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AN ELECTROMYOGRAPHY (EMG) STUDY OF TWO DYNAMIC SURFACES: HIPPOTHERAPY AND SWISS BALL

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A Scholarly Project

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Doctor of Physical Therapy

Grand Forks, North Dakota
May 2005

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This Scholarly Project, submitted by Melissa Metcalf, Roslyn Muller, Tanya Schimek, and Erica Wheeler in partial fulfillment of the requirements of the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

Peggy Mohr
(Graduate School Advisor)

Thomas Mohr
(Chairperson, Physical Therapy)

PERMISSION

Title	An Electromyography (EMG) Study of Two Dynamic Surfaces: Hippotherapy and Swiss Ball
Department	Physical Therapy
Degree	Doctor of Physical Therapy

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Date 12-9-04

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The support and encouragement from our families and friends have given us the strength and determination needed to complete our education and this research project. Thank you all for your support.

ABSTRACT

The use of horseback riding as a therapeutic intervention has been used since the fifth century, B.C.[1] It has been proposed that the physical benefits of horseback riding include: improved posture, balance, muscle strength, decreased spasticity, improved gait patterns, and coordination. Unfortunately, at the current time, hippotherapy, the use of horses in physical therapy intervention, has been poorly documented due to little objective research. The purpose of this study was to provide an objective measure of children's postural muscle activity through the use of electromyography (EMG) and electrogoniometry on two dynamic surfaces. Data was analyzed for differences in postural muscle activity and range of motion (ROM) when using a horse as a dynamic therapeutic surface as compared to a therapeutic ball as a dynamic surface. Goniometric data was collected in the frontal and sagittal planes for pelvic and trunk ROM.

Thirteen, typically developing children between the ages of 3 and 12, and two children with developmental disabilities between the ages of 6 and 11, completed the research protocol including walking 20 feet, one trial of each of the following: static sitting for 10 seconds, static standing for 10 seconds, riding a horse for 30 seconds, and sitting on a dynamic therapeutic ball for 30 seconds. Muscle activity of the rectus abdominis (RA), external obliques (EO), and lumbar erector spinae (LES) muscles, was recorded through surface electrodes, muscle activity in each trial was compared with the muscle activity during the walking as the reference baseline.

Results of this study provided objective data on the effects of two dynamic surfaces, a horse and therapeutic ball, on postural muscle activity in typically developing children. Compared to the therapeutic ball, when the subjects were on the horse they had significantly ($\rho<0.05$) more muscle activity in the RA and EO muscles.

Goniometric results showed that overall the subjects had more ROM in the frontal plane during the therapeutic ball activity (2.8 to 9.4 degrees) as compared to walking (1.6 to 6.9 degrees) and horse activity (2.1 to 9.9 degrees). Subjects also had more ROM in the sagittal plane during therapeutic ball activity (1.9 to 17.8 degrees) as compared to walking (2.5 to 15.0 degrees) and horse activity (0.4 to 20.9 degrees).

This study provided an objective measure of postural muscle activity and pelvic and trunk ROM present in subjects during activities on two dynamic surfaces, the horse and therapeutic ball, compared to walking. It was found that there was more postural muscle activity present in subjects while on the horse versus on the therapeutic ball. Overall, subjects had more ROM in the frontal and sagittal planes during the therapeutic ball activity as compared to the walking and the horse activity, however, ROM for walking and horse activity was similar. Further research is needed in the field of hippotherapy to provide more objective and quantifiable data in order to fully determine the effects of hippotherapy, especially the long-term effects on function.

CHAPTER I

INTRODUCTION

The use of horseback riding as a therapeutic modality began as early as the fifth century, B.C., when horses were used in the rehabilitation of Greek soldiers.[1] The first documented study of the value of therapeutic horseback riding was in 1875 by Cassaign, a French physician. He proposed that the riding treatments were helpful in improving posture, balance, and joint movement, as well as providing psychological benefits. At the turn of the century, England recognized riding for individuals with disabilities as a beneficial form of therapy; and offered riding therapy for wounded soldiers at the Oxford Hospital during World War I. By the 1950's, British physiotherapists were exploring the possibilities of riding as therapy for all types of disabling conditions.

Therapeutic riding was introduced in Scandinavia in 1946 after two outbreaks of poliomyelitis.[2] Liz Hartel, an accomplished horsewoman stricken with the disease, brought attention to riding for individuals with disabilities when she won the silver medal for dressage at the 1952 Helsinki Olympic Games. She and Ulla Harpoth, a physiotherapist from Copenhagen, went on to incorporate the use horses in therapy for their patients.

In the United States, riding for individuals with disabilities developed as a form of recreation, a means of motivation for education, and a way to provide therapeutic benefits.[2] MacKinnon et al[1] proposed that the physical benefits of riding include: improved posture, balance, muscle strength, decreased spasticity, improved gait patterns, and coordination. Psychosocial benefits have also been proposed and included an increase in self-esteem and a decrease in depression scores.

The North American Riding for the Handicapped Association (NARHA) was founded in 1969 to serve as an advisory body to the various riding groups for individuals with disabilities across the United States and its neighboring countries.[2] NARHA provides safety guidelines and training, certifies therapeutic riding instructors, accredits therapeutic riding centers, disseminates information, and offers low-cost insurance to its member organizations. Today, riders with disabilities have demonstrated remarkable accomplishments in national and international sport riding competitions.

The American Hippotherapy Association[3] has defined hippotherapy as treatment with the help of the horse' from the Greek word, 'hippos' meaning horse. Specially trained physical and occupational therapists use this treatment for clients with movement dysfunction. In hippotherapy, the horse influences the client rather than the client controlling the horse. The client is positioned on the horse and actively responds to the movement of the horse. The therapist directs the movement of the horse; analyzes the client's responses; and adjusts the treatment accordingly. This strategy is used as part of an integrated treatment program to achieve functional outcomes. Therapeutic riding encompasses a variety of equine activities in which people with disabilities participate without the supervision or direction of a licensed physical or occupational therapist.

Unfortunately, at this time efficacy of hippotherapy, specifically, the use of horses in physical therapy intervention, is poorly documented due to little objective research.[1] In a review of the literature, MacKinnon et al[1] concluded that limitations of previous studies were small sample sizes and weak scientific rigor, including the lack of homogeneous populations, quantitative reports and control groups, the limited use of standardized measures, the failure to measure and control potential confounding variables and report procedures performed, and limitations in documentation of the extent and significance of changes.

The purpose of this study was to provide an objective measure of children's postural muscle activity when using two dynamic surfaces through the use of EMG and electrogoniometry. Data was analyzed for differences in postural muscle activity and ROM between the use of a horse as a dynamic therapeutic surface as compared to a therapeutic ball as a dynamic therapeutic surface.

The research questions investigated were: What muscle activity was present in postural muscles when using the horse as a dynamic surface? What muscle activity was present in postural muscles when using the therapeutic ball as a dynamic surface? Was there a significant difference in muscle activity between the uses of two dynamic surfaces (horse and therapeutic ball)? If significantly more muscle activity was found during the use of hippotherapy as compared to a therapeutic ball, then it would potentially show that hippotherapy may be a more effective therapeutic intervention to improve postural control in children.

CHAPTER II

LITERATURE REVIEW

Hippotherapy is a physical therapy treatment strategy in which the movement of a horse is used to improve posture, balance, and overall function. According to Benda, McGibbon, and Grant,[4] inclusion of hippotherapy as part of a comprehensive treatment plan to enhance physical therapy outcomes has the added benefit of engaging and motivating the child. In a study of nineteen children, aged four to twelve years with cerebral palsy (CP), by MacKinnon, Noh, Laviviere, MacPhail, Allan, and Laliberte,[5] parents reported improvements in their children's social skills, motivation, willingness to try new activities, self-confidence, self-esteem, cooperation, and enthusiasm following participation in a six month hippotherapy program.

During hippotherapy, the horse is used as a treatment modality similar to the use of therapy balls and bolsters typically seen in a pediatric physical therapy clinic.[6] The horse is a dynamic base of support on which clients must control and coordinate their movement.[7] Bliss[8] reported that the warmth and movement of the horse's body has been shown to reduce spasticity in the adductors of the rider's legs, and to improve coordination through the trunk and upper extremities. Medical doctors, psychiatrists, physical and occupational therapists, speech therapists, and teachers refer patients and students to riding programs for the individuals with disabilities.

Biomechanics on the Horse

Fleck[9] used motion analysis to study 24 able bodied subjects' movement, aged ten to thirteen years. In this study he found that the biomechanics of human walking and horseback riding were similar in terms of lateral pelvic tilt, direction of displacement, and temporal assessments in stride. Fleck also found that children sitting on horseback and walking had the same angular measurements in lateral pelvic tilt. In this same study, vertical displacement of a child's center of gravity was less in riding than walking, and lateral pelvic shift was significantly greater in riding compared to walking. Therefore, Fleck proposed that hippotherapy techniques may enable some individuals with disabilities to adapt to the mechanics of normal walking.

