THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE
Volume 22, Number 1, 2016, pp. 9–24

DOI: 10.1089/acm.2015.0171

The Efficacy of Equine-Assisted Activities and Therapies on Improving Physical Function

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Abstract

Objective: To summarize the physical benefits of therapeutic horseback riding and hippotherapy and suggest directions for future research.

Methods: Review of databases for peer-reviewed articles related to equine-assisted activities and therapies. Databases included MEDLINE via EBSCO, Web of Science, PubMed, Google Scholar, and Academic Search Complete. Articles were limited to those with full-text access published in English since 1987.

Results: Acute and residual improvements in physical benefits, such as gross motor function (e.g., walking, running, jumping), spasticity, muscle symmetry, posture, balance, and gait occur in adults and children with varying disabilities. The benefits appear to be greatest following multiweek interventions with one or more sessions per week. Modest acute cardiovascular responses are observed during equine-assisted activities and therapies with little or no evidence for training improvements in heart rate or blood pressure at rest or during riding.

Conclusion: The present body of literature provides evidence that equine-assisted activities and therapies are an effective means of improving many measures of physical health. However, more controlled trials are urgently needed to strengthen the current knowledge base, establish dose-response characteristics of equine-assisted activities and therapies, and explore the physiologic basis for the promising results suggested from the literature.

Introduction

EQUINE-ASSISTED ACTIVITIES AND THERAPIES (EAAT) is a broad term that encompasses therapeutic horseback riding and hippotherapy (Box 1). Therapeutic horseback riding includes teaching specific riding skills to those with a variety of disabilities by nonlicensed professionals.[1,2] Hippotherapy is conducted by physical, occupational, and speech therapists. Hippotherapy interventions use the rhythmic movement of the horse to include a variety of activities on horseback that are designed to improve functional abilities and quality of life of individuals with neuromuscular impairments.[1,3]

Horseback riding as a therapeutic tool has been studied in those with some form of cerebral palsy (CP),[2,4–32] Down syndrome (DS),[9,19,33–35] multiple sclerosis (MS),[36–40] spina bifida,[19] spinal cord injury (SCI),[41–43] traumatic brain injury (TBI),[10,19,32,44] stroke,[10,45] autism spectrum disorder,[19,46] intellectual disabilities,[47] and developmental delay.[9,11,19]

EAAT appears clinically useful for improving measures of gross motor function,[2,6,12–20,28,29,31,33] spasticity,[30,38,42,43] and muscle asymmetry.[12,22] EAAT improves posture[4–8,33,36,46] and balance[9,10,28,31,34,37–40,45,47] in individuals with CP and other disorders. Likewise, balance and lower-limb strength are improved in healthy, elderly patients.[48–50]

EAAT may contribute to enhanced physical function as the horse elicits passive and active stretching from the rider, and allows the rider to facilitate righting and equilibrium reactions while on the horse. The rider, then, reproduces movement patterns that are similar to those of natural human activities, such as walking.[2] More specifically, the pelvic girdle and torso undergo a similar range of motion in both activities.[51–54]

Improvements in these factors are thought to be critical for enhancing gait. Walking is crucial for maintaining activities of daily living (ADLs) and quality of life and gait appears to be enhanced following EAAT in adults and children being treated for neuromuscular disorders.[10,18,31,32,35,36,38,45] In addition, decreased energy expenditure while walking has been reported following EAAT.[18,27]

Cardiorespiratory responses have been reported in healthy participants[55–65] and in participants with a chronic condition

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Box 1. Definitions of Key Terms

Term	*Definition*
Equine-assisted activities and therapies	A broad term that includes any activities or therapies that incorporate equines. The term includes any specific riding center activity (e.g., therapeutic horseback riding) and any rehabilitative treatment (e.g., hippotherapy).[1]
Hippotherapy	A physical, occupational, or speech therapy treatment modality that is conducted by licensed therapists and uses equine movement.[1,2]
Therapeutic horseback riding	A treatment modality that uses equine movement and aims to improve physical and psychosocial attributes of the rider in addition to teaching specific riding skills. This equine-assisted activity does not involve licensed therapists.[1,3]

riding a horse.[18,25–27] Although cardiovascular responses to horseback riding are difficult to measure, the stresses of horseback riding appear to be less than that of low-intensity walking.[66,67] The purpose of this review is to provide a historical context of EAAT, summarize the physical benefits, identify gaps in current understanding, and suggest directions for future research.

