the front and back of the machine by resistant/tension cords. The tension cords located at the front of the machine above the speed dial are adjusted (Appendix D). LC2 and RC2 are connected to LC1 and RC1 (Appendix D). Velcro gloves are placed on the individual to ensure firm gripping of the hand bars. Feet are placed in the foot compartments, and legs are set to the forward motion. Speed is typically set to 30 or 32 rpm, but was altered depending on the comfort level of the subject.

### **Speed Procedure**

Speed was measured in revolutions per minute (rpm) through adjusting the dial at the front of the Q. Adjustment of speed protocol was only studied in the Montevideo students. Previous to this study, the students exercised on the Q at a speed of 30 rpm. Students appeared comfortable and overall happy while performing exercises at this speed. On February 8<sup>th</sup>, the speed was increased to 32 rpm. Students again appeared comfortable exercising at this speed and overall continued to appear alert, engaged, and happy. However, as the speed was increased to 34 rpm on March 18<sup>th</sup>, there was a drastic reverse in mood. Students A (Montevideo), B, and C all appeared strained, unhappy, and uncomfortable. Speed was immediately restored to 32 rpm and remained at this speed until the final measurements were recorded on April 29<sup>th</sup>. Thus, increases in speed impacted the students' ability to perform and mood. Direct correlations to ROM measurements could not be studied as speed protocol was halted due to safety precautions. Measurements prior to March 23<sup>rd</sup> were inaccurate due to inconsistent usage of the goniometer and could not accurately compare ROM outcomes between 30 rpm and 32 rpm.

Moreover, speed protocol took a different approach at Spotswood High School for

students A (Spotswood), D, and E. As students began protocol following a long summer off of minimal activity, students started the Q protocol at a slower pace. Each student started at a speed of 20 rpm. This speed protocol was continued until September 19th 2016, when the speed was gradually increased to 25 rpm. Speed remained at this pace until final data collection on October 19th 2016, as this speed appeared to be the most comfortable pace for the students. Speed would decrease in response to student discomfort or illness and would typically regress from 25 rpm to 20 rpm.

### **Procedure Timeline**

Data collection first began on January 27th, 2016 at Montevideo Middle School, and students A (Montevideo), B and C were studied. On January 27th, the protocol implemented was shoulder flexion protocol. Beginning on March 18th, the knee flexion protocol was then incorporated, and a foam wedge was inserted in the foot capsules to encourage dorsiflexion of the ankle. Beginning on April 15th, 2016, the crossing midline protocol was added in conjunction with the knee flexion protocol. This protocol continued until data collection ceased following April 29th, 2016.

Data collection then restarted on September 7th, 2016, at Spotswood High School, and students A(Spotswood), D, and E were studied. As students began the Q protocol following a long summer of zero Q intervention, a mild protocol was first implemented. The first regimen involved 15 minutes of the alternating reciprocal pattern protocol and 15 minutes of crossing midline protocol. This continued until October 3rd, 2016, when protocol switched to 15 minutes of alternating reciprocal protocol and 15 minutes of knee flexion protocol. Data collection occurred until October 19th.



## **Statistical Measures**

A multitude of statistical measures were calculated to determine the effectiveness of the Q on knee and shoulder ROM outcomes. Data was stored in a safe file on the researcher's computer accessed only by Quadriciser researchers and Dr. Moran. All data was then analyzed through input on the Statistical Package for Social Sciences (SPSS) and Microsoft Excel. All statistical measures were calculated at an individual and group level.

Means and changes in means demonstrated the average degree of change in knee and shoulder ROM, while also illustrating whether a positive or negative change occurred between pre and post measures. Standard deviation measures depicted variance amongst individual subjects, as well as indicated variance in ROM outcomes. Immediate impact as well as cumulative impact were calculated to analyze the short-term and long-term effect of the Q on ROM outcomes. The immediate impact measured the ROM difference between the baseline pre ROM measurement and the baseline post ROM measurement during week one. The cumulative impact involved the difference between the initial baseline pre intervention ROM measurement and the final post ROM measurement following the completion of the intervention. Additionally, latency values depicted the weekly change in pre and post ROM measures following intervention. Pre and post ROM values were isolated for both the shoulder and knee, and a per weekly difference was calculated (i.e. the difference between week two and three, the difference between week three and four, etc.). Latency weekly changes were also analyzed to possibly indicate sustenance.

Furthermore, changes in level measured the change in post ROM results through calculating the difference in change from initial baseline measurements over a three-week period. Changes in level were also analyzed to determine ROM sustenance. Non-overlapping

data points statistical measures synthesized the effectiveness of the Q in producing favorable ROM outcomes. Non-overlapping data points indicate how many data points differ. The amount of non-overlapping data points (higher than baseline ROM) were counted and divided by the overall number of data points, and multiplied by 100 to produce a percent of effectiveness. Values ranging from 91%-100% are considered highly effective, 71%-90% are moderately effective, 50%-70% are minimally effective, and under 50% is not effective. Thus, the higher the percentage, the more change observed, and the higher the effectiveness of the intervention.

Lastly, trendlines were produced to analyze the general pattern of ROM outcomes due to Q intervention. This also gave insight as to whether the Q produces sustaining ROM results. Trendlines exceeding a statistical order of three were not analyzed due to high unreliability and large variance amongst data points. Thus, it is difficult to make a statistical and real-world inference.  $R^2$  values are depicted on figures to illustrate trendline reliability. The closer the  $R^2$  is to one, the more reliable the trendline. However, increasing the order results in a  $R^2$  value close to one. Trendlines that required an order above three expressed low  $R^2$  values and were thus deemed too unreliable to analyze.

However, shoulder flexion data for student C was insufficient to be analyzed due to unexpected events such as seizures, illness, and absences. Shoulder extension measurements were also insufficient for student A (Montevideo), B, and C, due to inaccuracy of measurements in the beginning stages of data collection. Knee ROM measurements were consistently recorded while shoulder measurements were only recorded during shoulder-specific exercise implementation. Paired, two-tailed t-tests were calculated to determine statistical significance. However, due to a small sample size, the data was non-parametric, and thus t-tests produced inaccurate results.

## Chapter 3: Quantitative & Qualitative Results

### Knee Extension ROM

#### Means & Change in Means

In analyzing the Q impact on knee ROM, means across individual students and the entire group depicted average ROM change from the pre measurement to the post measurement (Table 1).

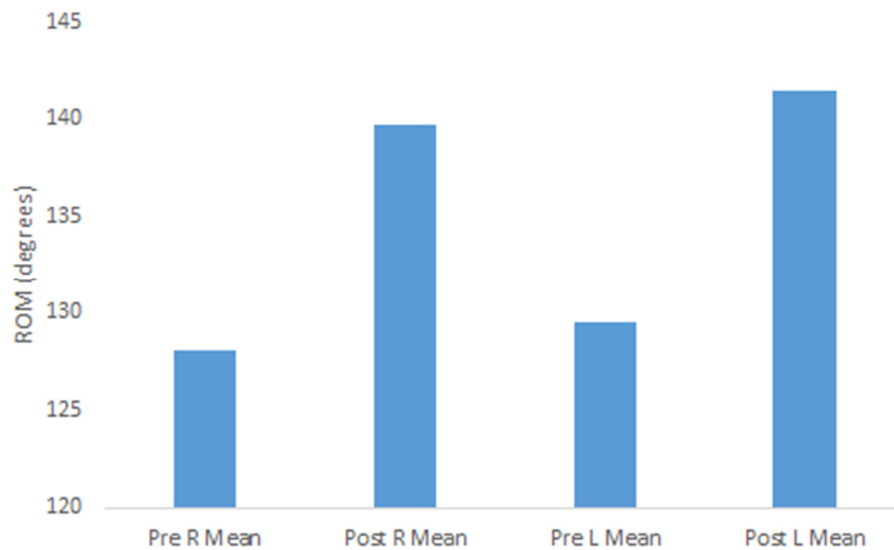
Table 1. Means Knee ROM

Student	Pre Right knee	Post Right knee	Pre Left Knee	Post Left Knee	$\Delta$ Means Right	$\Delta$ Means Left
A (Spotswood)	114.27	130.46	115.69	130.87	16.19	15.18
A (Montevideo)	119.2	134.2	115.6	137.4	15	21.8
B	114.27	130.46	115.69	130.87	16.19	15.18
C	156.67	169	161.33	169	12.33	7.67
D	118.18	122.12	121.92	128.46	3.94	6.54
E	142.87	157.25	143.63	156.25	14.38	12.62
Group (All students)	128.06	139.75	129.46	141.48	11.69	12.02

*Note.* ROM measurements are measured in degrees.

At an individual level, all subjects demonstrated a positive change in ROM from pre to post measurements with the right increasing from 128.06 degrees to 139.75 degrees, and the left increasing from 129.46 degrees to 141.48 degrees (Table 1). Similarly, the group change in means also further the notion of a positive increase in post ROM as well as illustrated symmetry amongst the right and left knee with values of 11.69 degrees and 12.02 degrees respectively (Table 1).

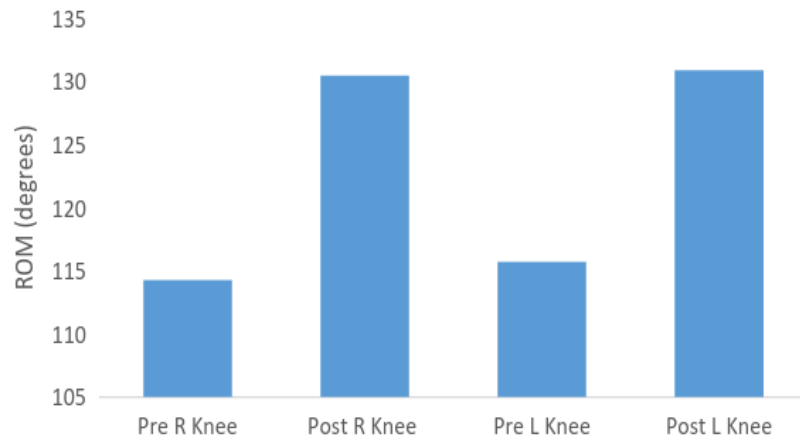
Moreover, in graphing the group average means of pre and post knee ROM measurements, Figure 1 further depicts a positive change following post Q measurements.



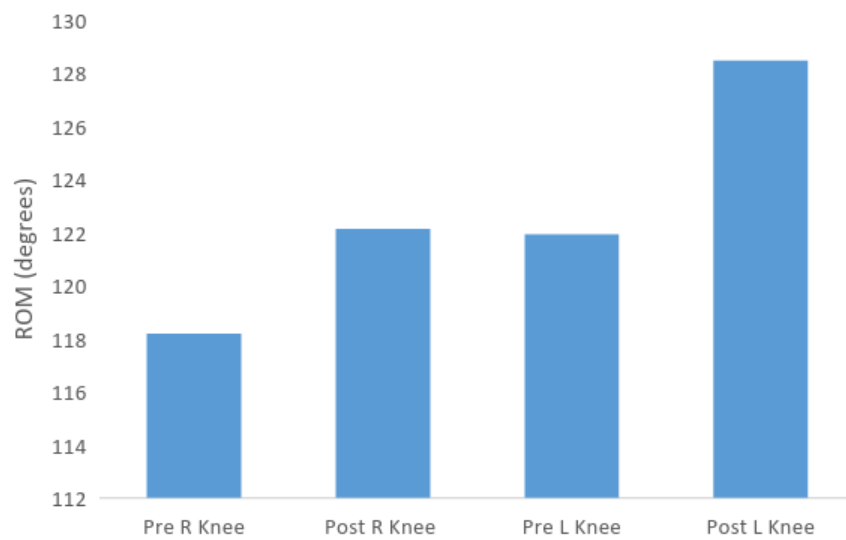
**Figure 1.** Group averages for pre and post Q ROM knee measurements.

