I. Introduction

Hippotherapy is a highly specialized intervention that utilizes an equine's movement to achieve various rehabilitative goals in a patient's plan of care, working as an adjunct to other traditional therapies.[1] Contrary to therapeutic riding which tends to focus on the riders' technique and control of the horse, hippotherapy focuses on the patients' posture and movements that may lead to improvements in righting and equilibrium reactions, postural control, coordination, tone, general motor function, respiration, and sensory modulation.[1] Hippotherapy can be incorporated into treatment by a variety of different rehabilitative disciplines including occupational, speech, and physical therapy; this review will focus on the application of hippotherapy by physical therapists. The following review will explain the theory of hippotherapy and the effects of an equine's movement on human kinematics, intervention methods utilized in hippotherapy sessions, and specific evidence-based pediatric patient populations that are shown to benefit from this intervention.

II. Biomechanics of Hippotherapy

Studies investigating hippotherapy examine two primary movement comparisons: the general similarities between horse gait and human gait and the similarities in joint kinematics of the rider's spine and pelvis while on and off the horse. In comparing horse gait to human gait, it is important to understand the similarities and differences reported for temporal-spatial parameters of each gait cycle. Uchiyama et al ultimately found the stride-phase acceleration were not significantly different between horse and human strides.[2] The calculated curves for stride-phase acceleration of the horses correlated positively with the human participants, suggesting a similarity in the timing of the stride

patterns during walking.[2] Because the acceleration of the horse's limbs into stride phase is comparable to the same phase occurring simultaneously in human walking, one can assume that the sensory inputs when riding a horse would be similar to those during ambulation.[2]

The second comparison made within the literature is the movement of the rider's spine and pelvis both on and off the horse, suggesting the horse's ability to impart the normal kinematic movement needed for ambulation. Goldmann et. al used telemetric surface electromyography and three-dimensional analysis to perform motion analysis on the human pelvis and spine when riding a horse.[3] Results from this study show that a rider's movement on a horse is a reaction to the horse's movement.[3] More specifically, the lumbar spine motion of the rider directly follows the motion of the horse's trunk.[3] The horse's pelvis has the same three-dimensional motions as the rider's pelvis because of the synchronous movement imposed from the horse to the rider.[3] Garner et. al, in a similar study emphasizes the concept that the horse induces a "repetitive, cyclic pattern of motion"[4] to the rider that is similar to human ambulation and can be translated into normal motion off the horse.

Upon further investigation of joint kinematics on and off the horse, the study by Garner revealed important similarities and differences of pelvic displacement in several planes.[4] First, the researchers observed vertical pelvic displacement patterns to be similar when walking on foot and when riding.[4] During typical ambulation, the pelvis has two vertical peaks and valleys with each gait cycle, which are identically portrayed when looking at patterns of the rider's pelvis on the horse.[4] However, one important difference noted by Garner is that the biomechanical waveform for the individual during ambulation

is sinusoidal simulating bipedal gait, yet when on the horse, the waveform contains undulations because of the quadrupedal gait of the horse.[4] In terms of medial-lateral displacement, the displacement during riding lags in timing with the displacement during walking by approximately 25% of the gait cycle.[4] Lateral pelvic displacement in walking versus riding also shows slight differences in waveform**;** walking being sinusoidal and riding containing the same undulated pattern.[4] Lastly, anterior-posterior displacement of the pelvis for both scenarios is shown to have dual peaks and valleys and a similar sinusoidal waveform.[4] It is evident from these findings that there are strong similarities between the amount of pelvic displacement and pattern of displacement during typical ambulation and when riding a horse, particularly in vertical, and anterior-posterior planes.[4] The theory that the horse has the capacity to deliver similar kinematic forces to the rider mirroring those that occur with typical ambulation is therefore supported by the available evidence.