Materials and Methods

This review of the literature included searches of several databases (MEDLINE via EBSCO host, Web of Science, PubMed, Google Scholar, and Academic Search Complete) for related articles published in English since 1988. The search terms included: *horseback riding, equine therapy, hippotherapy, therapeutic horseback riding*, and combinations of these terms with *gross motor function, spasticity, posture, balance, gait, cardiovascular*, and *simulator*. One hundred and three articles that were related to horseback riding and EAAT were identified. Because of the scope of the paper, we excluded papers that did not include physical, cardiovascular, or metabolic outcomes. Articles were limited to peer-reviewed full text, published since 1987. Remaining were 77 articles that directly related to this review.

This review is intended foremost for therapists and healthcare providers who conduct EAAT to improve physical function in their patients. It is intended for those who are considering the use of EAAT and would like a broad overview of its purported benefits. This review will also be useful for researchers and healthcare providers interested in determining how to overcome the limitations in our current understanding of EAAT.

Results

History

Hippocrates was the first to describe the ''health-giving'' rhythm of the horse.[68] Documentation of the benefits of horses to health and well-being has existed since the fifth century BC, when Greek and Roman soldiers injured in battle were placed back on their mounts to facilitate recovery.[22] The first complete reference to the value of equine movement as an effective method to promote and conserve health was made by Mercurialis (1569) in the book *De Arte Gymnastica*.[68] In 1782, J.C. Tissot was the first to describe three forms of movement: active, passive, and a combination of active and passive movement, which is typical of equitation.[68]

In their review, Sterba et al.[2] stated that horseback riding as a form of therapy gained more recent acceptance after two serious epidemics of paralytic poliomyelitis that occurred in Scandinavia in 1946. These events led to the founding of the first two centers of therapeutic horseback riding in Copenhagen, Denmark, and Oslo, Norway, for the treatment of children with neuromuscular disorders, most notably children with poliomyelitis and CP. From 1953 onward, therapeutic horseback riding has been actively promoted by the International Polio Fellowship in England. The first book published on the use of the horse for therapeutic means appeared in Germany in 1961. In 1965, the development of the first therapeutic riding program in North America was established in Toronto, Ontario, Canada. The North American Riding for the Handicapped Association, now a part of the Professional Association of Therapeutic Horsemanship International, was founded in 1969 to support riders from both the United States and Canada.[2]

Physical effects of EAAT

Once placed on the horse, the rider is in a position that inhibits extension spasticity of the legs and applies a long-lasting stretching of the hip adductors.[38] This mechanism alone can be useful in reducing abnormally high muscle tone.[5] Balance can be improved if neuromuscular and vestibular mechanisms are affected. As the horse walks, its center of gravity is displaced three-dimensionally with a rhythmic movement very similar to that of the human pelvis during walking.[38] The horse's smooth and rhythmic gait elicits motor responses in the rider that are essential for movement patterns of a human pelvis while walking.[3] The rider's center of gravity shifts with the moving horse, facilitating righting and equilibrium reactions that improve trunk stability and posture.[3] In addition to musculoskeletal function and motor control, these reactions are thought to generate improvement in respiratory, circulatory, and digestive health.[3] A wide variety of measurement tools are available to assess physical function. The most common instruments are listed in Box 2.

Gross motor function

Gross motor skills are activities that use large muscle groups to perform complex movement patterns that incorporate trunk balance, coordination, strength, and mobility.[13] Table 1 summarizes the effects of EAAT on the gross motor function measure (GMFM) in children with various disabilities. Table 1 shows that dimension E (i.e., walking, running, and jumping) of the GMFM is improved more than dimensions A through D. Dimension E improved by 8.5% in children with CP after 18 weeks of therapeutic horseback riding[2] and by 10% in children with CP after 16 weeks of therapeutic horseback riding in another.[15] Similar improvements in total GMFM scores have been reported in