In interpreting individual patterns, students A and B produced the largest change in means, while student D produced the smallest change in means (Table 1). Student A at Montevideo produced a 15 degree change for the right knee and 21.8 degree change for the left knee, while producing a 16.19 degree change for the right and a 15.18 degree change for the left at Spotswood (Table 1). Student B depicted similar results, with an increase of 16.19 degrees for the right knee and a 15.18 degree increase for the left knee (Table 1). In comparison, student D produced small changes in means, with an increase of 3.94 degrees in the right and 6.54 degrees in the left (Table 1).

Lastly, individual students expressed great variation amongst the knee change in means, as the right ranged from 3.94 degrees to 16.19 degrees, and the left varied from 6.54 degrees to 21.8 degrees (Table 1). Students also varied in overall average knee ROM outcomes. For instance, while both student A (Spotswood) and student D express overall positive post knee ROM change, student A (Spotswood) represents symmetry amongst the right and left knee, while student D illustrates a larger change in the left knee relevant to the right knee (Figures 2 &3).



**Figure 2.** Average pre and post knee ROM measurements for student A (Spotswood).



**Figure 3.** Average pre and post knee ROM measurements for student D.

### **Standard Deviation**

There was a wide range of standard deviation (SD) amongst the group in terms of knee ROM measurements (Table 2).

**Table 2. Standard Deviation for Knee ROM**

Student	Pre Right knee	Post Right knee	Pre Left Knee	Post Left Knee
A (Spotswood)	5.42	12.7	7.54	11.5
A (Montevideo)	8.50	5.85	9.39	9.01
B	5.07	2.61	7.61	4.32
C	5.13	4.58	2.08	4.58
D	11.1	5.16	11.2	7.97
E	16.5	18.4	14.1	13.9
Group (All students)	16.8	18.0	17.7	16.1

*Note.* Standard deviation values represent degrees.

The group as a whole depicted a wide range of ROM measurements, as the overall SD values were considerably high (Table 2). Group SD values produced a right pre SD value of 16.8 degrees, post right value of 18.0 degrees, a pre left value of 17.7 degrees, and a post left value of 16.1 degrees (Table 2). Overall, group SD values were high, but also demonstrated symmetry amongst the right and left pre/post measurements, indicating a similar degree of change in both sides of the body.

Specific to individual subject, great variability also occurred amongst subjects. Student E demonstrated the largest deviation amongst pre and post knee ROM measurements, such as 16.5 degrees for the pre right knee and 18.4 degrees for the post right knee (Table 2). Student E also demonstrated great variance for the left, with a pre value of 14.1 degrees and a post value of 13.9 degrees (Table 2). Students B and C produced the lowest variance in ROM values in relation to the rest of the group (Table 2). Particularly low, student C expressed a SD value of 2.08 degrees for the pre left knee and student B expressed a SD value of 2.61 degrees for the post right knee (Table 2). These two SD values were the lowest in the entirety of SD calculations.

## Immediate & Cumulative Impact

Immediate and cumulative impact measures depicted the pre and post change during week one, as well as the change in knee ROM from beginning of Q intervention until the end of Q intervention (Table 3).

Table 3. Immediate and Cumulative Impact on Knee ROM

Student	Right Immediate	Left Immediate	Right Cumulative	Left Cumulative
A (Spotswood)	4.00	4.20	26.5	20.7
A (Montevideo)	6.00	9.00	7.00	6.00
B	7.00	14.0	9.00	21.0
C	12.0	12.0	9.00	3.00
D	13.0	17.8	26.2	28.6
E	15.0	16.2	43.8	33.9
Group Avg.	9.50	12.2	20.3	18.9

*Note.* All values represent degrees.

Group averages depicted both a positive immediate impact on knee ROM, as well as a positive cumulative impact on knee ROM. The right knee demonstrated an immediate impact of an increase of 9.50 degrees, with an overall cumulative increase of 20.3 degrees (Table 3).

Additionally, the left knee produced similar results, with an immediate change of 12.2 degrees, and a cumulative change of 18.9 degrees (Table 3). These values represent symmetry amongst the right and left knee in ROM outcomes. Students A (Spotswood), B, D, and E all illustrated positive immediate impacts on knee ROM, with a further increase cumulatively overtime (Table 3). While students A (Montevideo) and C demonstrated overall positive immediate and cumulative trends, the immediate impact on knee ROM produced higher changes in degrees relative to the cumulative impact. Student E produced the highest cumulative impacts for the right and left knee with values of 43.8 degrees and 33.9 degrees respectively (Table 3). Students A (Spotswood) and D also produced large leaps from immediate impact to cumulative impact

with respective values of 26.5 degrees and 20.7 degrees, and 26.2 degrees and 28.6 degrees (Table 3).

### Average Weekly Change

Average weekly change was calculated according to weekly changes in isolated pre measurements and isolated post measurements for both individual and the group (Table 4).

Table 4. Average Weekly Change for Knee ROM

Student	Pre Right Knee	Post Right Knee	Pre Left Knee	Post Left Knee
A (Spotswood)	0.817	3.75	-0.317	2.75
A (Montevideo)	-1.00	0.250	-4.00	-0.750
B	2.00	0.500	5.00	1.75
C	-5.00	-1.50	-1.50	-4.50
D	7.60	3.30	4.55	2.70
E	8.26	5.76	5.78	3.54
Group avg.	2.11	2.01	1.59	0.92

*Note.* Values represent averages in weekly differences for isolated pre and post ROM measures. All values are measured in degrees.

Weekly change for the pre ROM measurements of the right and left knee were 2.11 degrees and 1.59 degrees respectively (Table 4). The post weekly change for the right and left knee were 2.01 degrees and 0.920 degrees respectively (Table 4). In analyzing the latency results, student C regressed in all measures, producing negative values for both right and left knee ROM outcomes (Table 4). Student A (Montevideo) produced negative values in all areas with the exception of the post right knee and student A (Spotswood) regressed in the pre left knee (Table 4). Students B, D, and E produced all positive changes in both pre and post measures overtime (Table 4). Overall, the right knee demonstrates three regressions and the left knee demonstrates four regressions among individual subjects (Table 4).



## Levels of Change

In addition to analyzing the weekly change in ROM, the leap in change was also analyzed through performing changes in level measurements (Table 5).

Table 5. Levels of Change for Knee ROM

Student	Week 1 Post R	Week 1 Post L	Week 2 Post R	Week 2 Post L	Week 3 Post R	Week 3 Post L
A (Spotswood)	6.00	9.00	9.00	5.00	-5.00	-4.00
A (Montevideo)	6.00	9.00	9.00	5.00	-5.00	-4.00
B	7.00	14.0	7.00	21.0	11.0	22.0
C	12.0	12.0	3.00	6.00	9.00	3.00
D	13.0	17.8	20.2	27.2	15.6	9.50
E	9.00	-0.800	8.80	1.30	21.2	10.3
Group Avg.	8.83	10.2	9.50	10.9	7.80	6.13

*Note.* Levels of Change values represent degrees.

In interpreting the average group levels of change, the greatest change in post knee ROM measurements occurred during week two of the intervention. Specifically, the largest result occurred during week two for the left knee at a value of 10.9 degrees (Table 5). While week three produced change, it did not produce change to the degree of weeks one and two (Table 5). During week three, the right knee produced an average level of change of 7.80 degrees and a left of 6.13 degrees (Table 5). However, the group levels of change values increased for both the right and left knee in relation to the values produced in week one (Table 5). The right knee improved from a previous level of change of 8.83 degrees to 9.50 degrees, and the left improved from a value of 10.2 degrees to 10.9 degrees (Table 5).

Furthermore, levels of change/the degree of leap in data greatly varied amongst subjects. Student A at both Spotswood and Montevideo produced negative levels of change for the right and left knee at week three (Table 5). From week one to week two, Student A increased the right

knee level of change by three, but decreased in the left knee by four (Table 5). Student B demonstrated a continuous positive level of change in the left knee, eventually reaching her highest level of change of 22.0 degrees at week three (Table 5). Student B’s highest level of change on the right knee also occurred during week three, but was exactly half the value of the left knee (Table 5).

Moreover, student C consistently decreased overtime in level of change for the left knee starting at a change of 12 degrees to a final change of three degrees (Table 5). All right levels of change for student C were lower in comparison to week one, although a slight jump was identified from week two to three (Table 5). Student D demonstrated the largest change in levels during week two, with right and left values of 20.2 degrees and 27.2 degrees respectively (Table 5). Lastly, student E demonstrated the highest levels of change during week three, but produced a negative level of change for the left knee during week one (Table 5).

### **Non-Overlapping Data Points**

In correspondence, non-overlapping statistical measures were also taken to analyze the effectiveness of the Q in relation to ROM outcomes (Table 6).

**Table 6. Non-Overlapping Data Points for Knee ROM**

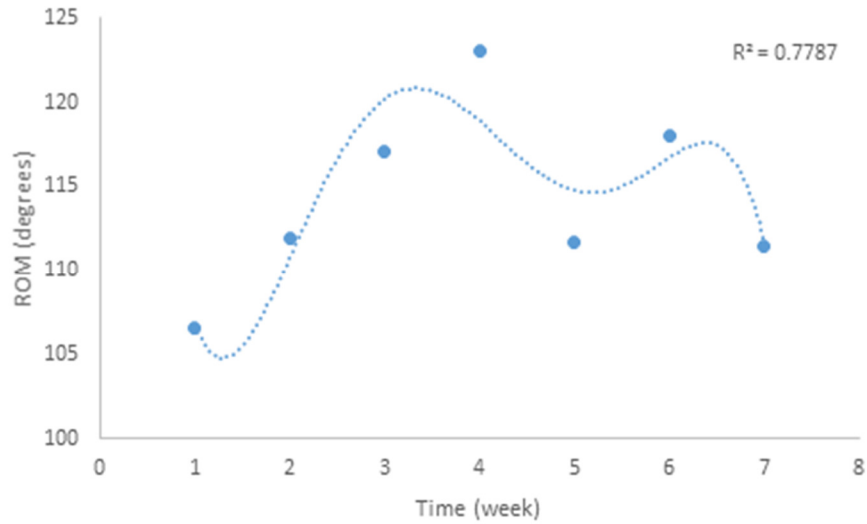
<b>Student</b>	<b>Right knee</b>	<b>Left Knee</b>
A (Spotswood)	100%	92.30%
A (Montevideo)	44.4%	44.40%
B	88.90%	100.00%
C	60.00%	80.00%
D	100.00%	100.00%
E	100.00%	100.00%
<b>Group Avg.</b>	<b>87.23%</b>	<b>86.12%</b>

*Note.* Values ranging from 91%-100% are considered highly effective, 71%-90% are moderately effective, 50%-70% are minimally effective, and under 50% is not effective.