It is important to note that the coupling these of multi-planar pelvic motions differs slightly when comparing the pelvis during human walking to the rider's pelvis on the horse.[4] On horseback, forward and upward displacements of the pelvis happen at the same time giving the trajectory of the pelvis a linear progression.[4] However, when a is human off the horse and walking, the pelvis moves superiorly and peaks forward during swing phase, and then inferior and backward during stance making the trajectory circular rather than linear.[4] Despite these differences, it does appear that the similarities in pelvic displacement along with the synchronous, repetitive motions may assist an individual in meeting his or her therapy goals, especially as they relate to normalizing gait.

III. Intervention Strategies

In hippotherapy, patients typically ride on a bareback pad to increase the sensory input from the horse to the patient and enhance the transmission of movement forces.[1-4] Specific positioning strategies during hippotherapy include sitting on the horse facing forward as well as seated facing backward.[1] There are upper extremity exercises that can be utilized during treatment including weight-bearing through the shoulder, elbow and wrist**,** reaching in various directions, and general active range of motion.[1] The lower extremity exercises often include ankle pumps, cuing the horse to move forward with coordinated bilateral movement, and the weight bearing activities through the use of stirrups.[1] The treating therapist can also incorporate trunk exercises such as leaning forward, backward, and rotating to pet or engage with the horse.[1] The therapist can also instruct the horse leader to guide the horse in serpentines, figure-8 patterns, or a circle to challenge the patient's balance in various planes.[1]

Many research studies reference the McGibbon protocol for hippotherapy which comprises 30 minute sessions with a certified therapist.[5] Positioning on the horse has the child facing forward initially and is placed backward during the session to encourage thoracic extension and increased anterior pelvic tilt to provide an improvement in postural alignment.[5] The treatment sessions included three considerations for each patient: muscle relaxation and elongation, optimal postural alignment with independent sitting balance, and active exercises for the trunk and extremities.[5] For muscle relaxation and elongation, the therapist is advised to verbally encourage the child to relax and focus on the rhythmic movement of the equine.[5] To assist with postural alignment, the therapist will provide manual assistance to maintain proper positioning of

the patient's head, trunk and lower extremities while they are riding the horse, overtime attempting to limit the amount of physical assistance needed to maintain upright posture.[5] Lastly, active exercises in the McGibbon protocol, include stretching, strengthening, and weight shifting while still considering proper positioning and alignment.[5] In combination, the interventions utilized as part of this protocol have been shown to improve the patient's motor control and postural alignment.[5]

IV. Pediatric Conditions

Cerebral Palsy (CP) is the most widely studied pediatric diagnosis in the investigation of the benefits of hippotherapy. In a randomized controlled trial, children with spastic cerebral palsy participated in either hippotherapy or conventional physical therapy for 12 weeks.[6] Participants in the intervention group were provided with hippotherapy via the McGibbon protocol and the researchers compared differences in adductor spasticity amongst the two groups using the Modified Ashworth Scale.[6] Results of this study show that after 12 weeks of hippotherapy, the treatment group had significantly less spasticity in their adductor muscles compared to the conventional physical therapy treatment group.[6] In a similar randomized controlled trial, Kwon et al explored motor function using the Gross Motor Function Measure (GMFM-66 and GMFM-88) and balance with the Pediatric Balance Scale (PBS) in children with CP ranging in functional mobility from GMFCS levels I-IV.[7] Significant differences were found after 8 weeks of hippotherapy in favor of the hippotherapy groups in the GMFM-66 and -88 dimensions B, C, D, and E, (sitting, crawling, kneeling, standing, walking, running and jumping).[7] This study also found that those who were classified in the GMFCS levels II, III, and IV improved significantly more than those in GMFCS level I for

the hippotherapy group.[7] All GMFCS levels in the hippotherapy group improved in balance significantly more than the control group receiving conventional physical therapy services alone.[7] Both randomized controlled trials show the potential motoric improvements that can occur by using hippotherapy as a complement to conventional physical therapy, because, in both studies, all subjects receiving hippotherapy also received conventional physical therapy services.[6,7]

