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The quadriciser's effect on range of motion and upper body motor control in children with mixed quadriplegia due to chromosomal disorders

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The Quadriciser's Effect on Range of Motion and Upper Body Motor Control in Children with
Mixed Quadriplegia due to Chromosomal Disorders

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

by Jillian Paige Serigano

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

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PUBLIC PRESENTATION

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Table of Contents

Acknowledgements	1
List of Tables	2
List of Figures	3
Abstract	4
Introduction	5
Methods	11
Results	14
Discussion	24
Conclusions	26
Appendices	30
References	35

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List of Tables

Table 1. Subject one change in means from data points from weeks 1-10.

Table 2. Subject two change in means from data points from weeks 1-10.

Table 3. Change in levels from pre intervention to post quadriciser use from week one in subject one.

Table 4. Change in levels from pre intervention to post quadriciser use from week one in subject two.

Table 5. Change in range of motion values between pre-intervention to week 10 for subject one.

Table 6. Change in range of motion values between pre-intervention to week 10 for subject two.

Table 7. Non-overlapping data point effectiveness for subject one.

Table 8. Non-overlapping data point effectiveness for subject two.

Table 9. Change in means from data points from weeks 1-10.

Table 10. Change in levels from pre intervention to post quadriciser use on week one.

Table 11. Change in reach task values between pre-intervention to week 10.

Table 12. Non-overlapping data points.

List of Figures:

Figure 1. Subject using the upper body portion of the quadriciser.

Figure 2. Subject completing the timed reach task.

Figure 3. Pre and post range of motion measurements of subject one's right shoulder for weeks 1-10.

Figure 4. Pre and post range of motion measurements of subject one's left shoulder for weeks 1-10.

Figure 5. Pre and post range of motion measurements of subject two's left knee.

Figure 6. Pre and post range of motion measurements of subject two's right knee.

Figure 7. Pre and post reach task time for subject one.

Figure 8. Pre and post reach task time for subject two.

Abstract:

PURPOSE: The purpose of this experiment is to determine the effects that the quadriciser has on range of motion and upper body motor control in children with mixed quadriplegia due to chromosomal deletion disorders. **METHODS:** Two subjects with different chromosomal deletion disorders participated in this study. They completed a 10-week passive exercise intervention using the quadriciser. Range of motion of the elbow and shoulder were taken pre and post quadriciser use for both subjects. For one subject, hip and knee measurements were also taken. Both subjects also completed a timed reach task pre and post quadriciser use to test motor control. **RESULTS:** The only consistent changes in range of motion between pre and post quadriciser use were in one subject's right shoulder and the other subject's left knee. All other changes in range of motion showed some improvement, but were inconsistent. Reach task time generally increased post quadriciser use for one subject showing a decrease in task speed. The other subject did not experience any changes in reach task time. **CONCLUSIONS:** The quadriciser may temporarily improve range of motion in people with mixed quadriplegia. However, there is no evidence to support that it helps to improve upper body motor control.

Key Words: quadriciser, mixed quadriplegia, passive exercise, range of motion, fluidity of motion

Introduction

The human genome consists of 23 pairs of chromosomes, which contain all of the genetic material needed to create and sustain life (National Institutes of Health, 2017). Each chromosome consists of DNA that contains the codes for various proteins vital to human structure and function (National Institutes of Health, 2017). There is a vast variety of diseases and disorders that can occur in humans if a chromosome is damaged, absent, or too abundant. While some chromosomal disorders, like Down syndrome, are relatively common, others are far rarer.

Chromosomal disorders

1p36 chromosome 1 deletion syndrome is an uncommon disorder; it occurs in an estimated 1 in 5,000 to 10,000 live births (National Institutes of Health, 2017). The rate of incidence for this disorder is the same for all people regardless of gender or ethnicity (Gajecka, Mackay, Shaffer, 2007). 1p36 chromosome 1 deletion syndrome is caused by a deletion that occurred either due to a random event during sperm or egg production or during early fetal development (National Institutes of Health, 2017). While the size of the deletion can vary among individuals, many of the symptoms remain generally consistent for those affected (Shaffer & Heilstedt, 2002). Nearly all people with 1p36 chromosome 1 deletion syndrome experience moderate to severe intellectual disabilities and impaired or nonexistent speech (Gajecka et al., 2007). Additionally, most have distinct facial features such as deep set eyes, a flat bridge of the nose, and a pointed chin (National Institutes of Health, 2017). Other symptoms including structural abnormalities of the heart or brain, seizures, hypotonia, dysphagia, skeletal abnormalities, and hearing loss may or may not be present depending on the size and severity of the deletion (Shaffer & Heilstedt, 2002).

In a 2008 study that examined 60 people with 1p36 chromosome 1 deletion syndrome, 71% of those affected had a heart defect, 44% experienced seizures, and 95% had low muscle tone (Battaglia et al., 2008). While 26% were able to walk independently and 76.7% were able to sit without support, others with more severe cases were nonambulatory and unable to sit or stand without assistance (Battaglia et al., 2008). Severe hypotonia, decreased muscle tone, especially in the trunk and upper body, can lead to decreased stabilization making it more challenging to sit upright (Gogola, Saulicz, Kuszewski, Matyja, Mysliwiec, 2014). Because core stabilization is vital to movement, people with poor trunk support have a more difficult time initiating movement and have poorer quality of movement (Bouisset, 1991).