Overall, group analysis demonstrated that 87.23% and 86.12% of data points did not overlap for the right and left knee respectively (Table 6). This indicates that the Q intervention was moderately effective in improving ROM for both the right and left knee (Table 6). Overall group values also demonstrated symmetry amongst the right and left knee. However, effectiveness varied per individual subject. Only 100% of data points for three of the six subjects did not overlap, indicating that the Q intervention was highly effective (Table 6). Subject A at the Spotswood location demonstrated high effectiveness of Q usage, while alternatively producing ineffective results at the Montevideo location (Table 6). The Q proved as moderately effective in the right knee and highly effective in the left knee for student B (Table 6). Student C produced minimally effective overlapping data results for the right knee while the left knee was moderately effective (Table 6). Students D and E produced highly effective results for both the right and left knee (Table 6).

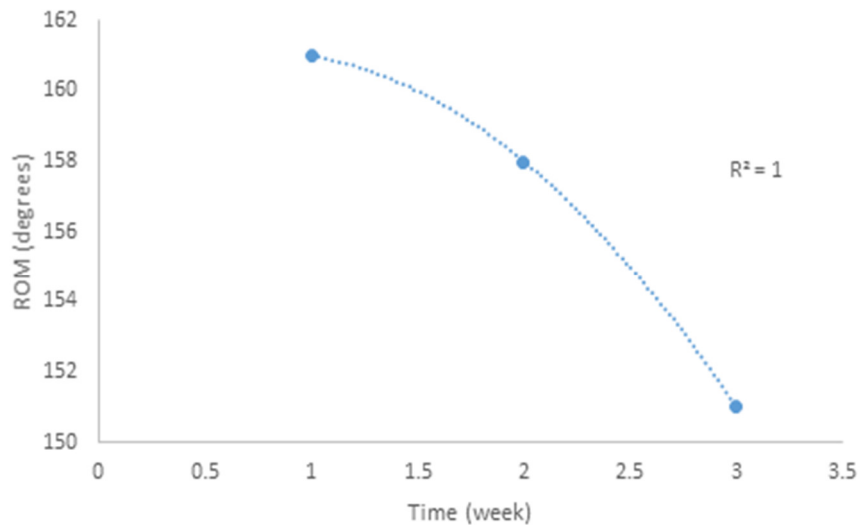
#### **Analysis of Slope/Trendline**

Lastly, changes in slope were analyzed to study a pattern of possible sustainability. Trendlines of right pre, left pre, right post, and left post were isolated and analyzed. However, subjects demonstrated great variability, and thus majority of the graphs were unable to be analyzed due to unreliable trendlines. Trendlines varied from a steady improvement, to a negative impact on knee ROM, to overall fluctuation. All of Student A (Spotswood)'s trendlines required an order of five and were thus unreliable (Figure 4).



**Figure 4.** Variance of right knee ROM measurements before Q implementation for student A (Spotswood). The polynomial trendline is represented at a power of five.

Three of student B's graphs utilized an order of three, while majority of student D and E's trendlines required a power of four. Half of student A (Montevideo) trendlines utilized an order of two while the other half utilized a power of four. Student C was the only subject with a consistent trendline pattern for knee ROM, all of which utilized an order of two (Figure 5).



**Figure 5.** Variance of right knee ROM measurements before Quadriciser implementation for student C. The polynomial trendline is represented at a power of two.

## Shoulder Flexion ROM

### Means & Change in Means

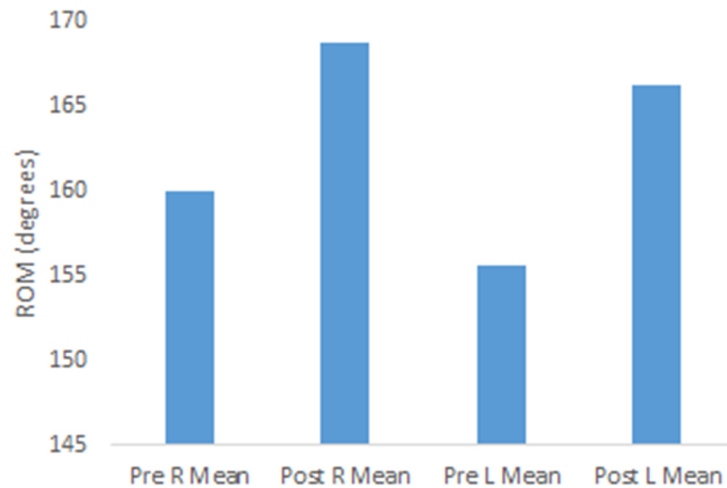
Means and change in means were calculated to analytically compare pre and post ROM measurements for shoulder flexion (Table 7).

Table 7. Means Shoulder Flexion ROM

Student	Pre Right Shoulder	Post Right Shoulder	Pre Left Shoulder	Post Left Shoulder	Δ Means Right	Δ Means Left
A (Spotswood)	165	173	150	164	7.57	14.1
A (Montevideo)	165	173	167	174	7.34	7.66
B	157	171	158	170	14.7	11.7
D	144	150	129	145	5.43	16.2
E	162	175	169	175	12.2	5.5
Group (All students)	160	169	156	166	8.66	10.7

*Note.* Mean and change in mean values represent degrees. Data for student C was insufficient.

The average group change in means depicts a positive change between pre and post shoulder flexion ROM measurements following Q intervention with the right improving from 160 degrees to 169 degrees and the left improving from 156 degrees to 166 degrees (Table 7). The change in means also demonstrated positive change as well as symmetry with a right shoulder flexion value of 8.66 degrees and a left shoulder flexion value of 10.7 degrees (Table 7). In comparing the group means, the left shoulder demonstrated slightly larger gains, but the overall post right shoulder flexion ROM measurement was 169 degrees while the left was 166 degrees (Table 7). Group averages were graphed to analyze the positive trend in a visual depiction (Figure 6).



**Figure 6.** Average pre and post shoulder flexion ROM measurements for students A (Montevideo & Spotswood), B, C, D, and E.

Furthermore, individual analysis demonstrated great variability in change of means, with the right ranging from 5.43 degrees to 14.7 degrees, and the left 5.5 degrees to 14.1 degrees (Table 7). The highest change in means for the right shoulder during flexion was attained by student B at a value of 14.7 degrees, while the highest change in means for the left was attained by student D at a value of 16.2 degrees (Table 7). Student D demonstrated the lowest change in means for right shoulder flexion at a value of 5.43 degrees, and student E demonstrated the lowest value for the left at 5.50 degrees (Table 7). The change in means for both the right and left shoulder flexion was similar in student A (Montevideo), with values of 7.34 degrees and 7.66 degrees respectively (Table 7). Student B demonstrated high changes in means, while also depicting symmetry of improvements amongst the right and left shoulder flexion ROM outcomes (Table 7).

### **Standard Deviation**

As students expressed varying diagnoses and abilities, standard deviation measures aided in better data approximation and analysis (Table 8).

Table 8. Standard Deviation for Shoulder Flexion ROM

Student	Pre Right Shoulder	Post Right Shoulder	Pre Left Shoulder	Post Left Shoulder
A (Spotswood)	9.07	9.70	6.11	8.42
A (Montevideo)	9.07	4.73	13.0	6.66
B	13.6	6.43	12.1	5.51
D	5.75	8.69	21.1	5.57
E	6.93	10.4	12.3	7.39
Group (All students)	11.5	11.5	18.6	12.4

*Note.* Data for Student C was insufficient.

*Note.* Standard deviation values represent degrees.

Group SD values were relatively high with a pre and post right shoulder deviation of 11.5 degrees, a pre left shoulder flexion deviation of 18.6 degrees, and a post left shoulder flexion deviation of 12.4 degrees (Table 8). Post shoulder flexion ROM values depicted symmetry, indicating a similar degree of change in both sides of the body (Table 8). It is noted that the largest variation occurs within the pre left shoulder flexion measurements (Table 8).

Furthermore, great variability occurred at the individual level ranging from 4.73 degrees to 10.4 degrees for the post right shoulder and 5.51 degrees to 8.42 degrees for the left shoulder (Table 8). Student D attained the highest SD value of 21.1 degrees for the pre left shoulder flexion (Table 8). Other relatively high values included student B's pre right shoulder flexion measurement of 13.6 degrees and student E's pre left shoulder measurement of 12.3 degrees (Table 8). Most subjects varied in their SD values across all measures, and the strongest variance was demonstrated by student D (Table 8). Student A (Spotswood) demonstrated the least deviation in values across all measures (Table 8).

## Immediate & Cumulative Impact

Immediate and cumulative impact measures depicted the pre and post change during week one, as well as the change in shoulder flexion ROM from beginning of Q intervention until post intervention (Table 9).

Table 9. Immediate and Cumulative Impact on Shoulder Flexion ROM

Student	Right Immediate	Left Immediate	Right Cumulative	Left Cumulative
A (Spotswood)	4.00	9.80	9.2	13.5
A (Montevideo)	14.0	17.0	12.0	16.0
B	32.0	25.0	20.0	19.0
D	2.1	4.4	18.6	-5.30
E	8.50	11.2	29.1	24.0
Group Avg.	12.1	13.5	17.8	13.4

*Note.* All values represent degrees. Data for student C was insufficient to analyze.

Group averages depicted overall positive trends in regards to immediate and cumulative impact on shoulder flexion ROM. The group average for right shoulder flexion cumulative impact produced higher ROM outcomes in relation to the immediate an immediate change of 12.1 degrees and a change of 17.8 degrees (Table 9). The left shoulder produced relatively identical group results with an immediate change of 13.5 degrees and a cumulative change of 13.4 degrees (Table 9). However, students A (Spotswood) and E demonstrated a continued increase in ROM cumulatively overtime (Table 9). Students A (Montevideo) and B demonstrated high immediate impact on shoulder flexion ROM, but demonstrated lower degrees of change in regards to cumulative impact (Table 9). Students A (Spotswood), D, and E all demonstrated positive immediate impacts on shoulder flexion ROM, and produced even higher cumulative impacts (Table 9). Student B demonstrates the highest immediate impact with a right value of 32.0 degrees and a left value of 25.0 degrees, while student E demonstrates the highest cumulative impact with respective values of 29.1 degrees and 24.0 degrees (Table 9). Student D illustrated



the lowest immediate impact, and also regressed in cumulative impact in the left shoulder, producing a change of -5.30 degrees (Table 9). This could likely account for a lower overall group cumulative impact as this data point serves as an outlier.

### **Average Weekly Change**

Average weekly change determined the magnitude of weekly change in isolated pre and post measurements for the right and left shoulder flexion ROM outcomes (Table 10).

Table 10. Average Weekly Change for Shoulder Flexion ROM

Student	Pre Right Shoulder	Pre Left Shoulder	Post Right Shoulder	Post left Shoulder
A (Spotswood)	-0.0330	1.73	-0.370	1.23
A (Montevideo)	3.50	-1.00	6.00	-0.500
B	5.50	-6.00	7.50	-3.00
D	5.45	8.30	-20.7	-4.85
E	4.55	10.3	10.9	6.40
Group Avg.	3.73	2.66	0.657	-0.144

*Note.* Average weekly change is measured in degrees. Data for student C was insufficient.

Overall, subjects demonstrated weekly change amongst isolated pre and post measures, however positive and negative change fluctuated throughout (Table 10). The largest change in latency for the group was produced by the pre right shoulder, with a weekly change of 3.73 degrees, while the lowest was produced by the post left shoulder with a weekly change of -0.144 degrees (Table 10). The smallest positive change for the overall group was attained by the pre left shoulder flexion with a weekly change of 0.657 degrees (Table 10). Student E demonstrated the largest positive changes in weekly latency for the post right shoulder and the pre left shoulder, with weekly changes of 10.3 degrees and 10.9 degrees respectively (Table 10). The largest negative latency change was attained by student D for the left pre shoulder with a weekly

change of -20.7 degrees (Table 10). Student E was the only student with an absence of negative latency values, and student A (Montevideo) produced two negative weekly change values for both post shoulder ROM measurements (Table 10).