Baumann and Gottwald[10] found that pelvic and lumbar rotation and lateral displacement during walking and riding were very close to the displacements during normal gait. Baumann proposed that hippotherapy allows a therapist to stimulate balance reactions and conditions that occur during normal ambulation for those patients who are unable to weight bear through their lower extremities.

Posture

Children with chronic disabilities often require that they be involved in therapeutic activities for many years of their lives.[1,6] Many children with chronic disabilities have problems with abnormal tone, contracture formation, poor or abnormal posturing, and numerous other problems. According to advocates of therapeutic riding,[6] physical therapy techniques performed during horseback riding provide children with strategies that will address the above issues as well as mobilizations of the pelvis, lumbar spine, hip joints, normalization of muscle tone, and development of equilibrium reactions in the trunk.

Posture and postural control play significant roles in development and function as both are needed to walk, reach, and move. Following a 10 week riding program, Bertoti[6] demonstrated that children with CP, aged 28 to 114 months, showed significantly improved postures ($\rho<0.05$), as documented through use of his Posture Assessment Scale, physical therapist assessment, and parent observation. Eight of 11 children in this study demonstrated increased midline head control, scapular stability, trunk elongation, pelvic alignment and erect posture; and decreased neck hyperextension, scapular retraction, lateral trunk flexion (improved symmetry), lumbar lordosis and postural scoliosis. Improvements observed by parents and physical therapists included: decreased fear of movement and hypertonicity; and improved weight bearing, and functional balance.

Appropriate posture is necessary for effective movement and functional skills and provides a stable and secure base of support.[8] Individuals with central nervous system damage may show signs of disrupted postural mechanisms. Land, Errington-Povalac, and Paul[8] conducted an eight week therapeutic riding program, with three female subjects aged ten to forty years, diagnosed with CNS damage. The subjects were videotaped prior to and following therapeutic riding to determine if any changes in sitting posture occurred. This study, using motion analysis, demonstrated significant improvements ($\rho<0.05$) in sitting posture in four of eight measures, one of which included flexion and extension of the trunk.

Effects of Hippotherapy on Gross Motor Function and Balance

Children with spastic CP may have impaired walking ability due to lack of selective muscle control, poor equilibrium responses, agonist-antagonist imbalance, and excessive co-contraction. McGibbon, Andrade, Widener, and Cintas[11] found that five children, aged nine to 11 years, diagnosed with spastic CP, showed a significant increase in scores on dimension E (walking, running, and jumping) of the Gross Motor Function Measure (GMFM), after an eight week program of hippotherapy. These children were tested in a pre-post test fashion with eight weeks between test dates. An inclusion criterion for this study was independent ambulation, with or without the use of orthoses or ambulation devices. One child received additional physical therapy treatments weekly while completing this study. Interventions during this study included forward and backward sitting during stretching and strengthening activities, and dynamic weight shifting activities. This study suggested that eight weeks of twice-weekly hippotherapy may result in decreased energy expenditure and increased efficiency during walking and gross motor function in children with CP.

McGibbon, Andrade, Widener, and Cintas[11] also concluded that variations in the horse's stride, velocity, and direction stimulate righting and equilibrium responses in the child by displacing the child's center of gravity and by facilitating dynamic postural stabilization and recovery from perturbation. They also hypothesized that hippotherapy may facilitate the transition from walking with ambulation aides to walking without aides by allowing the child repeated opportunities to experience postural challenges in the upright position and to practice postural control and head-trunk stabilization in response to variable forces and planes of movement. Therefore, it was concluded that therapeutic activities on a dynamic surface may help a child walk.

Casady and Nichols-Larsen[12] measured the effect of hippotherapy on children with CP using the PEDI and GMFM. The research design evaluated pre-treatment (pre-test 1 and pre-test 2), treatment (post-test 1), and post-treatment (post-test 2) trends in development. The four test dates were separated by 10-week intervals. Average inter-rater reliability between GMFM scorers was 94.6%. The PEDI and GMFM were strongly and significantly related to each other on each test date ($r = 0.729 – 0.836$). After a once weekly, 10 consecutive week hippotherapy program, the authors found a statistically significant treatment effect after the hippotherapy treatment phase (total PEDI score $\rho<0.05$; total GMFM score $\rho<0.05$), and no statistically significant change in function during the non-treatment phase.

Biery and Kauffman[13] evaluated eight subjects, aged 12 to 22 years, diagnosed with Down syndrome and disabilities including strabismus, mild to severe bilateral hearing loss, and nearsightedness, for standing balance and quadruped balance. All subjects were active in special education, physical education and swimming programs. Subjects maintained a consistent physical activity program throughout the study. Subjects were evaluated three times for standing balance and quadruped balance: six months prior to the 24-week hippotherapy program, at the beginning of the program, and at completion of the once-weekly program. Data was gathered by a hippotherapy instructor and two volunteers. Both standing and quadruped balance showed a significant improvement between the start and end of the hippotherapy program. Using paired *t*-tests, standing balance was statistically significantly improved ($\rho = 0.013$); quadruped balance improvements were assessed using the Quadruped Test and were shown to be statistically significant ($\rho = 0.001$).

Winchester, Kendall, Peters, Sears, and Winkley[14] evaluated the effects of a seven week, once-weekly hippotherapy program on gross motor function with pediatric clients who had a variety of diagnoses resulting in developmental delays. The authors evaluated seven children, aged 58 to 91 months, two of which were diagnosed with CP, one with spina bifida, three with Down syndrome, and one with a traumatic brain injury (TBI). A pre-test using the GMFM was given one week prior to the beginning of the study. Following completion of the study, two post-treatment measures, assessed one week and seven weeks post hippotherapy, were taken using the GMFM and a timed walking test on six of the subjects. The physical therapist used professional judgment to decide which two dimensions of the GMFM, based on each child's specific disabilities, would be used in order to minimize fatigue effect. A significant difference ($\rho = 0.01$) in GMFM scores were found, while no significant difference was found with the walking speed.

EMG Research

Roncesvalles, Woollacott, and Burtner[15] tested three hypotheses for mechanisms underlying balance control impairments in children with CP. His hypothesis stated that limited capacity in the neuromuscular system increases neural output with increased velocity of threat. Children that are typically developing show faster onset of muscle contraction with increased threats, allowing them to recover faster than children with CP. He also hypothesized that the limitations in the ability to respond to increased scaling of balance threats is due to inherent limitations in muscle response organization. In their experiment, the authors compared muscle activity of the gastrocnemius and tibialis anterior muscles of eight children, aged two to 10 years with spastic diplegia CP, 15 children that were developmentally-matched, aged nine months to 10 years, and 25 children, aged-matched, that were typically developing. During this study, each child stood on a plate that was translated backwards at varying amplitudes and velocities. Roncesvalles, Woollacott, and Burtner concluded that children with CP have impairments in balance control, due to insufficient levels of agonist muscle contraction when perturbation velocity and displacement amount is increased.

Woollacott, et al,[16] conducted an EMG study, comparing characteristics of muscle responses in two groups of children, seven normally developing children, and seven children with spastic diplegia, aged 10 months to 14 years. They found normally developing children fired their muscles in a distal to proximal fashion, whereas the children with spastic diplegia used co-activation of agonist/antagonist and synergistic muscles, and had a tendency toward increased proximal to distal muscle firing in response to perturbations at all ages. The authors concluded that the development of postural control in older children with spastic diplegia CP had muscle activation patterns typically seen in normal children who are at the pull-to-stand stage of development.

EMG research with hippotherapy is limited. The authors of this research project located only a single study in which both EMG and hippotherapy were used. In a study by Benda, McGibbon, and Grant,[4] 15 children with spastic CP, aged four to 12 years, were evaluated in a pre and post-test fashion for symmetry of cervical, thoracic, and lumbar paraspinal and hip adductor and abductor muscle activity during static sitting, static standing, and walking. For treatment, the children were split into two groups, with seven children participating in hippotherapy, which included four minutes of riding clockwise and four minutes of riding counterclockwise, and eight children sitting astride a stationary barrel for eight minutes. A percentage of change in EMG activity, from pre and post tests of each child's most asymmetric muscle group, was reported. The children who participated in the hippotherapy treatment demonstrated a greater percentage of improvement in symmetry of muscle activity (ρ =0.051) as a group compared to the group who sat on the barrel (ρ =0.24).

This review of literature indicated the need for further research to obtain objective data to support the efficacy and benefits of hippotherapy.

CHAPTER III

METHODOLOGY

Subjects

After this study was approved by an Institutional Review Board, 13 typically developing children, aged three to 12, served as subjects for this study. Volunteer subjects were recruited by personal invitation to participate. Prior to participation, the subjects and parents were informed about the research protocol and any potential risks of the activities they would be asked to complete. A signed parental consent and child assent were obtained.