Low muscle tone can be the result of numerous diseases and disorders that affect the nervous system (Naidoo, 2013). Like 1p36 chromosome 1 deletion syndrome, abnormalities in chromosome 9 can lead to hypotonia and poor trunk stability. A 9q22.3 microdeletion is even more uncommon than 1p36 deletion syndrome; only about three dozen cases have been reported in medical literature (National Institutes of Health, 2017). Because this condition is so rare, there is limited research on the effects of this disorder. Depending on the case, 9q22.3 microdeletion is either inherited by an unaffected parent, caused by a deletion that occurred during egg or sperm development, or occurs during early fetal development (National Institutes of Health, 2017). People affected with disorder typically display severe intellectual disabilities and motor impairments that interfere with the ability to sit, stand, and walk (National Institutes of Health, 2017). Low muscle tone and a lack of postural support inhibits the ability to hold the trunk upright in people with disorders that affect the nervous system like a 9q22.3 deletion (Gogola et al, 2014). Like some individuals with 1p36 chromosome 1 deletion syndrome, people with a

9q22.3 microdeletion with hypotonia may have poorer quality of movement due to the lack of core stability (Bouisset, 1991).

Muscle Tonicity

Individuals who have low muscle tone do not necessarily have it throughout their entire body. Mixed quadriplegia is when an individual experiences hypotonicity in some parts of the body and hypertonicity, high muscle tone, in other areas. High muscle tone is, in most cases, caused by hyperexcitability of spinal reflexes (Sheean & McGuire, 2009).

Increased muscle tone as a result of over activation of spinal reflexes causes increased involuntary muscle contractions and spasms. The muscle then tends to feel hard or stiff and to resist stretch and lengthening (Calderon-Gonzalez, Calderon-Sepulveda, Rincon-Reyes, Garcia-Ramirez, Mino-Arango, 1994). As a result, range of motion in joints controlled by affected muscles tends to be lower in people with hypertonicity. Additionally, muscle strength and control is reduced due to spasticity (Ulla-Britt & Lexell, 2012). This can lead to poor trunk stability, which can negatively impact the ability to initiate and complete voluntary movements (Sheean & McGuire, 2009).

Similarly, low muscle tone also results in reduced strength; people with hypotonicity typically have a harder time maintaining upright posture and experience increased fatigue in working muscles (Kumin, Chapman Von Hagel, Chapman Bahr, 2001). Because the muscles are weaker, people with hypotonicity sometimes have hindered muscle control and fluidity of motion. In addition to decreased strength, people with low muscle tone are often hypermobile. Range of motion in joints controlled by low tone muscles is greater than range of motion in joints with muscle tone within normal limits (Kumin et al., 2001).

Passive Exercise

Passive exercises may provide some improvements in strength to people with high or low muscle tone and improvements in flexibility and range of motion in people who have hypertonicity. While the effectiveness of passive exercise has not been extensively studied in people with mixed muscle tone and poor motor control, one study observing spasticity and range of motion in people with spastic hemiplegia found that passive upper arm exercise significantly improved the subjects range of motion in the shoulder and wrist joints (Shin et al., 2012). However, there was no improvement to the range of motion in the elbow joint, and there was no significant decrease in spasticity among the subjects (Shin et al., 2012). In another 2008 study, assisted movement with enhanced sensation was used on the ankle or wrist of chronic stroke patients with motor deficits. Most subjects experienced small (less than 10%) increases in strength. A joint positioning test, which measured joint positioning control and active range of motion, showed a 119% increase for subjects treated for lower extremity paresis and a 73% increase for subjects treated for upper extremity paresis (Cordo et al., 2008). Similarly, a 2012 study looking at the effect of a passive motion intervention of the neck on range of motion, strength, and muscular endurance concluded that there were significant increases in all measures (Cho, Jeong, Hwang 2012).

While many studies suggest that there are strength and range of motion benefits associated with passive exercise, some show that it does not produce any significant long term benefits. Continuous passive motion in addition to physiotherapy did not provide any long term benefits in range of motion or functional abilities in patients who underwent total knee arthroplasty (Lenssen, 2008). In a similar study involving total knee replacement patients, continuous passive motion in addition to physical therapy did not show any short term or long

term improvements in range of motion when compared to physical therapy alone (Herbold et al., 2014). While passive motion treatments have not been beneficial in total knee replacement patients, they have been effective in other populations (Cho et al., 2012; Cordo et al., 2008; Shin et al., 2012). It is possible that a passive motion intervention could benefit people with mixed quadriplegia due to chromosomal disorders.

Quadriciser

The quadriciser is a relatively new piece of exercise equipment that engages the participant in passive exercise. It is intended to be used by people with limited physical abilities with the goal of improving strength, motor control, and range of motion. Participants sit in the machine with hands and feet attached to the foot pedals and the grip assisted gloves (Quadriciser Corporation, 2000). The quadriciser then passively moves the user through a full range of motion by moving the legs in a cycling motion and by pumping the arms overhead. As the machine moves, users actively contribute to the motion at the best of their ability. The quadriciser has been used by people with a wide range of disabilities and diseases including cerebral palsy, chronic obstructive pulmonary disease, muscular dystrophy, and multiple sclerosis (Quadriciser Corporation, 2000).

A pilot study conducted in 2014 observed the changes in range of motion in 12 subjects with various orthopedic impairments following an eight week quadriciser exercise protocol (Moran, 2014). Subject diagnoses included cerebral palsy, arthrogryposis, stroke, and acari syndrome. All subjects experience muscle tone outside of normal limits due to their disorders. Each subject used the quadriciser for one hour per exercise session. The revolutions per minute (RPM) varied depending on the subjects' diagnoses, but the exercise pattern protocol, knee flexion, proprioceptive neuromuscular facilitation (PNF), and overhead extension, was the same

for all subjects. Range of motion measurements were taken pre and post quadriciser use in the shoulder, elbow, hip, knee, and ankle. On average, each subjects' range of motion improved for all joints measured between pre intervention to post week eight (Moran, 2014). However, subjects with high muscle tone had greater improvement than subjects with low tone. The only range of motion measurements that were changed statistically significantly were the right shoulder and the left and right hips (Moran, 2014).

The quadriciser study also recorded changes in subjects' functional gait before and after exercise sessions. Fluidity of motion was determined by the number of heel strikes the subject performed when walked a distance of 30 feet (Moran, 2014). The number of heel strikes increased statistically significantly after quadriciser use (Moran, 2014). This finding suggests that using the quadriciser may improve subjects' fluidity of motion.