Although positive functional outcomes are associated with hippotherapy, it is also important to investigate the longevity of those outcomes. McGibbon, in a pretest/posttest randomized controlled trial, investigated both short-term and long-term effects of hippotherapy for children with CP.[8] Phase I results of McGibbon's study demonstrate the advantages of hippotherapy for improving adductor symmetry during ambulation immediately following intervention.[8] Phase II of this study showed the long-term benefits after 12 weeks of hippotherapy for adductor symmetry and motor function using the GMFM.[8] This study did have a small sample size (n=6) for the phase II long-term portion, thus further studies should be performed for to confirm long-term effects of hippotherapy when used in adjunct with conventional physical therapy. Additional studies also support that hippotherapy for children with CP may lead to long-lasting improvements in postural control and general motor function.[9,10] Moraes et al is a longitudinal study over 36 weeks that investigated the effects of hippotherapy on the postural balance children with CP.[9] After 12 weeks of hippotherapy, there was a significant decrease in postural sway in the 13 subjects; improvements continued throughout the 36 weeks without stabilization.[9] This study suggests that long term hippotherapy intervention for children with CP could continue improving their postural

balance.[9] Mutoh et. al also looked at long term hippotherapy intervention for children with CP (GMFCS levels I-III) finding that after 48 weeks of hippotherapy intervention in conjunction with conventional therapy, significant improvements in the subjects' gross motor function were documented through the GMFM-66.[10]

The general consensus between all relevant studies is that hippotherapy intervention leads to improved symmetry, motor function, and postural control for children with CP.[6-10] However, the one stipulation is that these benefits have only been observed when hippotherapy is used in conjunction with conventional physical therapy services. [6-10] Due to lack of research concerning hippotherapy on its own, further research is needed to better examine a true comparison between participants receiving only hippotherapy or conventional therapy services. This would elucidate the effects of hippotherapy compared to conventional physical therapy when considered as a stand-alone intervention. Given the current state of the research**,** it is not justifiable or best practice to use hippotherapy as the sole physical therapy intervention because the stand-alone benefits have yet to be identified.

Children with Down Syndrome (DS) may also benefit from hippotherapy services according to the evidence. In pretest/posttest case reports of three children with DS, researchers observed the ankle joint kinematics of the participants before and after hippotherapy intervention.[11] The results suggest that hippotherapy can lead to significant improvements in proper angular kinematics at the ankle joint for individuals with DS based off gait analysis using the Peak Motus system.[11] Another case report study with 2 participants diagnosed with DS assessed motor function and postural control. Improvements in both the GMFM-66 and GMFM-88 were reported along with

improvements in postural control through the head and trunk.[12] Both studies have small sample sizes (n=3, n=2) limiting the use of the results to suggest significant clinical effects, although neither of the studied acknowledged any adverse events.[11,12] More studies in the future specific to individuals with DS and other chromosomal diagnoses could be helpful to support the use of hippotherapy interventions.

In terms of clinical decision making, an important aspect to note with children with DS is that these children tend to exhibit a higher likelihood of atlantoaxial instability.[13] Therefore it is crucial that the treating therapist communicate with the child's physician and obtain clearance prior to participation in hippotherapy.[13] If a patient with DS is cleared by the physician, the therapist still should monitor for any neurological symptoms or changes including: change in head control, gait, or bladder or bowel functioning, as well as increased muscle tone, or fatigue during or following treatment as all of these these can indicate laxity in the atlantoaxial joint.[13]