Two children with disabilities, aged six and 11 years, also served as subjects for this study. Their diagnoses included: CP and bilateral blindness and arthrogryposis multiplex congenital (AMC).

The following criteria were developed to screen for participation in this study. Inclusion criteria were: 1) ability to sit independently with feet on the ground and no back support; 2) ability to stand and walk independently with or without an assistive device; 3) ability to cooperate and follow verbal directions; and 4) sufficient hip abduction to sit astride a horse or therapeutic ball. Exclusion criteria were: 1) grand-mal seizures uncontrolled by medications; 2) known allergy to horses, dust, or adhesive used with electrodes; 3) atlanto-occipital joint instability; and 4) inability to communicate or comply with the parameters of this study.

Instrumentation

Testing Devices

The Swiss Ball used in this study was an 85 cm Physio-Gymnic™ Ball, This ball was distributed by Sportime International® (Atlanta, GA). The horse used in this study belonged to the hippotherapy facility where this study was conducted. This female horse was 15 years old and had 5 years of experience assisting in the provision of hippotherapy. A metronome set at 66 beats per minute was used for pacing of the horse and rolling of the ball to equalize the rhythms of the two dynamic surfaces.

Electromyography and Goniometry

A Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254) was used to collect the electromyographic data. A Penny and Giles M180 electrogoniometer (Biometrics Ltd, PO Box 340, Ladysmith, VA 22501) was used to measure range of motion (ROM) of the trunk in both the frontal and sagittal planes. The Noraxon Telemyo8 receiver collected the telemetried information from the EMG electrodes and the electrogoniometer. This information was then digitized by an analog to a digital interface board connected to a HP Pavilion xz275 laptop computer (Hewlett-Packard Company, 3000 Hanover Street, Palo Alto, CA 94304-1185). The Myosoft XP data collection software that accompanies the Telemyo8 EMG system was used to analyze the digitized EMG signals in a variety of forms.

EMG Normalization

The EMG signals were normalized using a comparison of muscle activity during walking as a reference value to the EMG activity during the ball activity and horse riding. EMG normalization is only used as an indicator of the levels of activation because muscle activity during a specific exercise can sometimes have normalized values that are higher than the reference value.

Electrode and Electrogoniometer Placement

Researchers associated with this study chose to evaluate the rectus abdominus (RA), external obliques (EO), and lumbar erector spinae (LES) muscles. These muscles were selected because of their actions involving trunk stability and movement. See Table 1 for specific actions for each muscle.[17,18]

Before electrodes were placed, the skin was prepared by shaving excess hair with an electric razor (Bikini Touch Hair Remover/Trimmer, Bikini Touch Online, Pacoima, CA), and by cleansing the shaved area with rubbing alcohol to decrease skin impedance. Twelve electrodes were used symmetrically and bilaterally over the RA, EO, LES. One ground electrode was placed over the subjects' most prominent spinous process of their lumbar vertebrae. The placement for the RA was two centimeters superior and two centimeters lateral to the umbilicus, while the EO placements were five centimeters superior to the anterior superior iliac spines. The LES electrodes were placed so they were horizontally aligned with the L3-4 interspace and four centimeters lateral to midline.[19] The placement of electrodes is shown in Figure 1, as noted by the

Table 1. Origins, Insertions, and Actions of Selected Muscles[17,18]

Muscle	Origin	Insertion	Action	Innervation
External Oblique	Ribs 5-12	Linea Alba, Pubic Tubercle, Anterior ½ of Iliac Crest	Bilaterally- Trunk Flexion Unilaterally- Rotates Trunk to Opposite Side and Side Flexion Trunk	Intercostals T7-T12 & L1, Iliohypogastric, Ilioinguinal
Lumbar Erector Spinae	Broad Tendon from Posterior Iliac Crest, Posterior Sacrum, Sacral and Inferior Lumbar Spinous Processes, and Supraspinous Ligament	Angle of Ribs, Transverse Processes, Spinous Processes, Mastoid process	Bilaterally- Extend Trunk and head, Unilaterally- Side Flexion Trunk	Dorsal Rami of Spinal Nerves of C1-S5
Rectus Abdominus	Pubic Symphysis, Pubic Crest	Xiphoid Process, Costal Cartilages of Ribs 5-7	Trunk Flexion	Intercostals T7-T12 & L1, Iliohypogastric, Ilioinguinal

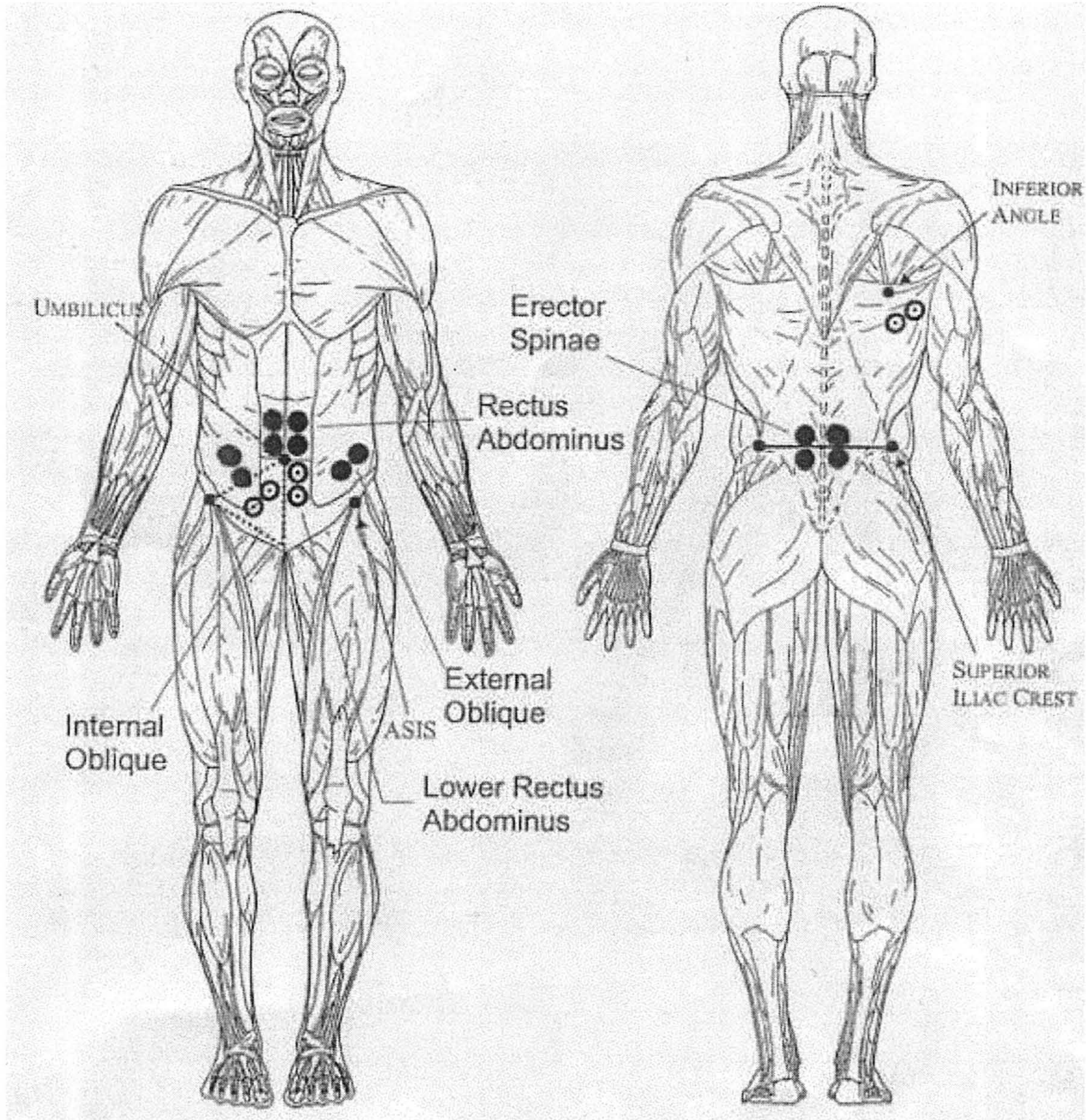
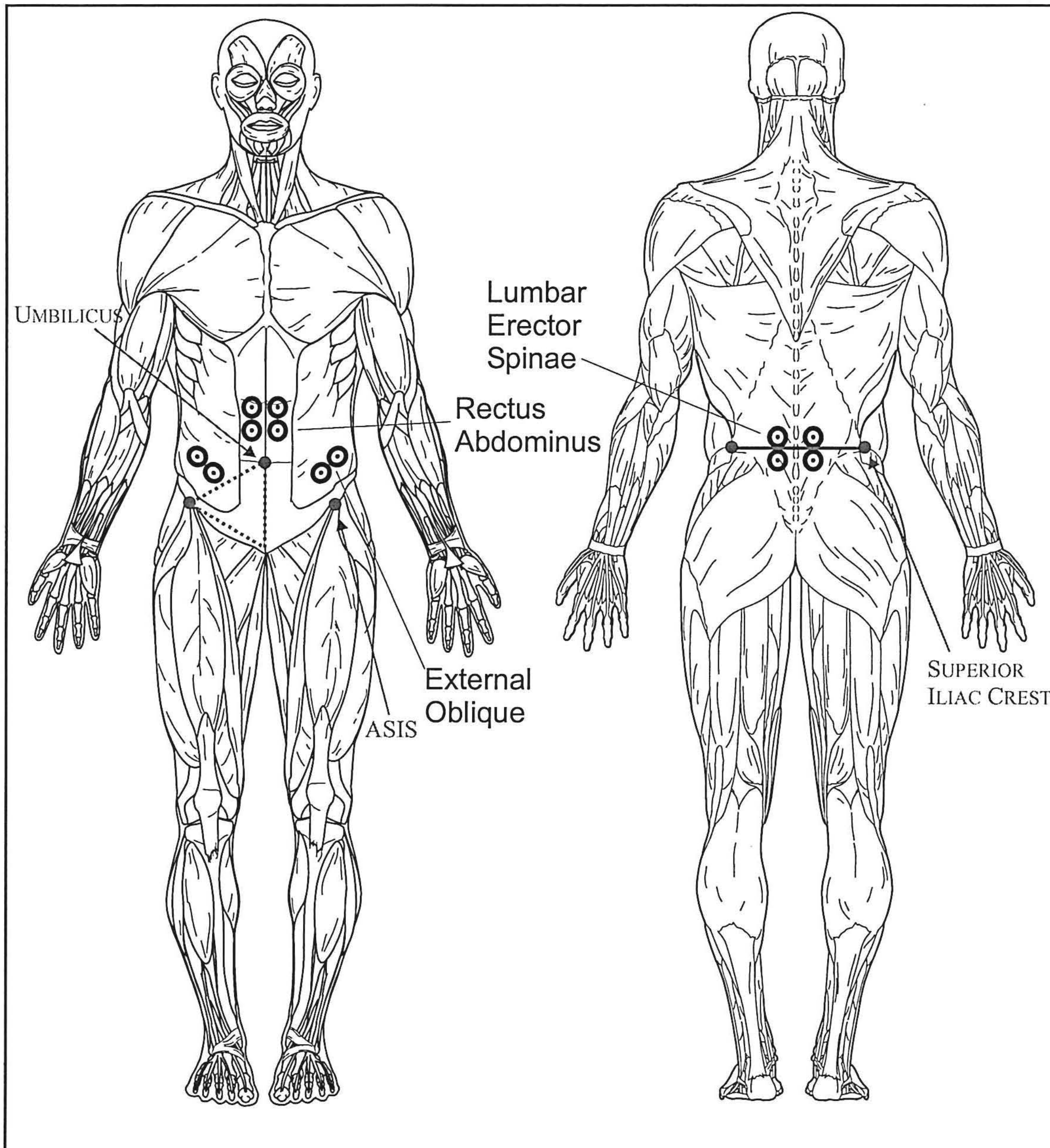