This pilot study provides initial evidence that the quadriciser has a positive impact on range of motion and fluidity of movement. The benefits of using the quadriciser in children with 1p36 deletion syndrome or a 9q22.3 deletion have not yet been studied. Passive exercise may mitigate the physical impairments associated with these deletion disorders. It has the potential to increase flexibility, range of motion, muscular strength, and, subsequently, improve motor control (Quadriciser Corporation, 2000).

Methods:

Subjects

Two middle school students participated in this study. One subject (subject one) has a 9q22.3 deletion, and the other (subject two) has chromosome 1p32 deletion syndrome. Both subjects experience mixed quadriplegia and have limited motor control and cognitive function. Subjects are between the ages of 11 and 13 years and are students at Montevideo Middle School in Harrisonburg, Virginia.

Experimental Design:

The study was a single subject design collecting pre-post measures across a 10-week intervention. Both subjects used the quadriciser for 30 minutes per day, the amount of time allotted in their class schedule, Monday through Friday. One subject (subject one) only used their upper body on the quadriciser due to potential safety concerns with the lower body exercise. The other subject (subject two) used both their arms and their legs from for weeks one through seven. A small abrasion developed on subject two's foot preventing lower body use for weeks eight through ten. The children's schoolteacher or TA supervised all exercise on the quadriciser.



Figure 1: Subject using the upper body portion of the quadriciser

Data were collected at the start of the study and every Monday morning for 10 weeks. Each Monday morning data were collected before and after the subject used the quadriciser for 30 minutes. The quadriciser intensity setting was kept at 30 rpm throughout the duration of the study for subject two. Subject one was set at 20 rpm for weeks one through four and 30 rpm for weeks five through ten. Revolutions per minute were decided based on the subjects' comfort level and exercise tolerance. The arm exercises changed during the 10 weeks to facilitate variations in protocol for participant range of motion. Both subjects performed vertical shoulder flexion for weeks one through five. Subject two performed horizontal shoulder flexion for weeks six through ten. Subject one did not follow protocol and continued with vertical shoulder flexion until week 10 because of safety concerns resulting from the subject's spasticity.

Pre and post tests were performed on range of motion and an object reach task. Range of motion was recorded at the elbow and shoulder for both subjects. Additional knee and hip measurements were taken for subject two because they used their lower body on the quadriciser. All measurements were taken by the primary researcher using a goniometer.

For the object reach task, subjects sat in a chair and were instructed to reach and grasp an object that was placed in front of them. Video recordings using a laptop were taken to document the quality of the movement. Time to retrieve the object was recorded from video analysis. Data were analyzed to determine acute changes in time to grab the object before and after exercise and long-term changes over the course of the ten weeks. Both subjects continued the same physical therapy treatments that they were receiving prior to the start of the study throughout the 10-week intervention. The physical therapist and the type and amount of treatment remained constant.



Figure 2: Subject completing the timed reach task.

Statistical analysis

Data analysis was done using a single subject design. Single subject analyses included changes in means between pre and post measurements, change in levels from pre intervention to post quadriciser use from week one, changes in values before intervention and post quadriciser use for week 10, and non-overlapping data points (Kazdin, 2011).

Results:

Range Of Motion

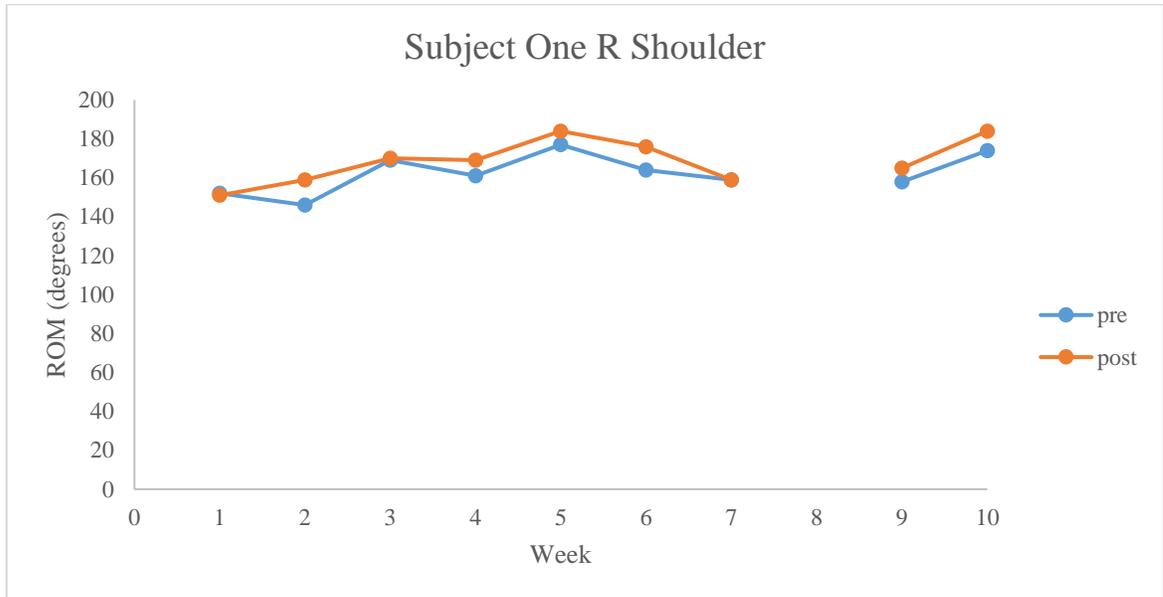


Figure 3: post measurements were consistently greater than the pre measurements. Range of motion improved from 152° to 184° between pre intervention and week 10.



Figure 4: Range of motion in subject one's left shoulder did not increase consistently.