### Levels of Change

Levels of change for shoulder flexion were measured to identify leaps in data following baseline measurements (Table 11).

Table 11. Levels of Change for Shoulder Flexion ROM

Student	Week 1 Post R	Week 1 Post L	Week 2 Post R	Week 2 Post L	Week 3 Post R	Week 3 Post L
A (Spotswood)	4.00	9.80	23.0	26.0	23.0	26.0
A (Montevideo)	14.0	17.0	21.0	28.0	12.0	16.0
B	32.0	25.0	30.0	30.0	20.0	19.0
D	2.10	4.40	8.6	-5.20	18.6	-5.30
E	8.50	11.2	21.6	24.0	29.1	24.0
Group Avg.	12.1	13.5	20.8	20.6	20.5	15.9

*Note.* Levels of change represent degrees.

In analyzing the group average for levels of change, the largest leap from baseline was achieved during week two for both the right and left shoulder, 20.8 degrees and 20.6 degrees respectively (Table 11). The week three level of change values were higher than the first week, but both lower than the third (Table 11). Additionally, the change in levels as a result of Q intervention greatly varied amongst individual subjects. Student B demonstrated the largest pattern of levels of change overall, and student D was the only subject to illustrate a negative level of change for week two and three post left shoulder measures with values of -5.20 degrees and -5.30 degrees respectively (Table 11). Moreover, student A (Spotswood) saw no change from week two to three as values remained at 23.0 degrees and 26.0 degrees respectively (Table 11). The overall smallest pattern in levels of change was achieved by student D (Table 11).

## Non-Overlapping Data Points

Non-overlapping data points were utilized to measure Q effectiveness on ROM outcomes for shoulder flexion (Table 12).

Table 12. Non-Overlapping Data Points for Shoulder Flexion ROM

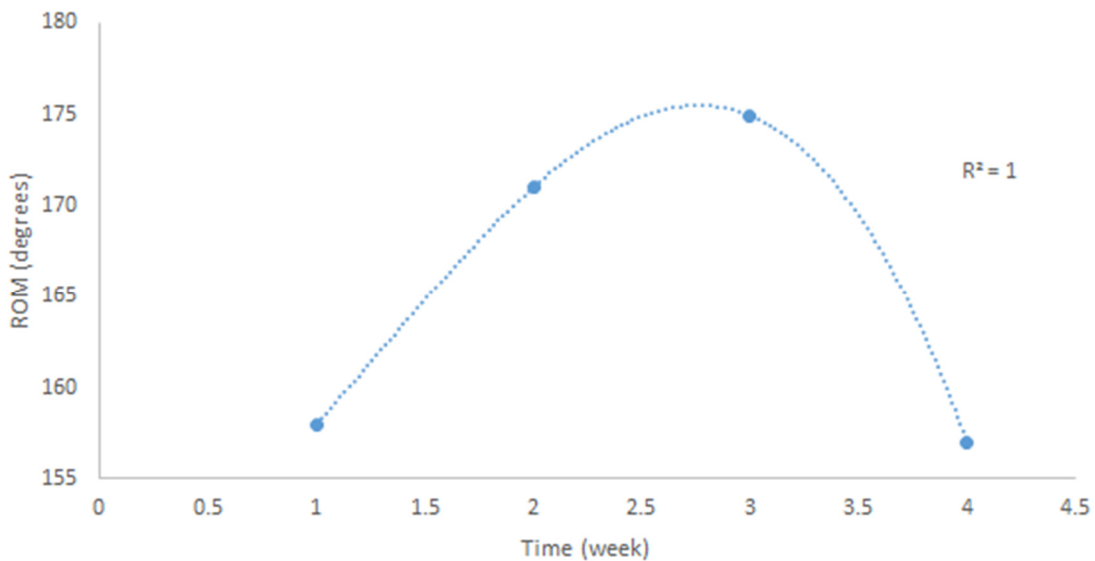
Student	Right Shoulder	Left Shoulder
A (Spotswood)	85.7%	85.7%
A (Montevideo)	100%	100%
B	100%	100%
D	100%	20.0%
E	100%	100%
Group Avg.	97.1%	81.14%

*Note.* Values ranging from 91%-100% are considered highly effective, 71%-90% are moderately effective, 50%-70% are minimally effective, and under 50% is not effective. Data for student C was insufficient.

In analyzing the group results, 97.1% of data points did not overlap for the right and 81.14% of data points did not overlap for the left (Table 12). This indicates that the Q intervention was highly effective for the right shoulder flexion ROM, but moderately effective for the left shoulder flexion ROM (Table 12). In three of the five subjects, 100% of data points did not overlap for the left, and 100% of data points did not overlap for four of the five subjects (Table 12). This demonstrates that the Q was highly effective for these individuals. Student D demonstrated that only 20.0% of data points overlapped for the left shoulder, indicating that the intervention was not effective (Table 12). Another interesting finding was that student A only demonstrated 100% effectiveness at Montevideo Middle School, but depicted moderate effectiveness while at Spotswood High School (Table 12).

### Analysis of Slope/Trendline

Trendline and slope were analyzed to determine if shoulder flexion ROM results were sustained due to implementation of the Q exercise regimen. Trendlines between subjects illustrated great variability, varying from steady improvement, a negative decline, and overall fluctuation. All students expressed reliable trendlines as all required an order of two with the exception of the pre right shoulder flexion trendline for student A (Spotswood) which required an order of a three (Figure 7).

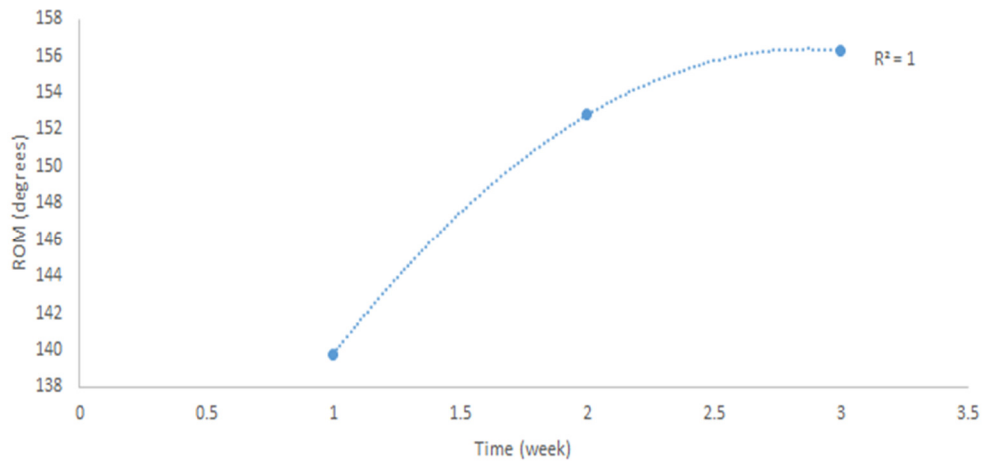


**Figure 7.** Variance of student A (Spotswood)'s pre Q shoulder flexion ROM measurements per week for the right shoulder. The polynomial trendline represents a power of three.

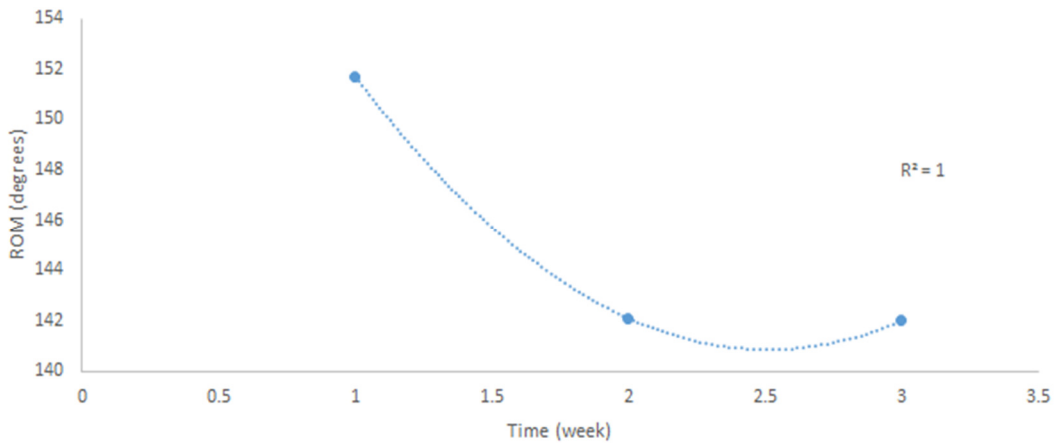
Over a four course period, student A (Spotswood) depicted a rise in weeks two and three of the right pre shoulder flexion ROM measurements, but then a drop in week four (Figure 7).

Student B also demonstrated a pattern similar to student A.

Student D's trendline results were not similar amongst the right and left shoulder during flexion. The right shoulder depicted a steady increase over a four-week period, whereas the left shoulder depicted a steady decline (Figures 8 & 9).

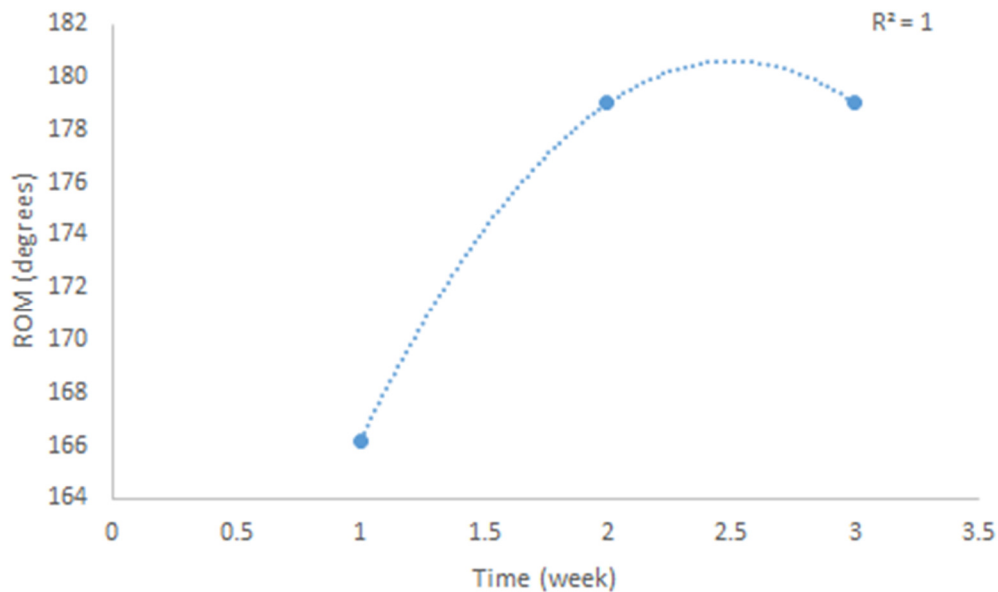


**Figure 8.** Variance of student D’s post Q shoulder flexion ROM measurements per week for the right shoulder. The polynomial trendline represents a power of two.



**Figure 9.** Variance of student D’s post Q shoulder flexion ROM measurements per week for the left shoulder. The polynomial trendline represents a power of two.