Box 2. Evaluative Tools to Assess Functional Outcomes

Method	*Acronym*	*Unique features*	*Reference*
Gross Motor Function			
Calculated gross motor function measure	GMFM-66	A calculated version of the GMFM-88, it has been developed and validated with similar reliability as the GMFM-88	12
Gross motor function measure assessed on horseback	GMFM-h	16-item measure that includes dimensions A and B from the GMFM-88 while riding a horse	14
Gross motor function measure	GMFM-88	88-item evaluative measure that is designed to quantify changes in gross motor skills without regard to quality of performance in individuals with various disorders It includes 5 dimensions: (A) lying and rolling; (B) sitting; (C) crawling and kneeling; (D) standing; (E) walking, running, jumping	19
Spasticity			
Ashworth Scale values	ASV	A scale, ranging 1–5, that is used to quantify spasticity in the hip, knee, and ankle while lying supine Grade 1: no increase in tone; grade 2: slight increase in tone when the limb is flexed or extended; grade 3: a greater increase in tone but the limb is easily flexed; grade 4: considerable increase in tone, passive movement is difficult; grade 5: limb rigid in flexion and extension	42
Muscle asymmetry			
Electromyography	EMG	Measurement of electrical activity of skeletal muscles using surface electrodes	12
Posture			
Assessment scale	–	A scale, ranging from 0 to 3, or severe to normal; assessed at the head, neck, shoulder, trunk, spine, and pelvis	5
Accelerometry	–	Sensors strategically placed on body landmarks that can measure acceleration in all three dimensions	33
Motion capture	–	Measurement of the three-dimensional position of reflective markers using video analysis	46
Force plates and center of pressure	–	Center of pressure calculated using a measurement of ground reaction forces in all three dimensions	46
Balance			
Pediatric balance scale	PBS	14-item standardized assessment including timed single-leg stance, tandem stance, alternating stool touch and forward reach; children's version of BBS	9
Quadruped balance test	QBT	While on hands and knees with eyes facing forward, a combination of raising both arms and legs	34
Standing balance test	SBT	Include standing on one leg with arms at sides, arms across chest, both blindfolded and without a blindfold	34
Berg balance scale	BBS	Originally designed for elderly, assess balance and fall risk in individuals with neuromuscular dysfunction; provides information on position changes and postural control while performing ADLs	37
Tinetti performance oriented mobility assessment	POMA	Same as BBS, but provides an additional assessment of gait	37
Timed up and go test	TUG	Measures physical mobility and balance; involves standing from a chair, walking 3 m, turning and walking back to the chair, and sitting back down	38
Stabilometry	–	Analyzes static postural balance by measuring magnitude of postural sway along A-P and M-L axes with respect to center of pressure	40
Interactive balance scale	IBS	Assesses static standing balance by measuring changes in the vertical pressure of the heels and toes	41
Fullerton advanced balance scale	FABS	Validated test of static and dynamic balance, appropriate for higher functioning individuals	49
Gait			
Free walking	–	Velocity assessed using at one's own volition	10
Walkway with pressure sensors	–	A portable, carpeted walkway embedded with pressure sensors that can measure gait speed	23
Walkway with microprocessors	–	Can measure gait speed, stride time, and stride length at any given speed	36
10-m walking test	–	Velocity and cadence assessed in 1 direction at maximum walking speed over 10 m	38
Motion capture	–	Measurement of the 3-dimensional position of reflective markers using video analysis	46

ADL, activity of daily living; A-P, antero-posterior; M-L, medial-lateral.

Table 1. Effects of Equine-Assisted Activities and Therapies on Gross Motor Function