Figure 5: Post measurements for range of motion were consistently higher than measurements taken before quadriciser exercise. Data missing for weeks two and four due to subject's absence.

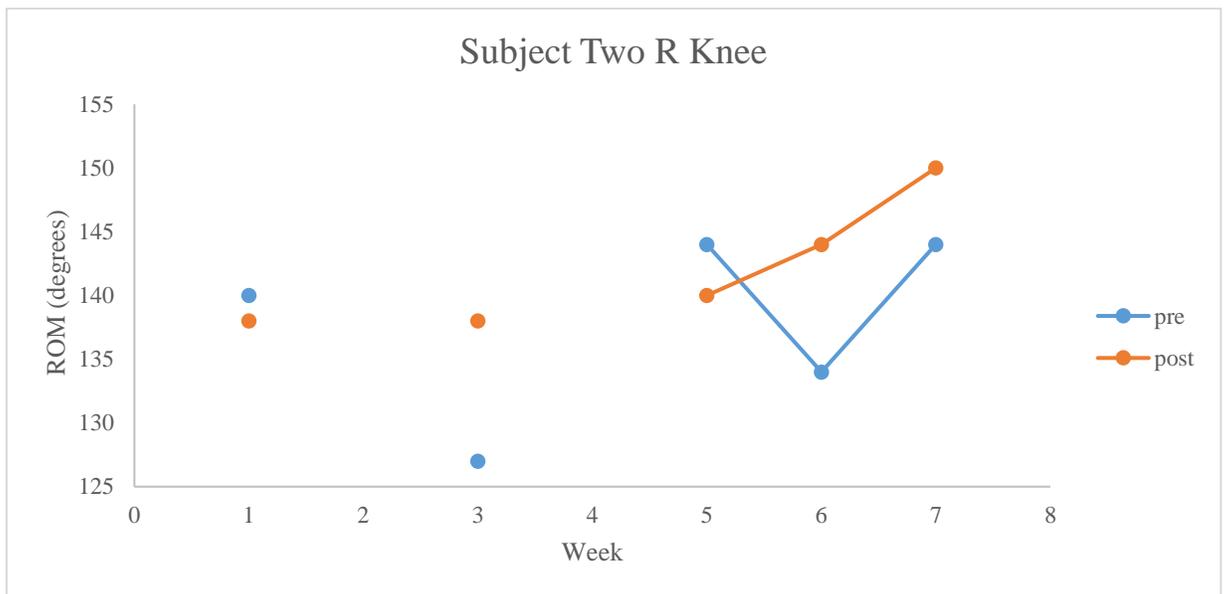


Figure 6: Pre and post measurements for range of motion. Data missing for weeks two and four due to subject's absence.

Subject one's right shoulder and subject two's left knee showed the most consistent increase between pre and most measurements each week. In both subject one's right shoulder and subject two's left knee, the post measurements were consistently higher than the measurements taken before quadriciser use, which shows an increase in range of motion.

However, these changes were only observed unilaterally. The range of motion in subject one's left shoulder and subject two's right knee did not increase as consistently after quadriciser use.

Table 1: Subject one change in means from data points from weeks 1-10

Subject one			
	Pre mean	Post mean	Change in mean
L elbow	176.8°	180°	3.1
R elbow	180°	180°	0
L shoulder	164.4°	167.8°	3.4
R shoulder	162.2°	168.5°	6.3

Table 2: Subject two change in means from data points from weeks 1-10

Subject two			
	Pre mean	Post mean	Change in mean
L elbow	180°	180°	0
R elbow	179.4°	180°	.625
L shoulder	174.7°	182.6°	6.87
R shoulder	176°	181.5°	5.25
L knee	141°	146.2°	5.2
R knee	137.8°	142°	4.2
L hip	113.25°	145°	11.75
R hip	126.25°	144°	17.75

* Values for lower extremity means are from weeks one through 7

On average, the range of motion in all joints improved or stayed the same for both subjects. Some change in means were large, like subject two's left and right hips, which increased 11.75 degrees and 17.75 degrees respectively. Other changes were less dramatic. For example, subject two's range of motion in the right elbow only improved by an average of .625 degrees. The only values that stayed the same were subject one's right elbow and subject two's left elbow. Both subjects' elbows were consistently measured at 180 degrees, which is a full range of motion.

Table 3: Change in levels from pre intervention to post quadriciser use from week one

Subject one			
joint	Pre	post	change
L elbow	152°	180°	28°
R elbow	180°	180°	0°
L shoulder	156°	175°	19°
R shoulder	152°	151°	-1°

Table 4: Change in levels from pre intervention to post quadriciser use from week one

Subject two			
Joint	Pre	Post	Change
L elbow	180°	180 °	0
R elbow	175 °	180 °	5
L shoulder	176 °	182 °	6
R shoulder	145 °	178 °	33
L knee	136 °	141 °	5
R knee	140 °	138 °	-2
L hip	121 °	--	--
R hip	110 °	--	--

*Post data for L and R hips were not gathered due to time constraints.

Change in levels from pre intervention to post quadriciser use for the first time shows improvements in range of motion. Range of motion in subject one's left elbow and left shoulder, and subject two's right shoulder show large increases after first time quadriciser use. However, these initial increases were not equal bilaterally. While the range of motion in subject one's left elbow and left shoulder increased 28 degrees and 19 degrees respectively, the range of motion in their right elbow did not change. Furthermore, range of motion decreased one degree in their right shoulder. Subject two's right shoulder increased by 33 degrees, but their left shoulder only increased by six degrees. However, the left shoulder range of motion did reach 182 degrees, which reflects slight hyperextension. Other values for range of motion show little difference pre and post use during week one.

Table 5: Change in range of motion values between pre-intervention to week 10.

Subject one			
	Pre intervention	Post Week 10	Change
L elbow	152°	180°	28°
R elbow	180°	180°	0°
L shoulder	156°	182°	26°
R shoulder	152°	184°	32°

Table 6: Change in range of motion values between pre-intervention to week 10.