Figure 1. Electrode Placement for Trunk.



Rectus Abdominus - 2 cm superior and 2 cm lateral to umbilicus
External Obliques - 5 cm superior to the ASIS
Lumbar Erector Spinae - horizontally aligned with the L3-4 interspace, 4 cm lateral to midline

Zipp P. Recommendations for the standardization of lead positions in surface electromyography. Eur J Appl Physiol. 1982;50:41-54.
Vakos J, Nitz A, Threlkeld J, Shapiro R, Horn T. Electromyographic activity of selected trunk and hip muscles during a squat lift. Spine. 1994;6:687-695.
Basmajian JV, Blumenstein R. Electrode Placement in EMG Biofeedback. Baltimore, MD: Williams & Wilkins; 1980.

Figure 1. Electrode Placements for Trunk.

darkened circles. An electrogoniometer was also placed from the subjects' lumbosacral junction to their mid to upper thoracic spinous processes, depending on subject's size. Electrode and goniometer placement on the subjects can be seen in Figures 2-5.

Procedure

Randomization

The order of events subsequent to the walking segment were randomized through the use of a coin toss. The events were grouped in pairs of sit and stand events and horse and therapeutic ball events. Walking was not randomized due to being selected as the baseline measure for muscle activity.

Walking

After electrode preparation and placement, the subjects were asked to walk 20 feet with as close to normal gait pattern as possible. While subjects walked, one researcher walked alongside, holding the telemetry units for the EMG and electrogoniometer.

Static Sitting & Standing

Static sitting and standing occurred for 10 seconds during EMG data collection. While sitting, the subjects were asked to sit "as still as a statue" on a therapy bench, with no back support, for 10 seconds. The subject's hands were placed on their knees, with feet supported or unsupported depending on the height of the subject. In standing, the subjects were asked to stand "as still as a statue" with feet shoulder width apart without an assistive device for 10 seconds.

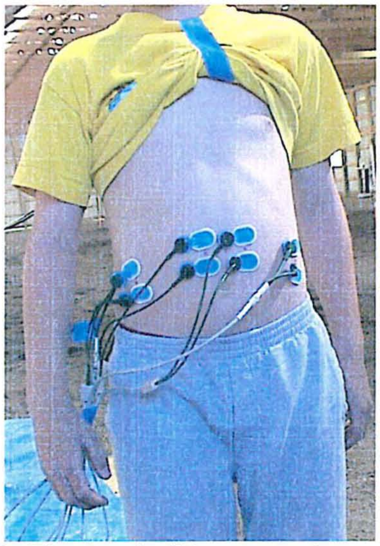


Figure 2. Electrode Placement on Front of Subject.

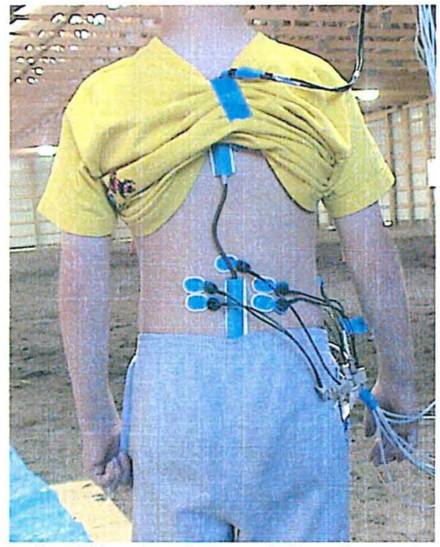


Figure 3. Electrode and Goniometer Placement on Back of Subject.

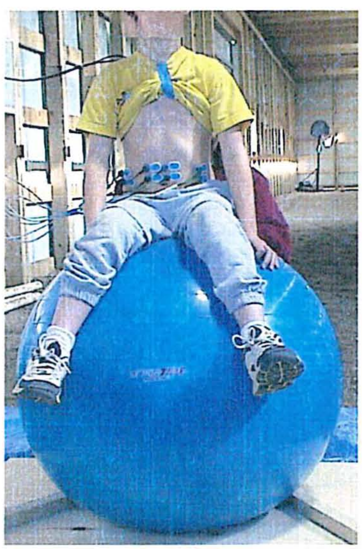


Figure 4. Subject Sitting on Ball.

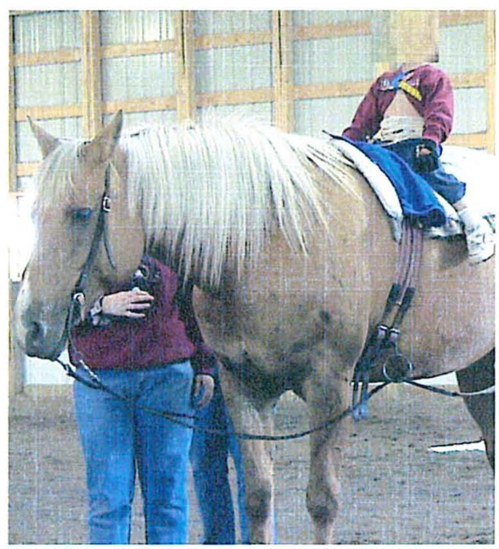


Figure 5. Subject Sitting on Horse.

Hippotherapy

The horse was walked in a straight line for 30 seconds while EMG data was collected. The horse was led and paced with a metronome. While riding, the subjects were in a forward sitting position with their hands on their knees.

Therapeutic Ball

Subjects sat on a dynamic therapeutic ball for 30 seconds while EMG data was collected. In a literature review completed by Riede,[10] Baumann found that the pelvis rotates a total of 16 degrees and Gottwald found that the lumbar spine rotates a total of 19 degrees while on the horse. To simulate the movement of a horse, the therapeutic ball in this study was alternately rolled in a 35° diagonal plane to the left and to the right (Figure 6, Figure 7), forward and back at the same metronome pace used with the horse. While sitting on the ball, the subjects' hands were placed on their knees, and they did not have foot or back support.