Study	Participants and groups	Duration/mode/frequency of therapy	Measures and methods	Outcomes
Case studies				
Drnach et al.[13]	1 child with CP, age 10.0 y	5 wk, 1 time/wk, 60 min/session	GMFM given before, immediately after, 5 wk after intervention	On average, significant improvements in dimensions D and E 5 wk after intervention versus baseline; no change in dimensions A, B, or C
Hsieh et al.[14]	1 child with CP, age 6.0 y	12 mo, 2 times/wk, 15 min/session; backward position during first 3 mo; propped prone position during last 9 mo	GMFM-88 (dimensions A, B) administered before and at months 3, 6, 9 and 12 of intervention; GMFM-h measured 1 time/month	At 3 mo, GMFM scores increased in dimension A from 21.6% to 31.4% and dimension B was unchanged; at 12 mo, scores increased in dimension A from 31.4% to 82.4% and increased in dimension B from 0% to 25%; GMFM-h score increased 29.2% to 81.3% from 3 to 12 mo of intervention
Champagne et al.[33]	2 children with DS, age 28.0 and 37.0 mo	11 wk, 1 time/wk, 30 min/session	GMFM-88 assessed before and after intervention	Improvements in scores in dimensions A–E for 1 child and in dimensions B–-E for second child after intervention; largest improvements observed in dimension E for both children
Therapeutic horseback riding				
Sterba et al.[2]	17 children with CP, age ≥5 y	18 wk, 1 time/wk, 60 min/session	GMFM-88 given 6 wk before, immediately before, every 6 wk during, 6 wk after intervention	On average, total score significantly increased at 18wk but returned to baseline levels 6 wk after intervention; dimension E score significantly increased at 12 wk and remained elevated at 18 wk and 6 wk after intervention
Mackinnon et al.[6]	19 children with CP, age ≥4 y; 10 in experimental group, 9 in control group	6 mo, 1 time/wk, 60 min/session	GMFM, with a focus on dimension E, administered before and after intervention	Total scores and dimension E score improved in both groups, but improvement was not significant
Cherng et al.[15]	14 children with CP, age ≥3 y	16 wk of riding and 16 wk of conventional therapy, 2 times/wk, 40 min/session	GMFM-88 administered before, 16 wk after riding, 16 wk after conventional therapy	No difference in score of dimensions A–D after riding; on average, significant improvement in dimension E score and total GMFM score after riding
Davis et al.[16]	99 children with CP, age ≥4 y; 50 in experimental group, 49 in control group	10 wk, 1 time/wk, 30–40 min/session	GMFM-66 given before and after intervention	No significant difference in total score
Winchester et al.[19]	7 children, age ≥4 y; 2 with CP, others with various disorders	7 wk, 1 time/wk, 60 min/session	GMFM-88 given 2 times before (scores were averaged), immediately after, 7 wk after intervention	On average, significant improvements in total score between baseline and immediately after intervention and between baseline and 7 wk after intervention

(*continued*)

Table 1. (Continued)

Study	*Participants and groups*	*Duration/mode/frequency of therapy*	*Measures and methods*	*Outcomes*
Hippotherapy				
McGibbon et al.[12]	6 children with CP, age ≥5 y	12 wk, 1 time/wk, 30 min/session	GMFM-66 given 12 wk before, immediately before, immediately after, 12 wk after intervention	All children improved total scores from 12 wk before to 12 wk after intervention
Casady et al.[17]	10 children with CP, age ≥2 y	10 wk, 1 time/wk, 45 min/session	GMFM-88 given 10 wk before, immediately before, immediately after, 10 wk after intervention	7 children had significantly greater total scores and a significantly greater score in dimension C from immediately before to immediately after intervention
McGibbon et al.[18]	5 children with CP, age ≥9 y	8 wk, 2 times/wk, 30 min/session	GMFM with a focus on dimension E, given 8 wk before, immediately before, immediately after intervention	All children showed significant improvement in dimension E score after intervention compared with either baseline scores; no change in two baseline scores
Hamill et al.[20]	3 children with CP, age ≥27 mo	10 wk, 1 time/wk, 50 min/session	GMFM with a focus on dimension B, given every 2 wk during intervention	No changes in dimension B score; parental perception included improvements in ROM and head control
Kwon et al.[28]	92 children with CP, age ≥4 years; 45 in experimental group, 46 in control group	8 wk, 2 times/wk, 30 min/session; aerobic exercise of same frequency/duration in control group; 3 h/wk of outside physiotherapy in both groups	GMFM-88 scores with additional calculation of GMFM-66 assessed before and after intervention	No difference in scores between groups at baseline; significant increase in GMFM-88, GMFM-66, dimension B–E scores in experimental group after intervention; with respect to GMFM level, significant improvement observed in experimental group after the intervention in dimension E for level I, dimensions D and E for level II, dimensions C and D for level III, and dimensions B and C for level IV
Park et al.[29]	55 children with CP, age ≥3 y; 34 in experimental group, 21 in control group	8 wk, 2 times/wk, 45 min/session	GMFM-88 and GMFM-66 assessed before and after intervention	No difference observed at baseline between groups; significant improvement observed with GMFM-88 and GMFM-66 scores in both groups after intervention; significantly greater GMFM-66 score and dimension E score observed with experimental group after intervention
Kwon et al.[31]	32 children with CP, age ≥ y; 16 in experimental group, 16 in control group	8 wk of hippotherapy (2 times/wk, 30 min/session) and conventional therapy (2 times/wk, 30 min/session) in experimental group; 8 wk of conventional therapy only (2 times/wk, 30 min/session) in control group	GMFM-88 scores with additional calculation of GMFM-66 assessed before and after intervention	No difference in scores between groups at baseline; significant interaction effect between groups was observed with GMFM-66 and dimension E

GMFM dimensions: A, lying and rolling; B, sitting; C, crawling and kneeling; D, standing; E, walking, running and jumping.