Student E’s trendline was consistent across all pre/post and right/left measures of shoulder flexion ROM. Student E consistently depicted a steady incline in shoulder flexion ROM, but then a drop at the third week of shoulder flexion measurements (Figure 10).



**Figure 10.** Variance of student E’s post Q shoulder flexion ROM measurements per week for the left shoulder. The polynomial trendline represents a power of two.

### Shoulder Extension ROM

#### Means & Change in Means

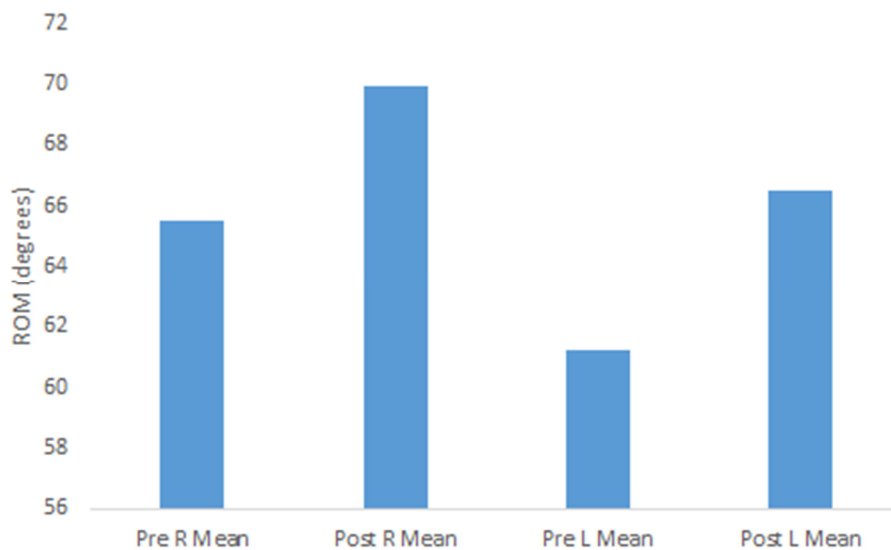
Data for Students A (Montevideo), B, and C were insufficient to report in regards to shoulder extension ROM outcomes. Sufficient shoulder extension ROM measures were produced in students A (Spotswood), D, and E. Means and change in means were calculated to compare average pre and post shoulder extension ROM measures (Table 13).

Table 13. Means Shoulder Extension ROM

Student	Pre Right Shoulder	Post Right Shoulder	Pre Left Shoulder	Post Left Shoulder	Δ Means Right	Δ Means Left
A (Spotswood)	67.9	72.2	66.7	70.1	4.30	3.4
D	57.6	65.8	50.8	61.0	8.20	10.2
E	70.1	71.2	64.5	67.3	1.10	2.8
Group (All students)	65.5	70.0	61.2	66.5	4.53	5.47

*Note.* Values represent degrees. Data for Montevideo students was insufficient.

Across the group, a positive change in ROM was illustrated as the right shoulder extension ROM increased from 65.5 degrees to 70.0 degrees, and the left shoulder extension ROM increased from 61.2 degrees to 66.5 degrees (Table 13). While students varied in shoulder extension ROM measures, the group average change in means demonstrated a positive trend as well as symmetry, with a right change in means of 4.53 degrees and a left change in means of 5.47 degrees (Table 13). The overall positive trend in post shoulder extension ROM values was further confirmed in analyzing its corresponding bar graph (Figure 11).



**Figure 11.** Average pre and post shoulder extension ROM measurements for students A (Spotswood), D, and E.

At the individual level, the changes in means depicted large variability ranging on the right side from 1.1 degrees to 8.2 degrees and the left from 2.8 degrees to 10.2 degrees (Table 13). Student D produced the largest changes in means for both the right and left with values of 8.20 degrees and 10.2 degrees respectively (Table 13). Student E produced the smallest change in means for both the right and left with values of 1.10 degrees and 2.80 degrees respectively (Table 13). The right shoulder produced higher ROM results in comparison to the left, with a

post group average of 70.0 degrees and 66.5 degrees respectively (Table 13).

### **Standard Deviation**

Standard deviation values were calculated for shoulder extension as subjects produced varying ROM results (Table 14).

**Table 14. Standard Deviation for Shoulder Extension ROM**

Student	Pre Right Shoulder	Post Right Shoulder	Pre Left Shoulder	Post Left Shoulder
A (Spotswood)	9.51	10.6	12.5	6.15
D	3.31	6.32	7.68	7.58
E	14.8	8.09	12.9	5.90
Group (All students)	10.6	8.31	12.5	6.99

*Note.* Standard deviation values represent degrees. Data for Montevideo students was insufficient.

In terms of group analysis, moderate variation occurred amongst pre and post shoulder extension ROM measurements (Table 14). Particularly, the pre shoulder extension measures with a right deviation of 10.6 degrees and a left of 12.5 degrees (Table 14). Symmetry was also demonstrated in post ROM measurements with a right deviation of 8.31 degrees and a left deviation of 6.99 degrees (Table 14). Great variability also occurred at the individual level. As an overall pattern, student D produced the smallest deviation in comparison to students A (Spotswood) and E (Table 14). The largest SD values were produced by student E for the pre ROM measurements with a right value of 14.8 degrees and a left of 12.9 degrees (Table 14). The lowest SD value was produced by student D for the pre right shoulder (Table 14).

### **Immediate & Cumulative Impact**

Paired t-tests were calculated to determine if significant change occurred amongst pre and post shoulder extension ROM outcomes following Q intervention (Table 15).



Table 15. Immediate and Cumulative Impact on Shoulder Extension ROM

Student	Right Immediate	Left Immediate	Right Cumulative	Left Cumulative
A (Spotswood)	0.900	2.00	14.1	12.5
D	0.400	3.90	4.50	12.7
E	6.00	-0.800	21.2	10.3
Group Avg.	2.4	1.7	13.3	11.8

*Note.* All values represent degrees. Data for Montevideo students was insufficient to analyze.

Group averages for immediate and cumulative impact on shoulder extension ROM demonstrated positive trends across all measures, with the cumulative impact producing the highest ROM outcomes (Table 15). The right shoulder produced an immediate impact of 2.4 degrees and a cumulative impact of 13.3 degrees, while the left produced an immediate impact of 1.7 degrees and a cumulative impact of 11.8 degrees (Table 15). These values possibly indicate symmetrical ROM outcomes in the right and left shoulder as they are close in value. Individually, each student illustrated drastic increases from immediate impact to cumulative impact (Table 15). Student E demonstrated very slight regression in the left shoulder for immediate impact with a value of -0.800 degrees, but produced a substantially higher left cumulative impact value of 10.3 degrees (Table 15). Student E also depicted the highest overall cumulative value of 21.2 degrees in the right shoulder (Table 15).

### **Average Weekly Change**

Changes in latency for shoulder extension were calculated to analyze weekly ROM changes (Table 16).

Table 16. Average Weekly Change for Shoulder Extension ROM

Student	Pre Right Shoulder	Pre Left Shoulder	Post Right Shoulder	Post left Shoulder
A (Spotswood)	3.00	4.40	1.73	3.50
D	-3.05	2.05	-1.15	4.40
E	13.90	7.60	7.05	5.55
Group Avg.	4.62	4.68	2.54	4.48

Note. Average weekly change values represent degrees. Data for Montevideo students was insufficient.

Overall, group average changes in latency were all positive values with a pre right shoulder weekly change of 4.62 degrees, a post right shoulder weekly change of 4.68 degrees, a pre left shoulder weekly change of 2.54 degrees, and a post left shoulder weekly change of 4.48 degrees (Table 16). Group averages were relatively similar in value with the exception of the pre left shoulder (Table 16). Student D was the only subject to produce negative latency values which were produced for both pre shoulder extension measurements (Table 16). Student E illustrated the highest latency change values for shoulder extension across all measures in comparison to subjects A (Spotswood) and D (Table 16).

### Levels of change

Levels of change for shoulder extension were calculated to illustrate a possible leap in data from baseline measures (Table 17).

Table 17. Levels of Change for Shoulder Extension ROM

Student	Week 1 Post R	Week 1 Post L	Week 2 Post R	Week 2 Post L	Week 3 Post R	Week 3 Post L
A (Spotswood)	0.900	2.00	17.9	11.3	25.1	14.0
D	0.400	3.90	12.8	-2.40	4.50	12.7
E	9.00	-0.800	8.80	1.30	21.2	10.3
Group Avg.	3.43	1.70	13.2	3.40	16.9	12.3

Note. Levels of change represent degrees. Data for Montevideo students was insufficient.

All group level of change values demonstrated a positive trend of change from baseline shoulder extension ROM measures (Table 17). The greatest overall leap in post measurements occurred during week three, with a right value of 16.9 degrees and a left value of 12.3 degrees (Table 17). The group demonstrated the smallest levels of change during week one for the post left shoulder with a value of 1.70 degrees (Table 17). Week one for the post right shoulder and week two for the post left shoulder also expressed low levels of change with respective values of 3.43 degrees and 3.40 degrees (Table 17). Levels of change greatly varied at the individual level. Student A (Spotswood) attained the highest level of change during week three for the post right shoulder with a value of 25.1 degrees (Table 17). Both students D and E produced one negative level of change value (Table 17). Levels of change values appear to fluctuate amongst all students at the individual level (Table 17). Students A (Spotswood) and E were the only subjects to produce the highest results for both shoulders at week three (Table 17).

### **Non-Overlapping Data Points**

Non-overlapping data points were calculated to determine overall Q efficiency in promoting shoulder extension ROM outcomes (Table 18).

**Table 18. Non-Overlapping Data Points for Shoulder Extension ROM**

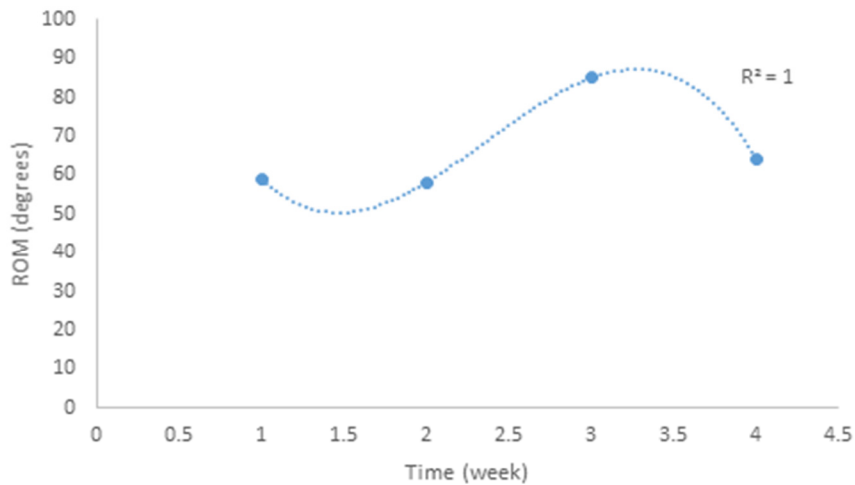
<b>Student</b>	<b>Right Shoulder</b>	<b>Left Shoulder</b>
A (Spotswood)	100%	85.7%
D	60.0%	40.0%
E	100%	60.0%
<b>Group Avg.</b>	<b>80.0%</b>	<b>61.9%</b>

*Note.* Values ranging from 91%-100% are considered highly effective, 71%-90% are moderately effective, 50%-70% are minimally effective, and under 50% is not effective. Data for Montevideo students was insufficient.