Subject two			
	Pre intervention	Post Week 10	Change
L elbow	180°	180°	0°
R elbow	175°	180°	5°
L shoulder	176°	188°	12°
R shoulder	145°	189°	44°
L knee	136°	150°	14°
R knee	140°	150°	10°
L hip	121°	176°	55°
R hip	110°	175°	65°

* Changes are for pre intervention to week seven for lower limb range of motion of subject two.

All values for range of motion in both subjects either increased or remained the same from pre intervention to post quadriciser use on week 10. Subject one's range of motion improved substantially in all joints except for the right elbow, which reflected no change. Their left elbow, left shoulder, and right shoulder improved by 28 degrees, 26 degrees, and 32 degrees respectively. No changes were observed in the right elbow, but the elbow was at full range prior to the intervention. The range of motion in subject two's right shoulder and both hips also increased substantially. The net increases highlight the cumulative effect that a 10-week quadriciser intervention can have on range of motion.

However, there were fluctuations in improvement for both subjects' range of motion in their left and right shoulders and in subject two's knees and right hip from week to week. Some weeks the range of motion would increase after quadriciser use, and some weeks it would decrease. This shows that while there is a net cumulative effect, the increases in range of motion are not always consistent week to week.

Table 7: Non-overlapping data point effectiveness in subject one

Subject one			
	non-overlapping data points	percent	effectiveness
L elbow	17/17	100%	highly
R elbow	no change	--	--
L shoulder	15/17	88%	moderate
R shoulder	15/17	88%	moderate

* Subject one's right elbow was measured at 180° every week pre and post quadriciser

Table 8: Non-overlapping data point effectiveness in subject two

Subject two			
	non-overlapping data points	percent	effectiveness
L elbow	No change	--	--
R elbow	16/16	100%	highly
L shoulder	13/16	81%	moderate
R shoulder	16/16	100%	highly
L knee	7/9	77% %	moderate
R knee	4/9	44%	not effective
L hip	8/9	88%	moderate
R hip	8/9	88%	moderate

* Subject two's left elbow was measured at 180° every week pre and post quadriciser.

Analysis through non-overlapping data points, the percent of values that are greater than the pre-intervention value, showed that the only measures where the intervention was not effective was subject two's right knee. For all other measures, the intervention was either highly or moderately effective in both subjects.

Reach Task

Subject one's reach task time was consistently higher after using the quadriciser than it was before. This means that subject one was generally slower after using the quadriciser. Subject two's reach task time was inconsistent. Some weeks they were faster before using the quadriciser, and others they were slower.

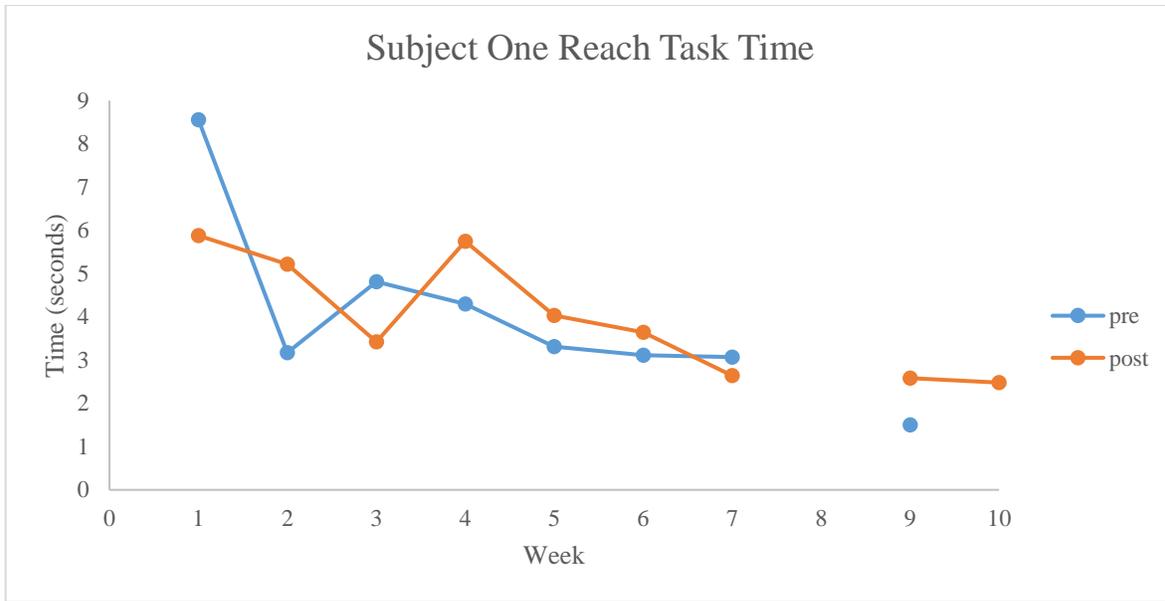


Figure 7: The post measurements are consistently higher than the pre measurements showing that the subject was slower at performing the reach task after using the quadriciser.