Data Analysis

Electromyography

The EMG signals were full wave rectified and smoothed using RMS averaging with a 50 msec window. The EMG data was exported to Noraxon Myosoft™ XP software for analysis and quantification of mean activity levels. For each subject, the level of EMG activity during each dynamic activity trial was compared to the EMG activity during the baseline walking activity. In the walking, sitting, and standing events, 5 consecutive seconds of consistent raw

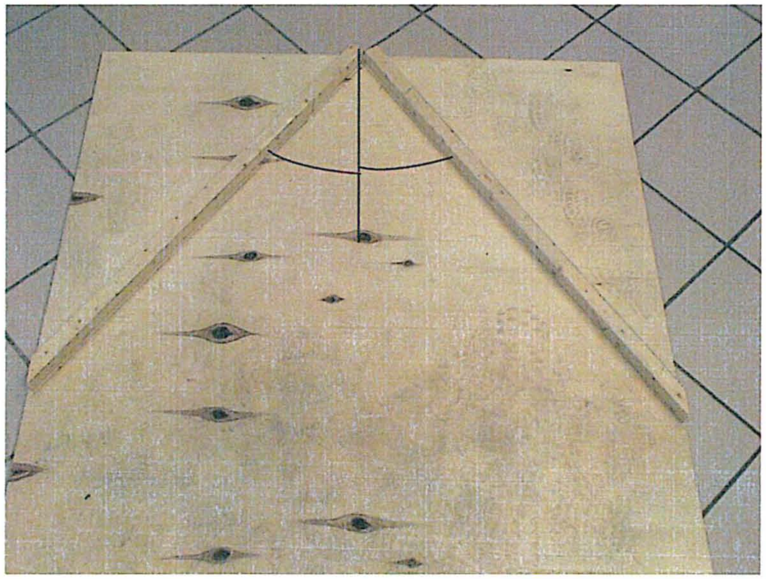


Figure 6. Ball Track.

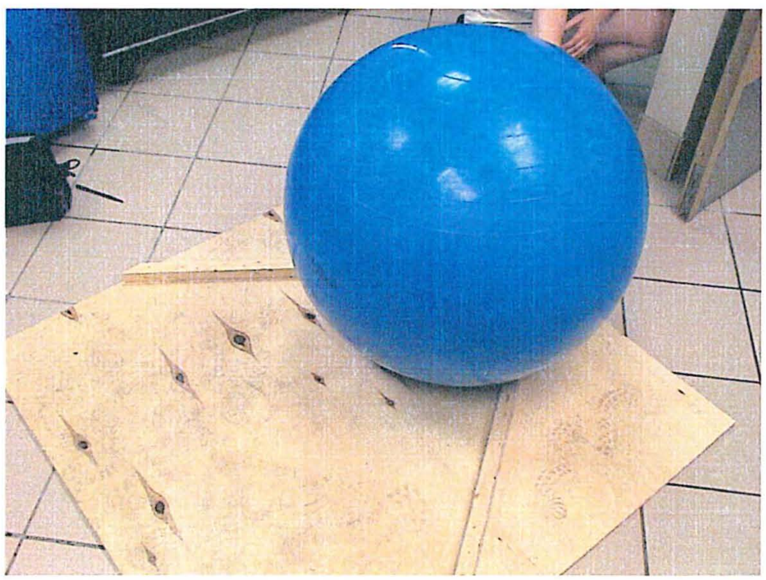


Figure 7. Ball on Ball Track.

EMG data were selected to be analyzed. For analysis of hippotherapy and therapeutic ball events, 10 consecutive seconds of consistent raw EMG data were selected. The software then selected the highest average muscle activity within each 5 or 10 second interval for intrasubject comparison. The EMG activity was converted to a percent (normalized) using the following formula:

$$\%\text{ Change in EMG} = \frac{\text{EMG Activity for Trial} - \text{EMG Activity for Walking}}{\text{EMG Activity for Therapy Trial}}$$

The normalized values were entered into SPSS™ Statistical software for descriptive analysis of postural muscle activity. The statistical analysis performed was a repeated measure ANOVA, with a significance level (α) of 0.05. The independent variables were the therapeutic ball activity and hippotherapy. The dependent variable was the percent change from the dynamic baseline activity, obtained during the walking activity.

Electrogoniometry

The range of motion data from the electrogoniometer was recorded both in the sagittal and frontal plane. The range of motion for each subject was displayed by the Noraxon Myosoft™ XP software. The mean of the peak range of motion and individual means of all subjects were calculated from the displayed values. The range of motion data was not subjected to statistical analysis, but was used to provide a quantitative comparison of the amount of range of motion between the different activities.

CHAPTER IV

RESULTS

Muscle activity was analyzed during baseline activity of walking and two dynamic surfaces, horse and therapeutic ball. The number of subjects reported, means, standard deviations, and the ANOVA results are summarized in Table 2. There was a significant difference in EMG activity found in all muscle groups while on the ball, except for the right LES. Significance between activity conditions is summarized in Table 3 and described below. In all cases, there was more muscle activity present in subjects while on the horse versus on the therapeutic ball (Figure 8). There was no significant difference in muscle activity between subjects on the horse and during walking in any muscle groups.

Lumbar Erector Spinae

In the left LES, a significant difference was found between activity conditions. The ball activity produced significantly less EMG activity than did walking ($\rho=0.001$). There was more muscle activity present during the horse activity compared to the therapeutic ball activitiy with all conditions in this muscle group, but it was not statistically significant.

Rectus Abdominus

There was a significant difference found between activity conditions in the left and right RA. The ball activity produced significantly less EMG activity than did walking ($\rho=0.001$, left RA; $\rho=0.000$, right RA). The horse activity produced significantly more EMG activity than the ball ($\rho=0.005$, left RA; $\rho=0.019$, right RA).

Table 2. Means, standard deviations, and ANOVA summary table for differences between baseline measure of walking and two dynamic surfaces (horse and ball).

Muscle Group	Activity	n	x	SD	df	F	ρ	η^2	Power
Left Lumbar Erector Spinae	Walk	13	100.000	0.000					
	Horse	13	86.277	33.749	2,24	7.441	0.003*	0.383	0.910
	Ball	13	62.915	29.788					
Right Lumbar Erector Spinae	Walk	13	100.00	0.000					
	Horse	13	96.154	39.580	2,24	0.830	0.448	0.065	0.175
	Ball	13	85.792	34.264					
Left Rectus Abdominus	Walk	13	100.00	0.000					
	Horse	13	137.754	137.754	2,24	7.790	0.002*	0.394	0.922
	Ball	13	75.900	75.900					
Right Rectus Abdominus	Walk	13	100.00	0.000					
	Horse	13	116.592	116.592	2,24	4.633	0.020*	0.279	0.727
	Ball	13	59.854	59.854					
Left External Oblique	Walk	13	100.00	0.000					
	Horse	13	100.031	10.883	2,24	19.175	0.000*	0.615	1.000
	Ball	13	52.662	7.404					
Right External Oblique	Walk	13	100.00	0.000					
	Horse	13	94.738	15.327	2,24	13.647	0.000*	0.532	0.995
	Ball	13	43.392	4.220					

*ρ < .05. There is a significant difference in EMG activity between ball and hippotherapy.

Table 3. Pairwise comparison of EMG data.

Muscle Group	**Activity**	**ρ**
Left Lumbar Erector Spinae	Walk→Horse	0.168
	Walk→Ball	0.001*
	Horse→Ball	0.061
Right Lumbar Erector Spinae	Walk→Horse	0.732
	Walk→Ball	0.161
	Horse→Ball	0.455
Left Rectus Abdominus	Walk→Horse	0.086
	Walk→Ball	0.001*
	Horse→Ball	0.005*
Right Rectus Abdominus	Walk→Horse	0.519
	Walk→Ball	0.000*
	Horse→Ball	0.019*
Left External Oblique	Walk→Horse	0.998
	Walk→Ball	0.000*
	Horse→Ball	0.000*
Right External Oblique	Walk→Horse	0.737
	Walk→Ball	0.000*
	Horse→Ball	0.002*

*$\rho < .05$. There is a significant difference in EMG activity between activities.