Group analysis demonstrated that 80.0% of the data points for right shoulder extension did not overlap and 61.9% data points for the left shoulder extension did not overlap (Table 18). Overall, the Q produced moderately effective results for the right shoulder and minimal effectiveness for the left shoulder during shoulder extension (Table 18). In the right shoulder, 100% of the data points did not overlap for students A (Spotswood) and D, indicating that the Q intervention was highly effective (Table 18). However, student A (Spotswood) demonstrated moderate effectiveness for the left shoulder, and student E demonstrated minimal effectiveness for the left shoulder (Table 18). Student D demonstrated minimal effectiveness for the right shoulder and no effectiveness for the left shoulder (Table 18).

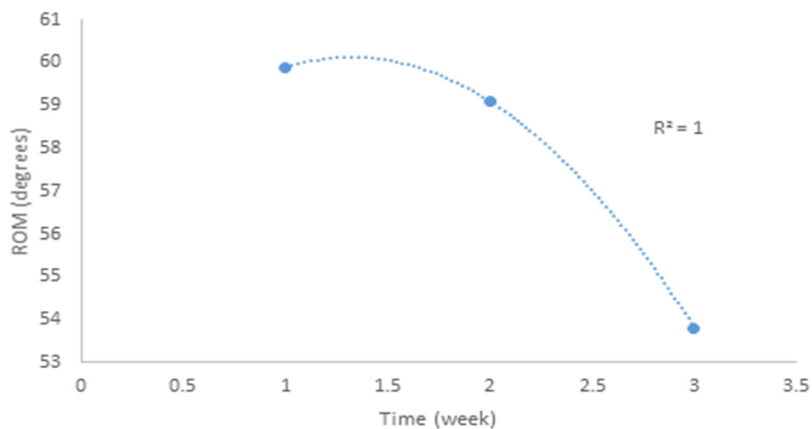
### **Trendline Analysis**

In analyzing trendline patterns, all students illustrated a reliable trendline with majority producing an order of two. Trendlines overall illustrated great variance and slopes that either demonstrated a positive trend, negative trend, or great fluctuation. Student A (Spotswood) produced relatively similar trendlines with a steady increase until week four, where a slight drop in shoulder extension ROM measurements was illustrated. However, student A (Spotswood) produced inconsistent results for the pre left shoulder, requiring an order of three (Figure 12).

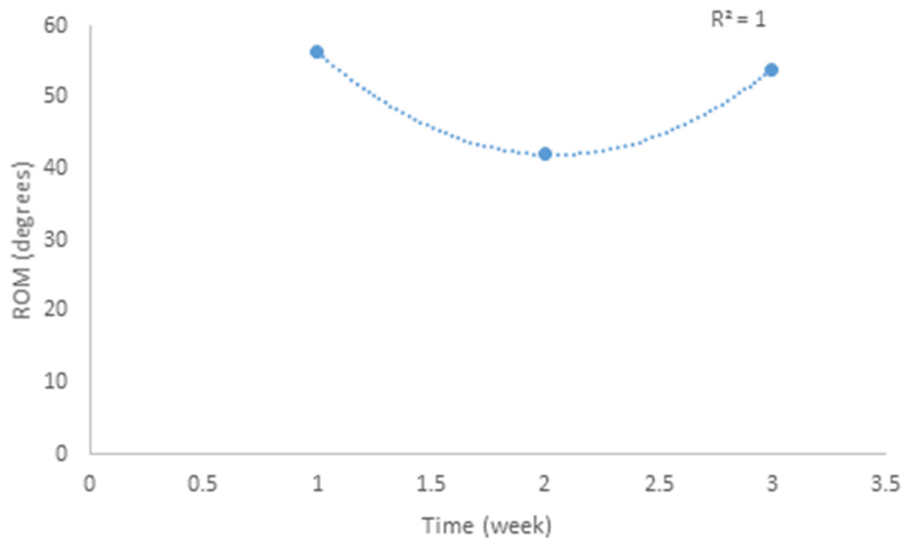


**Figure 12.** Variance of student A (Spotswood)’s pre left shoulder extension ROM measurements before Q implementation per week. The polynomial trendline represents an order of three.

Student D produced the most variation amongst trendline results. Student D demonstrated a decrease in the pre right shoulder overtime, a steady slope of the post right shoulder, and an overall pre and post left shoulder trendline with an observed drop during week two of data collection (Figures 13 & 14).

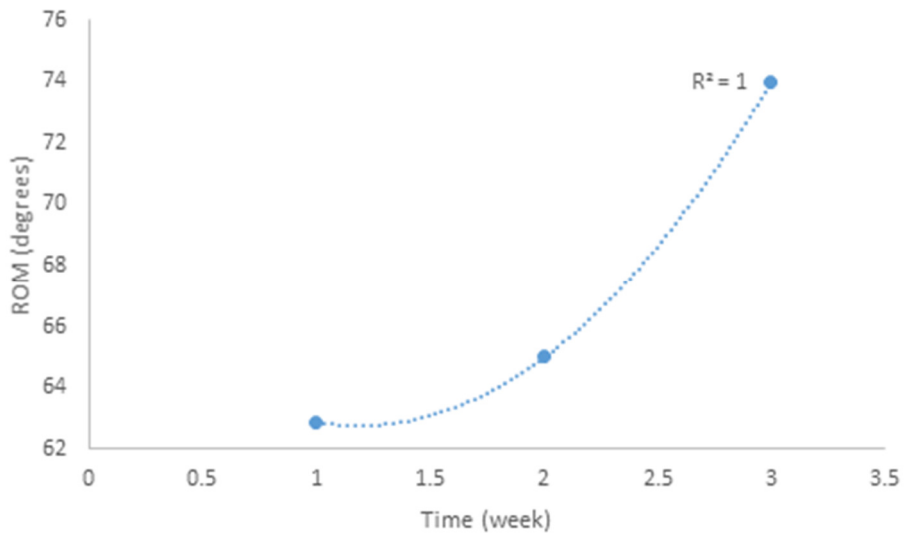


**Figure 13.** Variance of student D’s pre right shoulder extension ROM measurements before Q implementation per week. The polynomial trendline represents an order of two.



**Figure 14.** Variance of student D’s pre left shoulder extension ROM measurements before Q implementation per week. The polynomial trendline represents an order of two.

Student E produced the most consistent trendlines, all of which depicted a steady increase in shoulder extension ROM outcomes over time. Specifically, the left post shoulder illustrated the most drastic increase in ROM outcomes (Figure 15).



**Figure 15.** Variance of student E’s post left shoulder extension ROM measurements before Q implementation per week. The polynomial trendline represents an order of two.

## **Qualitative Results**

### **Student A**

In analyzing the qualitative data recorded for student A, a common habitual pattern amongst student A was mood. Specifically, student A was consistently happy and upbeat while utilizing the Q. Student A consistently smiled throughout the implemented workout regimens. While on the Q, students were allowed to listen to music as an iPad was attached to the device. Student A would especially enjoy singing along to Taylor Swift. However, happiness proved to serve as a neutral theme in relation to ROM measurements. Measurements fluctuated throughout Q implementation, as student A was consistently happy each time while on the Q. Specifically, when comparing the weeks of September 19<sup>th</sup> and September 26<sup>th</sup>, student A's post measurements for the knee, shoulder flexion, and shoulder extension all decreased on September 26<sup>th</sup>. Right and left knee measurements respectively dropped from 149 degrees and 143 degrees, to 126 degrees and 130 degrees. Right and left shoulder flexion respectively dropped from 181 degrees and 171 degrees to 168 degrees and 159 degrees, and shoulder extension dropped from 83.2 degrees and 75.1 degrees to 71.3 degrees and 71.6 degrees.

Another consistent pattern from observation was loose shoulders. Not only was student A's shoulder ROM measurements high, Student A's shoulders were also extremely flexible through manual movement. While measurements fluctuated, loose shoulders contribute to student A's diagnosis of mixed cerebral palsy. This characteristic could possibly account for higher shoulder measurements in relation to knee measurements. Knee joint ROM measurements were consistently low, and student A's legs always felt tight during pre Q measurements.

Furthermore, student A also frequently obtained colds and would often be congested. For instance, on October 19<sup>th</sup>, student A was sick and appeared distressed performing the knee

flexion/basic exercise protocol at 25 rpm. The speed was lowered to 20 rpm, and student A then appeared substantially less distressed. Sickness appeared to act as a negative pattern in correlation with ROM outcomes. For instance, on October 10<sup>th</sup>, it was noted that student A appeared to seem sick, and the following week expressed a cold. ROM measurements for knee extension decreased for both on pre and post measures. The pre right and left measurements on October 10<sup>th</sup> were respectively 118 degrees and 128 degrees, while on October 19<sup>th</sup> they were 112 degrees and 107 degrees. The right and left posts measurements on October 10<sup>th</sup> were respectively 142 degrees and 148 degrees in comparison to on October 19<sup>th</sup> which respectively were 133 degrees and 130 degrees.

Lastly, on October 3<sup>rd</sup>, student A also experienced a seizure while using the Q. While the pre measurements for knee extension were higher on October 3<sup>rd</sup>, following the seizure, post measurements decreased from the previous week. The right and left post measurements on September 26<sup>th</sup> were 126 degrees and 130 degrees respectively, while on October 3<sup>rd</sup> they respectively decreased to 123 degrees and 124 degrees. This possibly indicates that seizures while on the Q demonstrate a negative pattern on post measurements.

### **Student B**

Overall, student B was consistently engaged while on the Q, and always bobbed along to either country or rock music. Student B enjoyed singing along to music while on the Q and would consistently make eye contact. Similarly, student B always appeared alert and engaged during exercise protocols. However, engagement served as a neutral theme, as student B was consistently alert and measurements fluctuated from week to week. There were several instances where student B would initiate transport to the Q. Specifically, on April 8<sup>th</sup>, student B reached out and stood from a seated position on her own. Student B was then assisted in walking to the



Q.

However, student B occasionally resisted the Q, and would kick out the left foot from the lower leg compartment as well as slow the motion of the Q with her left leg. Student B could resist the Q through both arm and leg movements. On April 8<sup>th</sup>, it was noted that student B kicked the left leg out of the machine five times. From weeks of April 8<sup>th</sup> to April 15<sup>th</sup> when student B resisted the machine, post knee extension measurements increased by four degrees on the right, and one degree on the left. Thus, although resistance impacted the consistency of protocol, it served as a neutral theme in regards to ROM outcomes as the 30 minutes of exercise was eventually completed.

Moreover, measures to prevent the lower leg from kicking out included: tightening the straps, inserting foam pieces in the lower leg compartment, and holding student B's leg for the duration of the exercise. Ultimately, all of these implementations failed. The utilization of water shoes proved effective in preventing lower leg release beginning on April 22<sup>nd</sup>. However, while water shoes prevented inhibition of protocol, it did not directly correlate to an increase in ROM measurements. From weeks of April 22<sup>nd</sup> to April 29<sup>th</sup>, the post right knee ROM dropped from 141 degrees to 137 degrees respectively, while the left increased from 134 degrees to 142 degrees. The pre knee extension measurements were higher the week of April 29<sup>th</sup>. These inconsistent results indicate a neutral theme. It is also imperative to consider that the use of the Q overtime could also contribute to an increase in ROM.