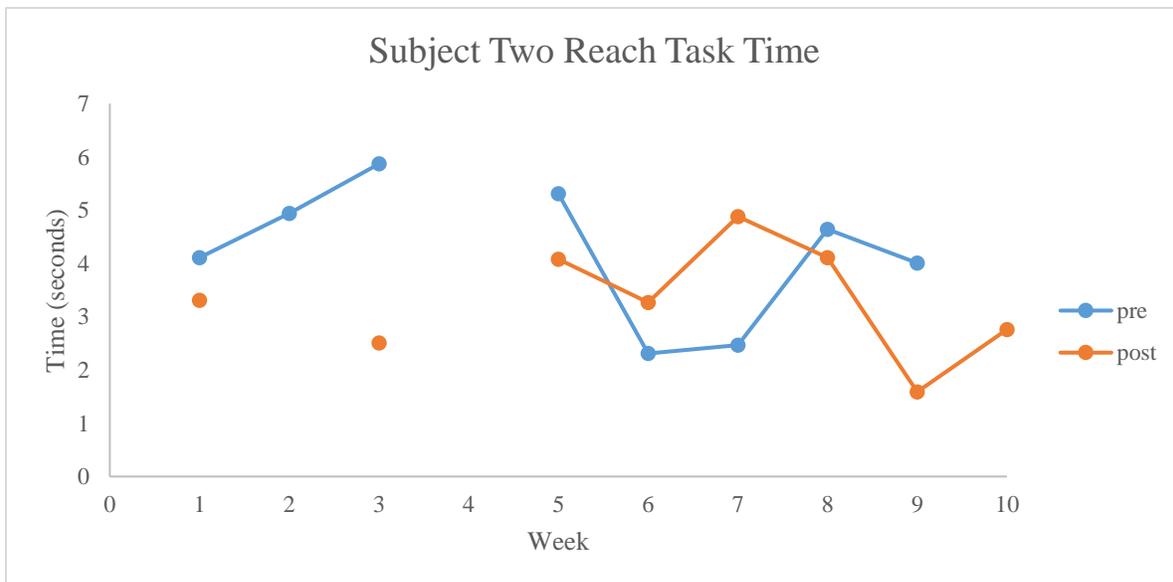


Figure 8: There was no significant change in subject two's reach task time over the course of the 10-week intervention

Table 9: Change in means from data points from weeks 1-10

Reach task time	Pre mean	Post mean	Change in mean
Subject one	3.97s	4.145s	.0166
Subject two	4.2s	3.39s	-0.71

*Note: positive value for reach time indicates a decrease in reach speed.

The change in the average pre and post values for subject one shows a slight average increase between pre and post times. This indicates subject was, on average, slower at completing the reach task after using the quadriciser. Subject two's reach task time showed an average decrease of .71 seconds showing that they were faster at completing the task after using the quadriciser.

Table 10: Change in levels from pre intervention to post quadriciser use on week one

Reach task time	Pre	Post	Change
Subject one	8.56s	5.88s	-2.68s
Subject two	4.11s	3.31s	-0.83

Both subject experienced improvements in their reach task time from pre-intervention to post quadriciser use during week one. However, for both subjects, the greatest change occurred during week three. Both subject's times decreased sharply post quadriciser use. This three-week time period likely reflects the latency of change or the time for the intervention to be impactful.

Table 11: Change in reach task values between pre-intervention to post week 10.

Reach task time	Pre intervention	Post week 10	Change
Subject one	8.56s	2.48s	-7.06s
Subject two	4.11s	2.76s	-1.35s

Both subjects completed their reach task in less time after quadriciser use on week 10 than they did before the 10-week intervention. Subjects one and two were 7.06 seconds and 1.35 seconds faster respectively. While both subjects experienced improvement in their reach task times, they did not have steady improvement over the course of the 10-week intervention. The reach task times fluctuated for both subjects, and while subject one's time increased between pre-intervention and week 10, they were still, on average, slower after using the quadriciser. However, the changes from pre-intervention to post week 10 reflect the cumulative effect that the quadriciser can have on reach task time.

Table 12: Non-overlapping data points

Reach task time	non-overlapping data points	percent	effectiveness
Subject one	16/16	100%	highly
Subject two	9/15	60%	minimally

When looking at non-overlapping data points the intervention was highly effective for subject one and minimally effective for subject two. However, subject one had an unusually high time during the first trial. It took 8.56 seconds to complete, which is significantly and abnormally higher than any other time it took to complete the task. Since all other times to complete the task were lower than 8.56 seconds, 100% of the subsequent times were faster than the initial time. Consequently, it appears that the intervention was highly effective. In reality, this may not be the case because, on average, subject one's reach time was slower after using the quadriciser.

Immediate and Cumulative Effects

The quadriciser produced both immediate and cumulative effects in range of motion on numerous, but not all joints. After the first exercise session subject one demonstrated the greatest improvements in their left elbow. They also showed significant initial improvement in the range of motion in their left shoulder. However, their range of motion in the right shoulder decreased after first exercise session.

Subject two demonstrated the greatest improvement after initial quadricier use in their right shoulder. The left shoulder improved six degrees from 176 to slight hyperextension of 182. Range of motion in subject two's knees had differing results after initial use. The left knee increased by five degrees, and the right knee decreased by two degrees.

The quadriciser has a greater and more consistent cumulative effect on range of motion. Comparing pre-intervention to post week 10, subject one showed substantial improvements in

range of motion in three out of four range of motion measurements. The greatest improvements were in their shoulders and left elbow.

Subject two experienced the greatest changes in range of motion in their hips. They also improved bilaterally in their knees and shoulders between pre intervention and post week 10.

The quadricisier also produced immediate and cumulative effects in the subjects' reach task times. Both subjects improved their time between pre and post initial quadriciser use. Subject one improved by 2.68 seconds, and subject two improved by .83 seconds.

Both subjects also demonstrated cumulative improvement between pre-intervention and post week ten. Subject one improved by 7.06 seconds, and subject two improved by 1.35 seconds.

Discussion:

The results of this study resemble those of past studies on passive exercise and range of motion. Passive exercise has been linked to increased range of motion in people with spastic hemiplegia, motor deficits, and upper and lower extremity paresis in previous studies (Cho et al., 2012; Cordo et al., 2008; Herbold et al., 2014; Lenssen, 2008; Shin et al., 2012).

A 2012 study looking at passive exercise on upper body range of motion in people with muscle spasticity due to hemiplegia and cerebral vascular disease concluded that the subjects who received treatment had significantly improved range of motion in the shoulder and wrist joints (Shin et al., 2012). However, no improvements were observed in the elbow joint. The results produced by the quadriciser contradict this finding. Range of motion in subject one's elbow increased dramatically after initial quadriciser use. After week one, both subjects consistently had 180 degrees of elbow range of motion, which is full range. Like the 2012 study, both subjects improved shoulder range of motion during the 10 week quadriciser intervention. While both subjects experienced average improvements in the range of motion in their shoulder joints pre and post quadriciser use and between pre-intervention and week 10, only subject one's right shoulder had any consistent improvement.