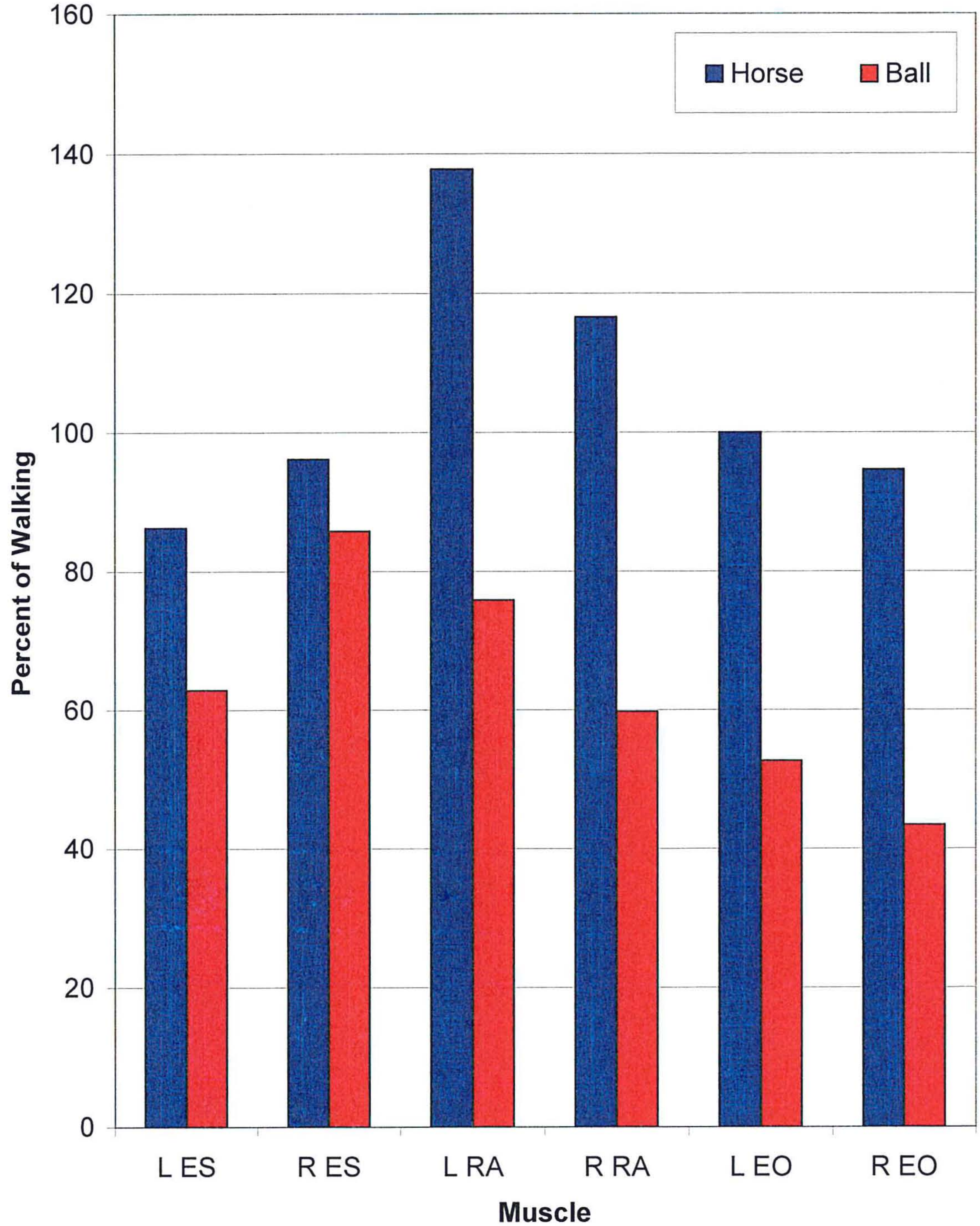


Figure 8. Electromyography: Muscle Activity as a Percent of Walking.

External Oblique

There was a significant difference found between activity conditions in the left and right external oblique muscles. The ball activity produced significantly less EMG activity than did walking (ρ=0.000, left EO; ρ=0.000, right EO). The horse activity produced significantly more EMG activity than the ball (ρ=0.000, left EO; ρ=0.002, right EO).

Electrogoniometric Results

Goniometric results showed that overall the subjects moved through more ROM in the frontal and sagittal planes during the therapeutic ball activity as compared to the walking and the horse activity (Figure 9, Figure 10). Average individual mean and peak ROM in both the frontal and sagittal planes were similar for walking and horse activities. The average individual mean in the frontal plane for walking and horse activities was 4.0 degrees, while on the ball the ROM was 5.2 degrees. In the sagittal plane, the average individual means were 6.1 degrees, 6.2 degrees, and 8.9 degrees for walking, horse, and ball activities, respectively.

The individual mean ROM for walking ranged from 1.8 to 6.9 degrees in the frontal plane, while in the sagittal plane the range for walking was 2.5 to 15.0 degrees. ROM ranged from 2.1 to 9.9 degrees in the frontal plane on the horse, while in the sagittal plane ROM ranged from 0.4 to 20.9 degrees. Subjects ROM ranged from 2.8 degrees to 9.4 degrees in the frontal plane, and 1.9 degrees to 17.8 in the sagittal plane. The peak ROM in the frontal plane during walking

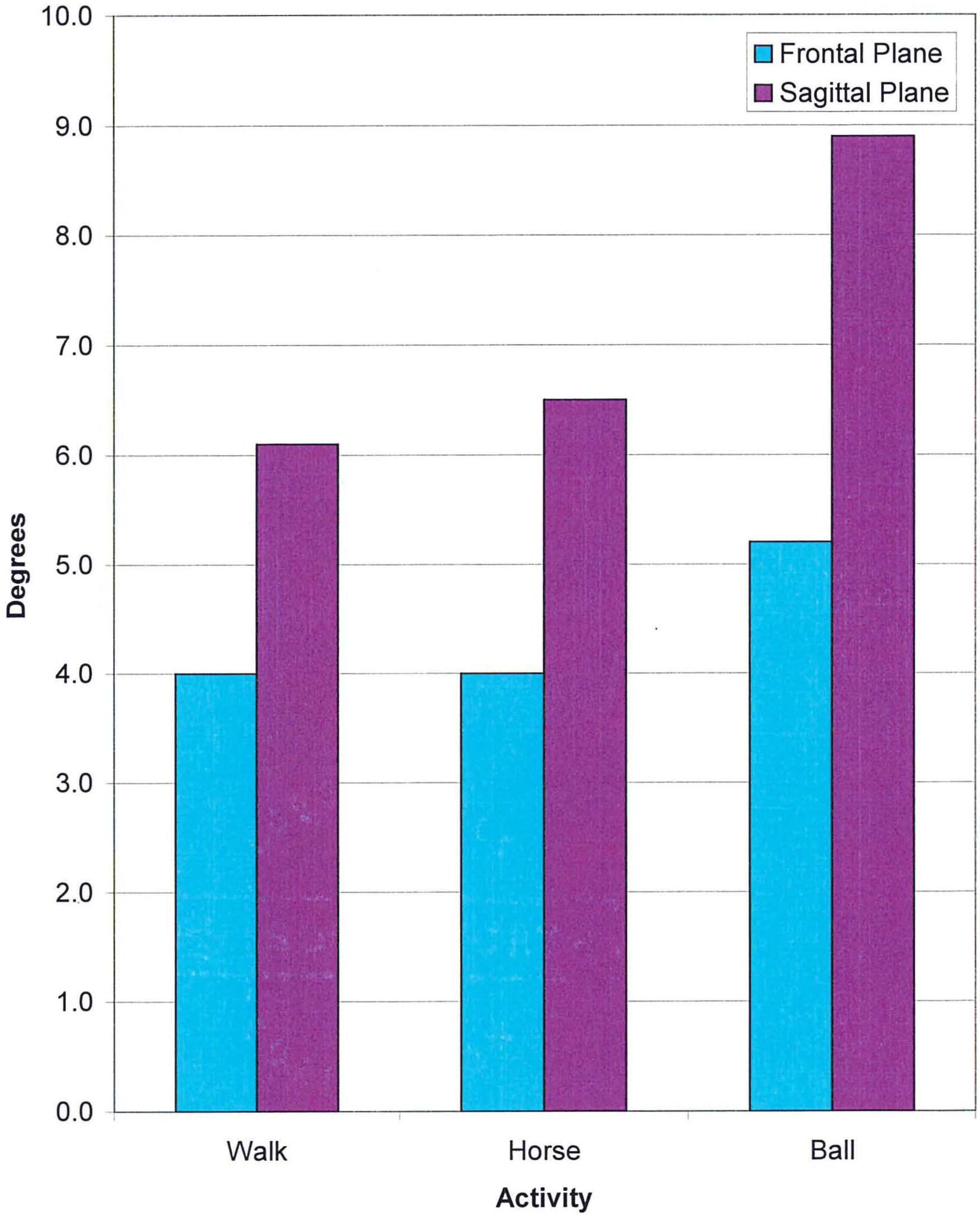


Figure 9. Goniometry Average Mean Degrees ROM by Activity in Each Plane.