### **Student C**

Student C produced overall inconsistent qualitative results regarding mood. Moods varied from sleepy, to irritable, to happy. It was noted that student C was typically more awake and alert in the afternoon. This was due to student C's frequency of seizure episodes, many of which

would prevent a full night of sleep. A few instances occurred where student C would fall asleep while on the Q, such as on April 22<sup>nd</sup>. However, alertness proved as a neutral theme. In comparing April 8<sup>th</sup> and April 22<sup>nd</sup>, there were several instances where student C would smile and giggle during the duration of the exercise. Alternatively, there were also several occurrences of screaming tantrums. Specifically, on March 18<sup>th</sup>, student C exhibited multiple screaming fits, resisted the machine, and appeared very irritable, such that student C did not finish using the Q. Yet, ROM knee extension measurements decreased on March 23<sup>rd</sup> where student C demonstrated multiple tantrums to April 8<sup>th</sup>, where student C was happy, laughing and singing. Ultimately, mood served as a neutral theme in regards to ROM improvement.

Furthermore, student C experienced an episode of multiple seizures while on the Q. On April 15<sup>th</sup>, student C experienced multiple seizures while in the Q and afterwards according to student C's nurse. Student C was extremely irritable after the episode and engaged in screaming fits. After dimming the lights and playing soothing music, student C became relaxed. Measurements were not taken as seizures continued post exercise.

### **Student D**

Student D was relatively consistent in mood while utilizing the Q. Student D was always happy and smiling while performing Q exercises. Student D would also socially interact with those around her. Student D was usually alert and engaged. Student D especially enjoyed singing along to Justin Bieber while on the Q. When asked if student D liked the Q, she responded "yes" on October 10<sup>th</sup>. The student's teacher noted that student D walks scissor-like normally, but improves in walking ability following exercise on the Q.

In comparing September 7<sup>th</sup> where student D appeared happy to September 26<sup>th</sup> where student D appeared strained and unhappy, post shoulder extension measurements increased on

the right about four degrees, while the left increased about nine degrees on September 26<sup>th</sup>. However, the pre shoulder extension measurements on September 7<sup>th</sup> were higher than on September 26<sup>th</sup>. Yet, in comparing knee extension exercises, all knee ROM measurements increased the week of October 3<sup>rd</sup> where student D was happy in comparison to September 26<sup>th</sup> when student D was not. Overall, mood produced inconsistent results in correlation to ROM outcomes, while time and continued use could also play a stronger factor in ROM outcomes.

However, ROM is limited with student D's right shoulder and arm. At times, the right arm would have difficulty following midline cross patterns, especially in preventing the hands from clashing. Additionally, there was also difficulty in placing on a right hand glove, as well as the right hand remaining attached to the hand bar. While student D favors her left side, changes in pre/post ROM measurements fluctuated for both the right and left shoulder. At times, the right produced higher results than the left. On September 26<sup>th</sup>, student D appeared distressed and the speed was decreased from 25 rpm to 20 rpm. Student D was absent on September 12<sup>th</sup>, and ROM measurements were not taken on October 19<sup>th</sup> due to a field trip. Although absent, student D's knee ROM measurements the following week were all higher than the previous. However, all left shoulder flexion and extension measurements dropped. Right shoulder flexion measurements increased, while right post extension decreased and the right pre extension remained about the same. Thus, absences also served as a neutral theme in regards to ROM outcomes.

### **Student E**

Overall, student E was very happy and smiley while on the Q. Student E enjoyed watching *Teenage Mutant Ninja Turtles* on the iPad while exercising. Interestingly, student E would initiate ROM measurements. Student E was aware of the types of measurements performed and when they were completed. Through observation and ease of measurements,

student E was the most mobile of the Spotswood High School group. Student E was very interactive socially while on the Q.

For the majority, student E was always happy, smiling, and engaged while on the Q. Only one instance occurred where student E fell asleep while on the Q, and this occurred on October 19<sup>th</sup>. In comparing ROM measurements from October 19<sup>th</sup>, all shoulder extension ROM measurements were the highest of all recorded measurements. The highest right pre and post knee ROM measurements were also recorded, as well as the post left knee measurement. However, the pre left knee decreased from 131 degrees to 125 degrees. Shoulder flexion produced inconsistent results on October 19<sup>th</sup>, where the pre right shoulder decreased, the left pre and post remained about the same, and the post right shoulder increased. However, it is to be noted that October 19<sup>th</sup> was the last day of recorded measurements, and the longest duration of Q use. Thus, tiredness seemed to not engender a negative impact on ROM as anticipated. On September 26<sup>th</sup>, student E was absent and did not exercise on the Q nor receive ROM measurements. However, absence did not impact ROM results the following week as all knee ROM measurements were higher on October 3<sup>rd</sup> than September 19<sup>th</sup>. Absence again served as a neutral theme in regards to ROM outcomes. However, further research on continuous absences versus sporadic absences should be further researched.

## **Chapter 4: Discussion, Conclusion, Limitations, & Future Studies**

### **Quantitative Discussion**

Ultimately, the Q demonstrates immediate and cumulative post ROM improvements for the knee joint. Positive post ROM results followed intervention, and ROM outcomes continued to increase overtime, indicating that continued use of the Q produces continued positive increase in knee ROM. The largest immediate, change in pre-post ROM was demonstrated in the knee

relative to the shoulder. The knee may attain a greater immediate ROM impact as students are predominately wheelchair-bound and do not receive movement of the lower limbs outside of the Q and physical therapy/physical education. This is an area that should be further studied as to whether the Q better improves ROM at particular joints. In addition to measured substantial positive change from pre to post, positive weekly change was also measured in knee ROM. Incremental increase in isolate pre and post ROM measures was found. In correspondence, leaps in knee ROM data was also observed. The largest leap occurred at week two, and a slight drop followed at week three. It is questioned whether this finding implies a possible plateau effect on knee ROM, and further research should explore this area. The Q engendered “moderately effective” results for both the right and left knee, indicating symmetrical ROM gains. While the Q produced “moderately effective” knee ROM results, it should be noted that students vary in diagnosis and are wheelchair-bound for the majority of their day. Increased Q usage could produce more favorable outcomes for knee ROM.

However, results fluctuated at the individual level as large SD values were observed. The degree of ROM improvement varied per subject. Although it is unclear, individual variation possibly indicates that the Q provides varying ROM outcomes depending on the differing diagnoses, capabilities, and likelihood of unplanned events. Furthermore, knee ROM sustainability overtime continues to be questioned and should be further researched. As a retention period was not implemented where no intervention took place, sustainability could not be analyzed. In correspondence, trendlines were unable to be analyzed due to unreliability of trendline order. This is likely because more data points were collected for the knee joint, indicating that great fluctuation overtime engendered an unreliable trendline. While sustenance is still uncertain, the hypothesis predicted a weekly, steady increase in ROM following Q

intervention, and cannot yet be fully accepted nor refuted as only an immediate and cumulative pre-post benefit was measured.

Moreover, the shoulder joint produced similar results to the knee joint, but slight variations occurred amongst shoulder flexion and extension. Both shoulder flexion and extension produced positive trends amongst immediate and cumulative ROM effects. An increase in ROM followed post intervention, as well as continued overtime with use. An immediate, positive increase in ROM was observed in post measures. However, positive post shoulder ROM measures were lower in comparison to the knee joint, and the shoulder extension ROM measures produced the lowest change in means. This may possibly indicate that Q usage produces larger, immediate ROM effects in the knee and shoulder flexion relative to shoulder extension. Additionally, average weekly change was also observed, although shoulder extension produced higher and more consistent results in comparison to shoulder flexion. While shoulder extension illustrated incremental weekly increases, shoulder flexion depicted both incremental increases, as well as regressions.

In correspondence, both shoulder ROM outcomes demonstrated leaps in data. Shoulder flexion ROM measures indicated the largest leap at week two, followed by a slight drop off in week three. Similar to the knee, this may possibly indicate a plateau phase and should be further researched. Shoulder extension differed in that the largest leap in data was recorded at week three, indicating that continued use of the Q produced continued, increased ROM benefits. Shoulder flexion ROM outcomes exuded high effectiveness for the right shoulder and moderate effectiveness for the left shoulder, while shoulder extension produced moderate effectiveness for the right and minimal effectiveness for the left. This illustrates possibly that the Q engenders a larger impact on shoulder flexion ROM outcomes, while also highlighting a discrepancy

amongst right and left shoulder outcomes. Further research needs to analyze the disparity between shoulder flexion and extension, as well as differences in the right and left shoulder.

Lastly, sustenance again could not be determined as a retention period of no Q intervention was not implemented. Further research is required to explore this area. While trendlines were overall reliable, their fluctuation continues to question sustainability. It is also possible that shoulder trendlines were reliable in relation to knee trendlines due to fewer data points. This could result in a lower likelihood of fluctuation amongst data points. In regards to an individual analysis, great variation occurred amongst students due to differing diagnoses, abilities, and unexpected events. High SD variances, as well as differences in degree of improvement possibly indicates that the Q produces varying ROM outcomes depending on the individual. Thus, while the Q produces beneficial results in terms of group trends, its degree of positive impact varies at the individual level.

Ultimately, the Q produces immediate and cumulative ROM outcomes across all three variables. At the individual level, ROM outcomes varied due to differing diagnoses, abilities, and unexpected events. For the majority, analysis depicts incremental weekly increases in ROM, improvement from baseline measures, and leaps in data across all three variables. Further research should analyze a possible plateau effect in the knee and shoulder flexion ROM following continued use. While immediate and cumulative impacts were measured, sustained impact continues to be questioned. Further research should implement a retention period to analyze the sustained impact on ROM outcomes. Thus, while an immediate and cumulative impact resulted, the hypothesis cannot yet be fully accepted nor rejected.

### **Qualitative Discussion**

Ultimately, the majority of students appeared very happy while on the Q and seemed to

enjoy using it each day. Music served as a motivator for the subjects in completing the intervention. Additionally, an increase in social interaction occurred while subjects utilized the Q. Social interaction appeared higher during and after intervention in comparison to before intervention. Students interacted with student volunteers, fellow classmates, nurses, and teachers. Future research should analyze the area of social interaction more in-depth to determine its impact following Q intervention. All students were typically engaged and alert during exercise protocols. When asked if the teacher at Spotswood noticed any impacts from the Q, he claimed that the students' moods improved following use of the Q. Thus, it is likely that the Q serves as a recreational and social activity for the students. However, level of engagement, mood, and alertness acted as neutral patterns and did not directly correlate with an increase in ROM measurements.

On the alternative, medical issues such as sickness and seizures engendered a negative impact on ROM outcomes. Students appeared more distressed during exercise when sick, and exercise protocol was thus altered. Additionally, absence from protocol served as a neutral theme and overall produced inconsistent results. Resistance to the Q also acted as a neutral theme, as the student eventually completed the duration of 30 minutes. Correspondingly, another pattern observed through manual ROM measurements across all students was an ease in obtaining post ROM measurements following exercise. Students physically felt tighter during the pre ROM measurements in comparison to post ROM measurements. Post measurements were thus easier to obtain in comparison to pre measurements.

### **Study Limitations**

There were a multitude of factors in this study that served as limitations, influencing the overall outcomes. Delimitations included time constraints, resource constraints, as well as a



small sample size. A timeline abided by the Honors College through James Madison University, as well as a full time class schedule impacted the duration and length of the study. Due to schedule constraints, Spotswood data was consistently recorded on Monday mornings from eight to eleven, and Montevideo data was consistently recorded on Friday mornings from eight to eleven. On a few occasions, data was recorded on Wednesday mornings from eight to eleven. Data was never collected in the afternoon. A small sample size correlated with resource constraints, as the Q device runs around \$20,000 and has only been implemented in several Virginia school programs, thus limiting the size of the study.