CP, cerebral palsy; GMFM, gross motor function measure; GMFM-88, 88-item gross motor function measure; GMFM-h , gross motor function measure assessed on horseback; DS, Down syndrome; GMFM-66, 66-item gross motor function measure; ROM, range of motion.

children with varying disorders, such as CP, DS, autism, spina bifida, and TBI.[19] Evidence also suggests that residual improvements in GMFM scores are maintained 4–16 weeks after therapeutic horseback riding.[2,15,19]

Hippotherapy may improve GMFM scores by 1%–14% in children with CP,[17,18] and improvements in GMFM scores can be maintained 12 weeks after hippotherapy ends.[12] However, there is evidence that improvements in GMFM score can also return to baseline 10 weeks after hippotherapy.[17] Although little evidence supports that hippotherapy can improve dimension B (i.e., sitting) of the GMFM, anecdotal evidence has included improvements in the participant's head control and range of motion (ROM) of the torso and head.[20] From the evidence presented in Table 1, it appears that children with CP exhibit a predominant acute response and typically improve most in dimension E after EAAT.

Spasticity

Spasticity is an accompanying phenomenon of SCIs and disorders and is defined as a ''velocity-dependent increase in muscle tone elicited by passive stretching.''[42] In EAAT, the rhythmic movement of the rider's trunk (flexion/extension) combined with trunk torsion has a beneficial effect on spasticity.[42] Spasticity is inhibited during riding because of a combination of flexion, extension, and external rotation at the hip joint.[43]

Table 2 shows the effects of therapeutic horseback riding and hippotherapy on the spasticity of participants with MS or SCI. The results provide evidence that EAAT can acutely reduce spasticity in patients who have SCI. In adults with SCI, improvement after 11 weeks of hippotherapy was greatest in individuals with the highest spasticity after 11 weeks.[42] However, there was no significant lasting effect (i.e., 4 days) in the spasticity of adults with SCI following 4 weeks of hippotherapy, suggesting that the results are not maintained in this population.[43] In children with CP, spasticity levels did not differ between a group that performed 12 weeks of therapeutic horseback riding and a group that performed outside therapy.[30] At present, there is insufficient quantifiable evidence to show that spasticity improves after EAAT in individuals with neurologic dysfunction other than SCI.

Muscle asymmetry

Physical growth accompanied by muscle asymmetry and long-term sensory and motor impairments leads to increasingly severe disability.[22] Muscle asymmetry can be characterized by an uneven distribution of spasticity on one side of the body and can contribute to abnormal posture, balance, and gait.[12] This muscle imbalance may lead to uneven bone growth, contractures, spinal deformities, scoliosis, imbalances in weight bearing, hip dislocation, chronic pain, and increasing difficulty with performance of basic motor skills defined in the GMFM.[22] Conventional medical procedures to correct muscle asymmetry are often invasive and can include selective dorsal rhizotomy, botulinum toxin injections, or tendon-release surgical procedures. These treatments are invasive and expensive and can require multiple repeated interventions. The benefits are often minimal and may not be worth the time, cost, and pain to the participant. The potential for EAAT to reduce muscle asymmetry may therefore be considerable; at the same time, EEAT may not be as cumbersome as other treatment options.

Although the mechanisms for these improvements are not clear, it appears that the repeated, small postural adjustments made through the rhythmic, symmetric movement of the horse are thought to help the rider achieve symmetric weight bearing.[24] Only 8 minutes of hippotherapy can transiently improve postural muscle asymmetry up to 64.6%,[22] and reduce adductor muscle asymmetry after 10 minutes by 41.2%, in children with CP.[12] The reduced asymmetry of adductor muscles reported after 12 weeks of hippotherapy can be sustained by as much as 48.2% after a 12-week detraining period.[12] These results suggest that adductor muscle asymmetry is reduced after single episodes of hippotherapy and that this effect, repeated with hippotherapy training, produces an adaptive improvement that can be sustained for several weeks. Although the interaction between acute and training effects has not been directly studied, hippotherapy appears to be an effective tool for reducing muscle asymmetry in children with CP. Indeed, the magnitude of effects is as strong as or stronger than what has been reported for passive stretching.[22]