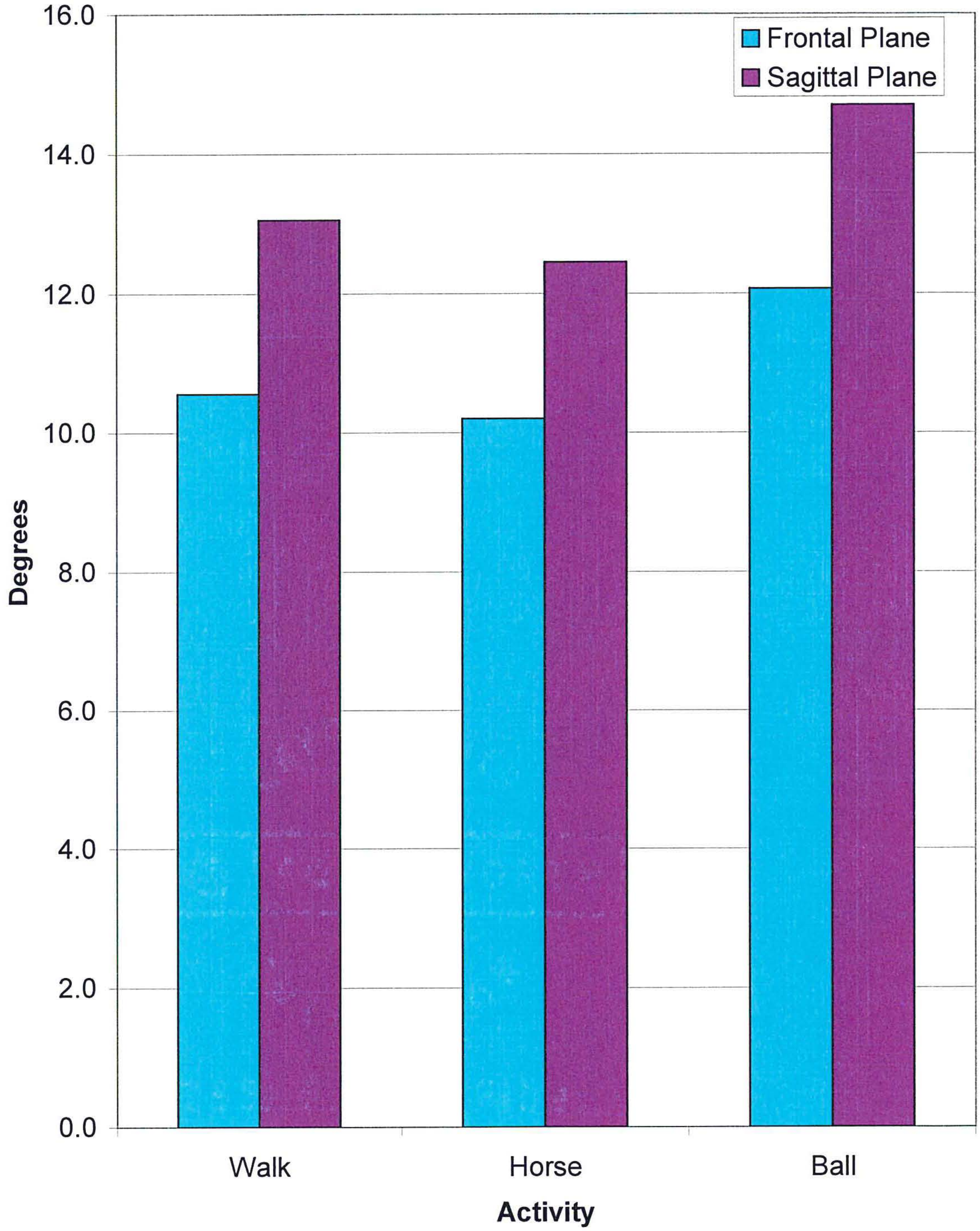


Figure 10. Goniometry Average Peak Degrees ROM by Activity in Each Plane.

ranged from 5.9 to 15.1 degrees, and 6.2 to 27.5 degrees in the sagittal plane. Peak ROM in the frontal plane while subjects were on the horse ranged from 5.8 to 20.3 degrees, and 0.5 to 27.3 degrees in the sagittal plane. The peak ROM in the frontal plane during therapeutic ball activities ranged from 7.5 to 17.5 degrees, and 6.4 to 21.4 degrees in the sagittal plane.

CHAPTER V

DISCUSSION

This study provided objective data on the effects of two dynamic surfaces, a horse and therapeutic ball, on postural muscle activity in typically developing children. Compared to the therapeutic ball, when the subjects were on the horse they had significantly more muscle activity in four out of the six muscle groups: left and right RA and EO. Therefore, if the goal of physical therapy is to facilitate muscle activity, hippotherapy may be a more effective therapeutic intervention than use of a therapeutic ball.

The left LES produced significantly less EMG muscle activity on the ball compared to walking. Therefore, for these subjects, walking may be a more effective therapeutic intervention than use of a therapeutic ball, if the goal of physical therapy is to facilitate muscle activity in the left LES. Despite more muscle activity occurring on the horse than on the therapeutic ball, the difference was not significant. Due to this finding, the use of a therapeutic ball and hippotherapy may both be effective therapeutic interventions.

In the right LES, significance was not found between any of the activities. This may be due to a preferred side dominance of the right compared to the left LES of the subjects tested. Horse movement was also in a clockwise motion for testing. If the direction was changed to a counterclockwise motion, the right LES may have shown more muscle activity and therefore produced significant values when compared to the other activities.

The RA and EO muscles showed a significant difference between the horse and therapeutic ball activities. Both muscle groups produced significantly ($\rho<0.05$) less EMG muscle activity on the ball as compared to walking. Horse activity produced significantly ($\rho<0.05$) more EMG muscle activity than therapeutic ball activity. Therefore, if the goal of physical therapy is to facilitate muscle activity, hippotherapy may be a more effective therapeutic intervention than therapeutic ball activities.

Lumbar flexion, extension, and bilateral side flexion ROM in subjects was greater on the therapeutic ball compared to the horse and walking. For specific data, see Figures 9-10. Results of this study showed that ROM in subjects, in frontal and sagittal planes, was very similar during walking and horse activities. Due to these results, if the goal of physical therapy is to improve gait, then hippotherapy may be a more effective therapeutic intervention. This further supports previous research completed by Land, Errington-Povalac, and Paul,[8] Fleck,[9] and Baumann and Gottwald[10] as stated in the literature review above.

Subjects with Disabilities

During completion of this study, two subjects with disabilities, a child with CP and a child with AMC, were assessed following the same protocol as described in the methods section of this document. Their muscle activity results are displayed in Table 4 and Figure 11.

The child with CP had more EMG muscle activity during walking compared to the horse and therapeutic ball activities. This subject's muscle activity was greater on the horse compared to the therapeutic ball. This subject's

Table 4. EMG Data for Subjects with Disabilities.

Subject with Cerebral Palsy			
Muscle Group	**Walk**	**Horse**	**Ball**
Left Lumbar Erector Spinae	100	11	3.2
Right Lumbar Erector Spinae	100	23.5	7.9
Left Rectus Abdominus	100	30.6	10.9
Right Rectus Abdominus	100	29.2	7.7
Left External Oblique	100	22.8	10.5
Right External Oblique	100	23.1	10.2
Subject with Arthrogryposis Multiplex Congenita			
Muscle Group	**Walk**	**Horse**	**Ball**
Left Lumbar Erector Spinae	100	40.8	69.6
Right Lumbar Erector Spinae	100	23.1	11.9
Left Rectus Abdominus	100	90.3	78.5
Right Rectus Abdominus	100	44.6	38.5
Left External Oblique	100	51.1	33.8
Right External Oblique	100	50.1	29.7