Two studies looking at the effects of continuous passive motion on patients who underwent total knee replacements or arthroplasty concluded that there were no significant long-term improvements in range of motion (Herbold et al., 2014; Lenssen, 2008). One of the two concluded that there were also no short-term benefits to the intervention when compared to traditional physical therapy interventions (Herbold et al., 2014). Conversely, the results of this study conclude that there were consistent improvements in range of motion in subject two's left

knee between pre and post quadriciser use. However, the range of motion in subject two's right knee did not improve steadily.

Other studies have concluded passive exercise may increase range of motion in certain populations, but those studies were conducted on the wrist, ankle, and neck joints (Cho et al., 2012; Cordo et al., 2008). The improvements observed in those studies were statistically significant. While the ankle, wrist, and neck joints were not observed in this study, the improvements observed in the joints that were studied provide evidence that there may be improvements in range of motion with the use of passive exercise.

The quadriciser study (Moran, 2014) conducted in 2014 resulted in similar conclusions to those produced in this study. There was an average cumulative effect in range of motion in all joints in both studies. The only statistically significant increases were in the subjects' right shoulders and left and right hips (Moran, 2014). However, the current study's small sample size did not allow for the analysis for statistical significance. The greatest cumulative improvements in range of motion were observed in subject one's shoulders and left elbow and subject two's hips. These findings are consistent with the 2014 quadriciser study, which suggests that a quadriciser exercise protocol may have the greatest benefits in range of motion in the shoulder, hip, and elbow joints.

Moran (2014) also concluded that there were statistically significant improvements to subjects' gait fluidity. The subjects increased the number of heel strikes they performed while walking after quadriciser use (Moran, 2012). These findings are inconsistent with the results from the timed reach task. The subjects either, on average, did not change or were slower after using the quadriciser. This indicated that they had worse motor control and fluidity of motion. It is possible that this is due to subject fatigue following the exercise bout.

Conclusion:

Limitations

There were numerous limitations of this study due to the skills of the researcher, the physical and intellectual impairments of the subjects, and the methods and equipment used. Each limitation could have an influence of the data and the research outcomes.

Researcher Limitations

The primary researcher did not have extensive hands-on experience with using a goniometer to measure joint angles prior to this study. Since the researcher was not trained in the usage of this device, error in joint measurements may be larger than they would be if measured by a trained professional. Additionally, it is likely that the researcher got better at measuring joint angles over time making the data obtained in the beginning of the study less accurate than data gathered later in the intervention. For example, the headrest for both subjects' wheelchairs interfered with shoulder measurements for the first few weeks. The researcher eventually learned how to get measurements while the subjects were sitting upright with assistance or while they were in their stander. Furthermore, since the researcher has never worked with nonverbal and intellectually challenged individuals before, the researcher was hesitant to push the subjects to their full range of motion out of fear of unknowingly injuring the subjects. Some joint angles, particularly in the first few weeks of the study, may be recorded as a smaller range of motion due to this.

Subject Limitations:

Due to the location where the research was done, the researcher only had access to two subjects. Because the number of subjects is so low, the results cannot be generalized to a greater

population. Furthermore, while the subjects have similar symptoms, they have different diagnoses, making the results even less generalizable. The study would have been much stronger had there been a larger participant pool and if all subjects had the same disorder.

Some data points are missing from the dataset because the researcher was unable to obtain them. This could be because of time restraints on the part of the researcher, illness of the subject, or subject absence from school. Because the subjects had severe intellectual and physical disorder, they would have frequent doctor's appointments causing them to miss school.

Additionally, working with subjects with severe intellectual and physical disabilities makes obtaining measurements more challenging for the researcher. On some days subject participation and compliance were lower making it more challenging to get an accurate measurement. The reach task, in particular, was highly dependent on the motivation of the subject. Some days the subjects would perform the task without hesitation, and on other days they would refuse. To motivate the subjects to perform the reach task, various objects for them to grab were used. The inconsistency of the object could have influenced the reach task time between trials.

Methodology and Equipment Limitations:

In addition to challenges with the reach task time, there were some technical issues with quadriciser use. Only subject two was able to use the lower body portion of the machine, and the boots on the machine were adult size and too big. This caused the abrasion on subject two's foot that prevented lower body exercise between weeks eight to ten. Additionally, subject two was able to kick their leg out of the boot because the boots were too big. The researcher would have to stop the machine to put the subject's foot back into the boot. Subject one did not use the lower body portion at all due to safety concerns.

Furthermore, only subject two was able to change the upper body exercise protocol from reaching overhead to shoulder flexion. Subject one did not switch exercises due to safety concerns. Their upper body exercises were different for the second five weeks, which may have influenced the results.

Finally, because there were only two subjects for this study, the statistical analysis was done as a single subject design. Visual inspection of changes in means between pre and post measurements, changes in values before intervention and post quadriciser use for week one, changes from week to week, changes from week one through week ten, and non-overlapping data points were done to highlight some of the changes in the data. While this helps describe the data, it does not represent statistically significant measurements or provide any definitive results of quadriciser use.

Future Directions:

This experiments design could be repeated with some key changes. To make the study stronger, there would need to be a larger sample size. This would make the results more generalizable and create a more robust statistical analysis.

Additionally, the researcher should have prior experience and training using a goniometer on similar populations to the subjects that will participate to minimize measurement errors. The researcher should also keep the measurement conditions the same for each joint measurement. For example, always taking the measurements at the same time and in the same position for each week.