In addition to delimitations, several threats to internal validity were also present. One of the most predominant threats involved instrumentation. Measuring the subjects' ROM while in the Q or their wheelchair possibly inhibited the full ROM as these objects served as barriers impeding movement—particularly of the shoulder joint. Inconsistent location of measurements was mainly attributable to time restraints and comfort-level of the subject. Additionally, the ROM measurements taken at Montevideo Middle School from the end of January 2016 to the beginning of March 2016 were deemed inaccurate due to inaccurate usage of a manual goniometer. Researcher bias is also a possible factor, as this was not a blind study, as well as the researcher was aware of the previous results from Dr. Thomas Moran's study.

Moreover, subject selection also acts as a threat to internal validity, as subjects were not randomized. Due to resource constraints, the study was limited to the subject populations with access to the Q. Additionally, the history of subjects also possibly influenced results as unexpected events such as absences, seizures, and illness could not be controlled. Each of these events possibly impacted the outcome of ROM results. A factor not controlled for in this study was the diagnosis of cerebral palsy as subjects differed in a mixed, high tone, or low tone

diagnosis. The students' differences in motor neuron and muscle spindle ability could thus in turn impact ROM outcomes, and the influence of the Q regimen specific to each subject.

Lastly, threats to external validity involves a skewed subject pool. The five subjects were predominantly female, with only one male utilized in the study. The male subject studied produced the most inconsistent results in regards of uncontrolled events such as absences, fits, and seizures. This limits the generalizability of this study to a cerebral palsy population.

## **Conclusion**

Ultimately, the results found in this study correlate with previous studies, particularly the Q study performed by Dr. Thomas Moran. Similar to Dr. Thomas Moran's study, significant Q ROM outcomes were found following a pre-posttest (Dr. Moran, 2014). Dr. Thomas Moran found significant increases in ROM for the shoulder and knee, as well as the elbow, hip, and ankle (Moran, 2014). He also obtained similar results that continue to question the sustenance of the Q, suggesting further research in this area (Moran, 2014). This study also correlates to the gymnastics and physical activity studies, as they both produced increased ROM results as well, but differs in that these studies also promoted sustained improvements, such as overall motor performance, strength, balance, etc. This study differs in regards to the swimming intervention in that knee ROM was also benefitted, whereas swimming only benefitted shoulder ROM. Thus, the Q provides promising results in regards to improving joint ROM, especially in severely orthopedically impaired populations. However, further research on the Q is necessary in regards to sustained ROM benefits. In sum, this study serves as a pilot study and requires further research, particularly as it utilized a small study sample of five individuals.

## **Future Studies**

In recommendations for future studies, there are several areas in need of improvement in

regards to precision of methodology, as well as several areas that could provide further insight on the efficiency and effectiveness of the Q.

First, in improving the precision of measurement and outcomes, future studies should record ROM measurements on different days and at different time periods. For example, ROM measurements taken on a Monday following a relatively sedentary weekend could possibly produce lower ROM results in comparison to a Wednesday afternoon. Comparing different days and times could indicate whether the Q produces sustaining ROM outcomes. In addition, an error in methodology in this specific study involved recording the highest ROM measurement achieved. However, in order to avoid researcher bias and to ensure accuracy in results, future measurements should be recorded minimally three times and averaged. Lastly, latency periods should also be implemented in protocol, as measurements taken before and post latency periods could also indicate sustainability. For example, in this specific study, do ROM measurements recorded for the students before winter break match measurements taken immediately after?

Furthermore, there are many possible areas of future research in regards to analyzing the Q's ability to improve ROM. One in particular that was not executed in this study is to compare the effectiveness of varying exercises. For instance, when implementing the knee flexion exercise instructed in the Q user manual, record as to whether knee ROM measurements increase in response to this exercise protocol (Appendix E). Comparing specific shoulder and knee exercise protocols, and their ROM outcomes can demonstrate whether they are more effective in producing favorable ROM results in comparison to the alternating reciprocal pattern protocol (Appendix D). Additionally, another interesting research area involving the Q could include comparing the machine to a physical therapist. Comparing whether the exercise protocol through the Q or the physical therapist produces increased, similar, or worse ROM measurements would

evaluate the practicality of the Q. These results could possibly indicate whether it is financially and practically appropriate to integrate the Q in healthcare facilities, hospitals, rehabilitation centers, etc. Results may also provide useful information to physical therapists, as the Q could be implemented in a therapy regimen. Lastly, in specific analysis of cerebral palsy, analyzing whether high or low tone types of cerebral palsy are improved by certain exercises could also produce insightful information.

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## Appendix A

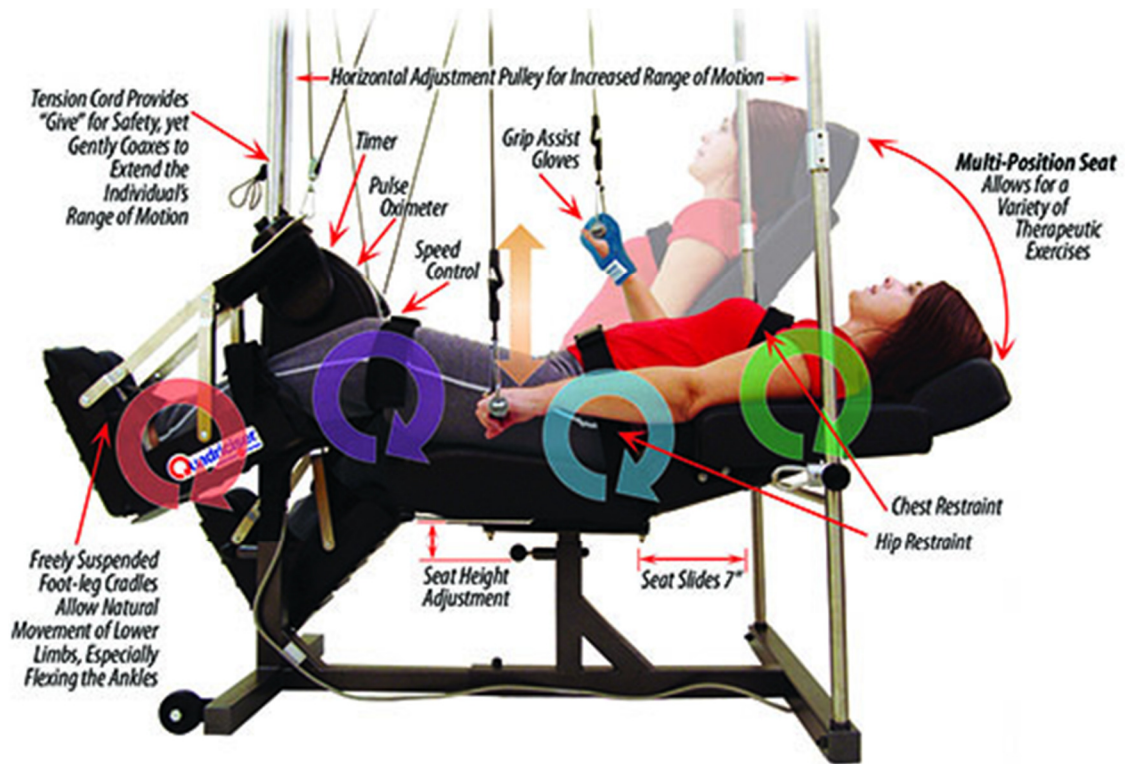
The Q device during the exercise, PNF. The individual is shown wearing Velcro gloves to assist in stable gripping of the hand bars.





## Appendix B

Depiction of arm extension tension cords on the Q.



## Appendix C

Illustration of the top bar and altering hand/arm positioning. This bar ranges from position one (front) to position eight (back). Additionally, the bottom bar is pointed out, and here long, metal

bars can attach to adjust attached resistance cords. These cords clip under the Q boot compartments and attach to a specified position on the bar depending on amount of tension.



## Appendix D

Q manual instructions on alternating reciprocal pattern.


**GENERAL QUADRICISER SET-UP**

**Quadriciser.**  
motorized P/A therapy  
*Movement equals Improvement!*

For general use the set up for the Quadriciser is very simple.

1. Position the user in the seat making sure that the knees do not touch the foot cradle stabilizer at any time during the rotation.
2. Make sure the lap belts is secured, and that the foot cradle strapping is secured.
3. Position **LHS** and **RHS** slightly forward of the users shoulder position. Adjust the hand height only as high as is comfortable for the user.
4. Set the timer to the desired session duration.
5. Set the direction to either forward or reverse.
6. Set the speed to a level where the user is comfortable.

Note: You may want to reference the Extension Bars page IX and the Strap Anchor Point page XII.



NOTICE: Quadriciser® Corporation makes no medical claim nor warrants any results from the use of the Quadriciser® or equipment. Individuals should consult their own physicians before using this equipment or use at their own risk. Results may vary with usage.

## Appendix E

Q manual instructions on knee flexion set-up.

**KNEE FLEXION**

**Quadriciser**  
motorized P/A therapy  
*Movement equals Improvement!*

**TO INCREASE FLEXION:**

1. Chair Position: Upright/slightly reclined
2. Hook one of the extra extension cords from under the heel of the foot cradle ① to the back of the 1/4" plate under the seat. ②
3. Lower seat height for more knee flexion. Make sure the knee does not come into contact with the foot cradle at any time during the rotation. (See Page IV.)
4. Fasten seat belts (lower belt holds pelvis in place).
5. Use foam foot wedge for more dorsiflexion. (See Page 01.)
6. Use gait wedge if necessary.
7. Choose direction: Forward or Reverse



**Caution:** Stop machine before applying tension cords. Make sure they are secure and slowly rotate one full cycle prior to increasing the speed.

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## Appendix F

Q manual instructions on shoulder flexion set-up.

**SHOULDER FLEXION**

**TO INCREASE FLEXION:**

1. Chair Position: Reclined at 90 degrees
2. Start **L-H5** and **R-H5** at **1** position on top bar.
3. Place hands on the hand grips, palms facing out. Tighten cords to increase hand elevation.
4. **L-C2** and **R-C2** are connected to **SS Bar**.
5. Move **L-H5** and **R-H5** from **1** towards **8** as far as the user can tolerate.




**SHOULDER FLEXION**

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## Appendix G

Q manual instructions on crossing midline set-up.

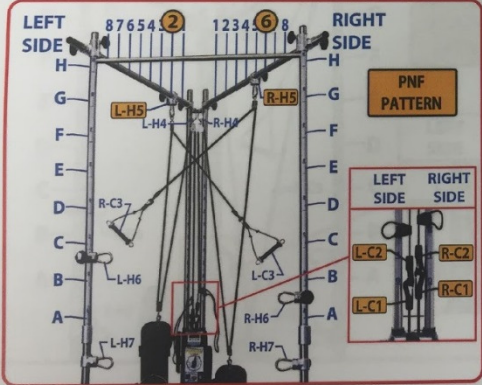




*Movement equals Improvement!*

### PNF PATTERN

**TO INCREASE ARM EXTENSION:**

1. Chair Position: Upright to slightly reclined
2. Have user grasp hand grips with the opposite hands, right hand to left grip and left hand to right grip.
3. Position **L-H5** at **2** on top bar and **R-H5** to position **6** on the top bar.
4. Gradually tighten cords to increase range of motion.
5. **L-C2** and **R-C2** are connected to **L-C1** and **R-C1**.
6. If hand is contracted, hook a small tension cord from the **SS Bar** to a small eye hook on the hand grip.





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