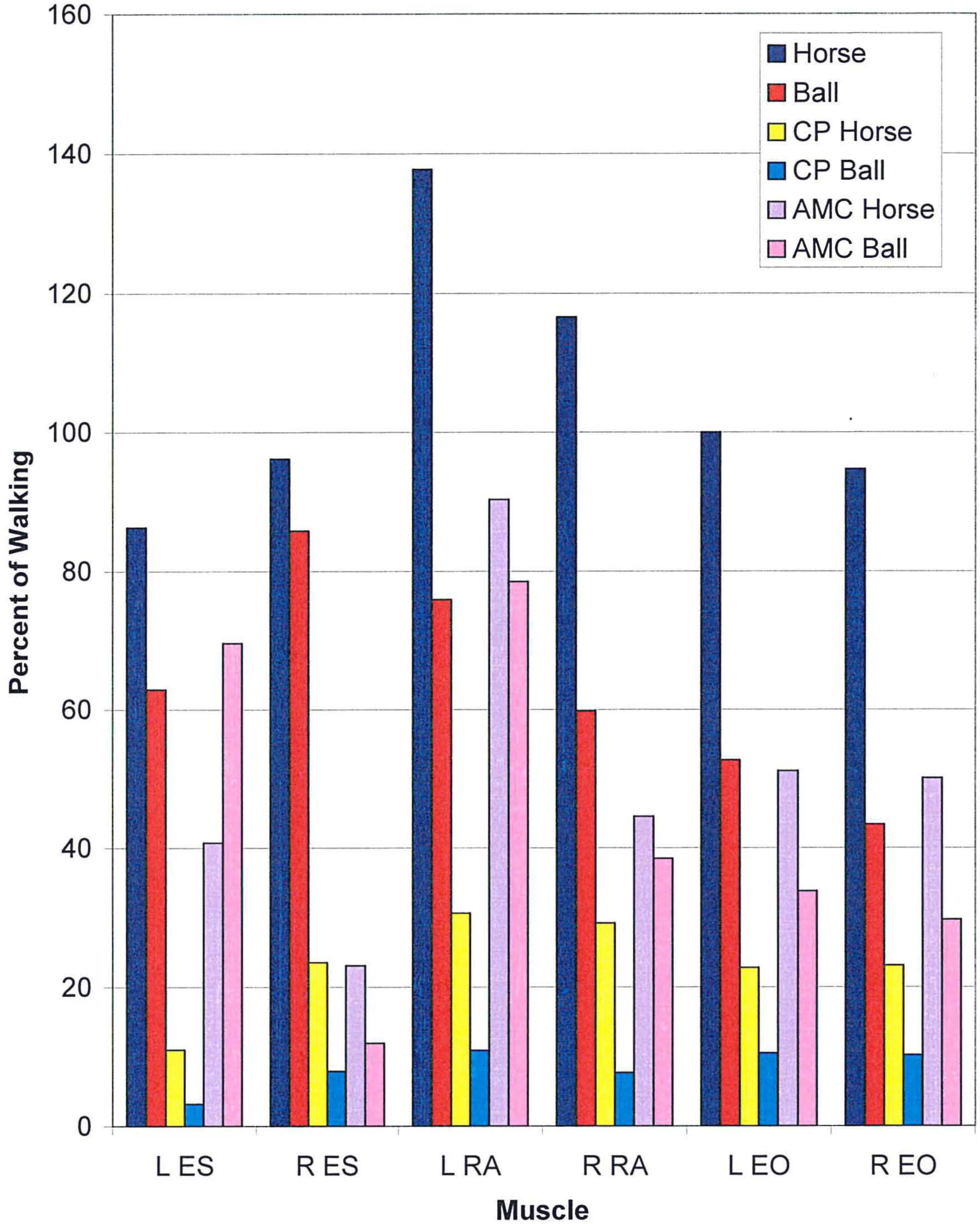


Figure 11. Electromyography: Muscle Activity as a Percent of Walking in Three Functional Groups.

EMG muscle activity, as a percent of walking, was less than that of the typically developing children. For this subject's ROM in the frontal plane, mean and peak ROM were greatest on the horse (12 and 21.1 degrees), and least during walking (5.8 and 15.6 degrees). In the sagittal plane mean ROM was greatest on the horse (7.5 degrees), and least while on the therapeutic ball (5.6 degrees). Peak ROM was greatest during walking (21.9 degrees), and least while on the horse (15.6 degrees). For this child with CP, hippotherapy is the most beneficial therapeutic intervention due to increased muscle activity and ROM while on the horse.

EMG muscle activity for the subject with AMC was greatest during walking. When comparing the two dynamic surfaces, greater EMG activity in all muscles, except the left LES, was evidenced when on the horse. For this subject's ROM in the frontal plane, mean and peak ROM were greatest during walking (22 and 27.4 degrees), and least while on the therapeutic ball (8 and 20.6 degrees). In the sagittal plane, mean ROM was equal on the therapeutic ball and walking (6.4 degrees), and least while on the horse (5.9 degrees). Peak ROM was greatest on the horse (19.7 degrees) and least during walking (13.9 degrees). For this child, walking is the most beneficial therapeutic intervention due to increased muscle activity and ROM. If this child were unable to walk, hippotherapy would be the most beneficial therapeutic intervention due to increased muscle activity and ROM compared to the therapeutic ball.

Limitations and Future Recommendations

There were numerous limitations to this study. In order to normalize results of a study, a sample size larger than 13 would be necessary. Two additional subjects with differing diagnoses were also studied. However, their data could not be generalized to other children with these diagnoses.

While electrode placement protocol was consistently used, electrode placement was not performed by the same researcher on all subjects. This lack of consistency may have led to some electrodes being placed in varying locations on the muscles. Some subjects had difficulty keeping the electrodes adhered to their skin. The researchers tried to eliminate this confounding variable by taping over the electrodes with self-adherent elastic wrap, so the electrodes would not become loose or fall off.

Some of the electrodes were partially corroded which may have interfered with signal transmission. This variable was controlled by rubbing off the corroded area as able or replacing electrodes if unable to rub off corrosion. During goniometric analysis, there were extreme values in the sagittal plane for three subjects, therefore these values were eliminated.

Despite using a metronome to pace the horse and the ball, movement between these dynamic activities may not have been equal. If the velocity of the horse or ball was increased or decreased, it may have caused more or less muscle activity and ROM in the frontal and/or sagittal plane. Also, it is very difficult to pace a horse with a metronome. This variable was addressed by the use of the same horse handler for all subjects. In order to decrease the significance of movement deviations with all subjects, the researchers used a ball track (Figure 6, Figure 7) to standardize the movement, as well as the same researcher to roll the therapeutic ball. This limitation could have been further decreased through use of additional track support to further standardize the movement of the ball.

The same horse was used for all subjects in this study. This may have been a benefit as well as a limitation. The benefit of using the same horse was that all subjects were exposed to the same gait pattern. However, this horse's gait pattern may not have been the most effective gait pattern to produce significant results for the subjects tested. This variable could be eliminated in the future by using a variety of horses during a pre-test to determine which horse is most appropriate for all subjects to be studied, with input from the horse handler.

With the large range in ages of the subjects in this study, three to 12 years, the subjects may have been at different stages of development. Therefore, EMG activity may have varied within the subject population. For example, normal walking isn't fully achieved until a child reaches seven years of age,[19] so the child at age three will have a different gait pattern when compared to a child age 12.

Multiple subjects in this study had previous riding experience, whereas for others, it was their first experience on a horse. This may have been a variable because the subjects with greater riding experience were more comfortable and accustomed to the movement of the horse, which may have affected their data. Those subjects with little or no riding experience demonstrated more apprehension and anxiety while on the horse. This may have affected their data by creating more muscle activity due to muscle guarding.

Future studies that may validate the use of hippotherapy may include research of muscle symmetry on two dynamic surfaces and research of agonist and antagonist muscle activity during hippotherapy that includes velocity and cadence alterations. Other studies may investigate variations in ROM due to muscle activity, when muscles are most active compared to least active while child is on the horse, and if a preferred dominance in muscle activity occurs while a child is on the horse.

Clinical Implications

Hippotherapy has been shown to be a beneficial therapeutic intervention to improve balance, posture, coordination, strength and flexibility.[6-8,11,13] During walking, the pelvis rotates forward and backward 5 degrees, 10 degrees total, as well as a total of 15 degrees of lateral rotation.[20] The ground reaction force coming up through the femur and pelvis causes rotational trunk movement as well.

When on a horse, a child's pelvis will be mobilized as an effect of the horse's movement. This will in turn increase the ROM of the lumbar spine. Also, children's reactions to the movement of the horse with their upper trunk will facilitate movement of their pelvises'. Postural muscle facilitation may also occur as the child reacts to the horse's movement. Children who receive physical therapy on a regular basis may also demonstrate increased motivation because the horse is such a unique and gentle animal.

Therapeutic ball intervention also causes the pelvis to be mobilized. This occurs because the ball causes the pelvis the move, which in turn causes the lumbar spine to move, creating increases in ROM. Likewise, when the child compensates by using the upper trunk (lumbar spine), the pelvis is mobilized indirectly. Child's reactions to movement of the therapeutic ball causes increased muscle facilitation and increased muscle activity.

From the results of this study, if a child can walk, walking will provide the greatest therapeutic benefits. If a child is unable to walk, there may be increased therapeutic benefits provided by the horse. If a child has contraindications to hippotherapy and cannot walk, the therapeutic ball will provide therapeutic benefits.

However, children with postural asymmetries and muscle imbalances may exhibit increased energy expenditure during walking. As cited by Waters and Mulroy,[21] the average walking speed of a child with spastic diplegia CP is 0.67 miles per second, which is 57% of normal walking speed. Interventions that improve poor biomechanical alignment may decrease energy expenditure and increase walking efficiency, including speed. If proper postural alignment can be attained through the use of therapeutic ball or hippotherapy interventions, then these interventions may be beneficial to children with postural asymmetries and muscle imbalances.

Conclusion

This study provided an objective measure of postural muscle activity and ROM present in subjects during activities on two dynamic surfaces, the horse and therapeutic ball, compared to walking. It was found that there was more postural muscle activity present in subjects while on the horse versus on the therapeutic ball. There was no significant difference in muscle activity between subjects on the horse and during walking in all muscle groups. Overall, subjects had more ROM in the frontal and sagittal planes during the therapeutic ball activity as compared to the walking and the horse activity, however, ROM for walking and horse activity was similar. Further research is needed in the field of hippotherapy to provide more objective and quantifiable data to validate long-term effects of hippotherapy on function.

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