The reach task could be improved by keeping the object that the subject reaches for consistent throughout the study. Changes in shape, weight, and color could influence the time to reach and grab the object. In addition, motion sensors could be used to detect the number of

plains in which the motion is occurring. This will provide a more accurate measurement of quality of motion.

This study could also be expanded to see how the quadriciser affects populations with different diagnoses. There is a variety of illness that can limit a person's range of motion or impair quality of motion. By looking at different populations, a researcher could discover which, if any, people benefit.

The study could also be expanded to observe the long-term effects that quadriciser can have on range of motion and quality of movement. Do people continue to improve over time or is there a point where people tend to plateau? When the quadriciser is no longer in use, how long do the effects last? There are still many areas of research that should be explored to determine the full effectiveness of the quadriciser.

Appendices

Informed Consent	31
Site Coordinator Letter of Permission	34

Parent/Guardian Informed Consent

Identification of Investigators & Purpose of Study

Your child is being asked to participate in a research study conducted by Thomas E. Moran, Ph.D., CAPE, Joshua R. Pate, Ph.D., and Trent A. Hargens, Ph.D., FACSM from James Madison University. The purpose of this study is to investigate whether the Quadriciser, a passive-active motorized therapy unit which allows for independent movement of all four limbs, could improve overall functioning of elementary and middle school students with severe orthopedic impairments as well as multiple disabilities. The study is designed to investigate improvement in functioning of three primary areas: (1) physical health, (2) activities of daily living (ADLs), and (3) readiness to learn.

Research Procedures

Should you decide to allow your child to participate in this research study, you will be asked to sign this consent form once all your questions have been answered to your satisfaction. This study consists of an exercise protocol that will be administered to individual participants in your child's school. Your child will use the Quadriciser five days a week for 30-60 minutes per day. The study is split into three phases, which allows the researchers to investigate the impact of specific exercises (completed on the Quadriciser) on each participant's level of functioning. Following each phase, you and/or your child's teacher will be asked to provide answers to a series of questions related to whether the Quadriciser, a passive-active motorized therapy unit which allows for independent movement of all four limbs, could improve overall functioning? Your child will be videotaped periodically during the study to inform the researcher's on his or her improvements. The video footage will only be seen by the researchers.

Time Required

Participation in this study will require 30-60 minutes each school day of your child's time. Responding to interview questions will only take 10-15 minutes of your (and/or your child's teacher) time.

Risks

The investigator perceives the following are possible risks arising from your child's involvement with this study: There are always risks when your child engages in physical activity. The machine, Quadriciser, assists each participant to move in a slow, controlled manner which will minimize risk. In addition, the researchers have extensive experience on appropriate exercise protocols for individuals with physical limitations. Finally, your child's special education teacher, nurse, and/or physical therapist will be consulted before the protocol begins. Your child will be supervised during all exercise sessions. As parent/guardian, you have the ability to ask questions throughout the study or remove your child at any time if there are concerns.

Benefits

Potential benefits from participation in this study include improved range of motion and functionality for the participants as well as improved activities of daily living and academic readiness. Additional benefits will be a greater understanding of which exercises produce favorable changes in movement behavior than others. Finally, interview responses will be kept

anonymous ensuring participants can be completely honest. Also allows researchers to investigate how individual responses may potentially change during the course of the study.

Payment for participation

There is no compensation for participation in this study

Confidentiality

The results of this research will be presented at a conference as well as submitted for publication. Your child will be identified in the research records by a code name or number. The researchers retain the right to use and publish non-identifiable data. When the results of this research are published or discussed in conferences, no information will be included that would reveal your child's identity. All data will be stored in a secure location accessible only to the researchers. Upon completion of the study, all information that matches up individual respondents (including audio/video tapes) with their answers will be destroyed.

There is one exception to confidentiality we need to make you aware of. In certain research studies, it is our ethical responsibility to report situations of child abuse, child neglect, or any life-threatening situation to appropriate authorities. However, we are not seeking this type of information in our study nor will you be asked questions about these issues.

Participation & Withdrawal

Your child's participation is entirely voluntary. He/she is free to choose not to participate. Should you and your child choose to participate, he/she can withdraw at any time without consequences of any kind.

Questions about the Study

If you have questions or concerns during the time of your child's participation in this study, or after its completion or you would like to receive a copy of the final aggregate results of this study, please contact:

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Questions about Your Rights as a Research Subject

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Chair, Institutional Review Board
James Madison University
(540) 568-2834
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Giving of Consent

I have read this consent form and I understand what is being requested of my child as a participant in this study. I freely consent for my child to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

I give consent for my child to be video taped during their interview. _____ (parent’s initial)

Name of Child (Printed)

Name of Parent/Guardian (Printed)

Name of Parent/Guardian (Signed) Date

Name of Researcher (Signed)

Site Coordinator Letter of Permission

May 6, 2016

Institutional Review Board
James Madison University
MSC 5738
601 University Boulevard
Harrisonburg, VA 22807

Dear Institutional Review Board,

I hereby agree to allow Thomas E. Moran, Ph.D., CAPE, Joshua R. Pate, Ph.D., and Trent A. Hargens, Ph.D., FACSM, from James Madison University to conduct his research at Montevideo Middle School and Peakview Elementary School. I understand that the purpose of the study is to investigate whether the Quadriciser, a passive-active motorized therapy unit which allows for independent movement of all four limbs, could improve overall functioning of elementary and middle school students with severe orthopedic impairments as well as multiple disabilities. The study is designed to investigate improvement in functioning of three primary areas: (1) physical health, (2) activities of daily living (ADLs), and (3) readiness to learn.

By signing this letter of permission, I am agreeing to the following:

JMU researcher(s) have permission to be on Montevideo Middle School and Peakview Elementary School premise.

JMU researcher(s) have access to the data collected to perform the data analysis both for presentation to Montevideo Middle School and Peakview Elementary School and/or for publication purposes.

Sincerely,

Scott Hand, Director of Special Education
Rockingham County Schools

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