Research also focuses on hippotherapy intervention for children with general motor delays and neurological impairments. Kraft et al conducted a case series investigating the effects of hippotherapy for 9 children with various neurological impairments.[14] Some improvements in motor function were noted with the GMFM; however, most improvements were reported by caregivers anecdotally and were not seen with an objective measure.[14] Encheff et al analyzed gait by observing the limb in stance phase of children with neurological impairments leading to abnormal ambulation patterns.[1] This small sample size pretest/posttest study (n=11) found that hippotherapy may lead to normalization of the position of the pelvis.[1] Pre-hippotherapy intervention analysis noted that subjects tended to have flexion at the trunk relative to the pelvis at initial contact of

the lower extremity instead of the typical 5 degrees of extension.[1] Also, the pelvis in the sagittal plane before treatment was on average 12 degrees of anterior pelvic tilt compared to a typical neutral position.[1] Post-treatment**,** pelvic position in the sagittal plane during initial contact improved by an average of 8.5 degrees, showing that hippotherapy has the potential to lead to normalized pelvic positioning during ambulation for children with neurological impairments.[1] This study also suggests that the trend toward a more normalized pelvic position influences improvements with trunk and hip alignment during ambulation.[1] Similar to the studies related to CP and DS, these studies are fundamentally limited by small sample sizes. Further research could attempt to expand sample sizes for children with developmental delays and other neurological impairments, or use more standardized outcome measures compared to parental reports.

Lastly, an additional pediatric diagnosis shown in the literature to benefit from hippotherapy is children with Autism Spectrum Disorder (ASD). Individuals with ASD have impairments including limited social skills and communication, as well as sensorimotor impairments, and some motor impairments.[15] The specific motor impairments can affect a child's ability to initiate movements, motor plan, and switch between goal-oriented movements to engage in developmentally appropriate activities.[15] Children with ASD also tend to have less postural control than children who are typically developing.[15] A small sample (n=7) of children with ASD completed 12 hippotherapy sessions; results demonstrated that there was a significant improvement in postural stability, via the use of a video motion capture system with force plates**.**[15] There was also a significant decrease in movement variability of sway, which translates

into improved ability to response to unexpected perturbation when walking.[15] Behavioral changes were also noted including improvements in receptive communication, coping strategies, and participation in daily activities.[15] Another study specifically investigated the gross motor skills of two children diagnosed with ASD before and after hippotherapy intervention.[16] The interventions used for the subjects challenged the participants' gross motor skills including core stability and extremity strength.[16] Results reported improvements in body coordination, strength, and agility.[16] These two studies show the potential for hippotherapy to assist with improvement in postural control and gross motor function for children with ASD; however, with the small sample sizes it is difficult to generalize the findings.

The general consensus amongst all of the available research suggests that hippotherapy intervention may improve gross motor skills and postural stability for a large variety of pediatric diagnoses.[6-16] Transmission of movement patterns from the horse to the rider provides a unique opportunity to alter and normalize movement patterns for children who display abnormal or inefficient gait. It appears that when used in combination with traditional physical therapy intervention and modalities, the child is provided with a more comprehensive treatment approach and the likelihood for achieving a positive functional outcome becomes even greater. The associated improvements in body structure, function and activity reported for the pediatric diagnoses discussed in this review can translate into a child's ability to participate in recreation, leisure, and play activities with peers, which is important for psychological health and overall quality of life. As noted throughout the review, the main barriers for generalizing results of these studies to larger pediatric population are derived from the

small sample sizes and the heavier prevalence of case reports and longitudinal designs. These factors tend limit the ability to draw cause-and-effect relationships between the intervention and the proposed therapeutic outcomes. It would be beneficial for further research obtain larger sample sizes, as well as include long-term follow up to highlight the carry-over effects hippotherapy treatment has on general functional mobility. Despite these limitations, there is great promise in augmenting physical therapy outcomes through introducing hippotherapy in several pediatric populations. By combining the evidence, intervention protocols and sound clinical judgment, a physical therapist can confidently refer a child to hippotherapy with the goal of amplifying and potentially expediting a child's therapeutic goals when used in conjunction with traditional physical therapy services.

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