Posture

The repetitive, rhythmic movement of the horse during therapeutic horseback riding and hippotherapy allows the rider to learn to anticipate the correct response in order to remain on the horse.[4] Proper postural control, defined as the average position of the back and trunk relative to the pelvis, is necessary in this learning process.[4] During hippotherapy, the rider has numerous opportunities to respond to the movement of the horse while performing functional tasks, such as reaching and stretching.[20] The therapy forces the rider to produce compensatory movements in order to maintain postural control on a dynamic surface, thus leading to a reduction in the changes of the rider's center of gravity.[4]

The effects of therapeutic horseback riding and hippotherapy on posture are reported in Table 3. During one session of therapeutic horseback riding, lateral trunk displacement can change up to 10.2 degrees in children with CP compared with 5.8 degrees in healthy controls.[8] Ten weeks of therapeutic horseback riding can significantly improve posture in children with CP, as evidenced by improved trunk displacement, head stability, and pelvic alignment and decreased neck hyperextension.[5] Despite these singular findings, there is insufficient evidence to conclude that posture is improved. The variety of postural assessments and subjective nature of evaluate measures make it difficult to determine the influence of therapeutic horseback riding and hippotherapy. More well-controlled studies that include standardized tests of posture and motion capture technology before and after EAAT are needed to assess acute and chronic responses. If posture is indeed improved, the residual effect of EAAT is also unknown.

Balance

According to Hammer et al.,[38] the improvement in a participant's balance can be expected after completion of EAAT because riding a horse is a balance-demanding task. The movements of the horse are thought to constantly change vestibular sensory information, requiring the rider to adjust in order to stay upright. Changes in the speed and

Table 2. Effects of Equine-Assisted Activities and Therapies on Spasticity

Study	*Participants and groups*	*Duration/mode/ frequency of therapy*	*Measures and methods*	*Outcomes*
Therapeutic horseback riding				
Baik et al.[30]	16 children with CP; 8 in experimental group (age 12.1 ± 3.6 y), 8 in control group (age 8.1 ± 2.6 y)	12 wk, 2 times/wk, 60 min/ session	Knee joint muscle tone assessed before and after intervention	Significant improvement in modified ASVs observed after intervention in experimental group; no differences observed between groups after intervention
Hammer et al.[38]	11 adults with MS, age ≥35 y	10 wk, 1 time/wk, 30 min/ session	Palmar and plantar flexors, elbow and knee flexors/extensors in a sitting position assessed before and after intervention	One participant had decreased, but not significant, overall spasticity after intervention
Hippotherapy				
Lechner et al.[42]	32 participants with SCI, age ≥16 y	On average, 11 sessions lasting 25–30 min/ session	Bilateral hip and knee flexion/ extension, hip abduction/ adduction, ankle dorsiflexion/ plantar flexion while in a supine position assessed before and after intervention	ASVs significantly lower after intervention; greatest improvement observed in participants with high spasticity (ASV >38)
Lechner et al.[43]	12 adults with SCI, age ≥27 y	Interventions were control, hippotherapy, sitting astride a Bobath roll, and sitting on a stool with a rocking seat; each lasted 4 wk, 2 times/wk, 25 min/session	Hip and knee flexion/extension and hip abduction while in a supine position assessed before, immediately after, and 3–4 d after intervention	Significant decrease in ASVs observed in experimental group compared with control; ASV scores were decreased (not significant) in Bobath roll group and rocking seat group compared with control group; no significant long-term effects were observed due to hippotherapy in any group

ASV, Ashworth scale value; MS, multiple sclerosis; SCI, spinal cord injury.

Table 3. Effects of Equine-Assisted Activities and Therapies on Posture

Study	*Participants and groups*	*Duration/mode/frequency of therapy*	*Measures and methods*	*Outcomes*
Case studies				
Haehl et al.[4]	2 children with CP, age 4.0 and 9.0 y	12 wk, 1 time/wk; 20 min/session for 9-year-old, 40 min/session for 4-year-old	Postural control and stability measured before and after intervention using video motion capture	Postural stability was greater after intervention for both children
Shurtleff et al.[7]	1 child with CP, age 6.0 y	12 wk, 1 time/wk, 45 min/session	Head/trunk control measured using motion capture before, immediately after, 24 wk after, 9 mo after intervention	Significant improvements in head/trunk control from before to immediately after intervention; no change from immediately after to 24 wk after intervention; improvement in postural sway 9 mo after intervention
Champagne et al.[33]	2 children with DS, age 28.0 and 37.0 mo	11 wk, 1 time/wk, 30 min/session	Accelerometry of head/trunk in vertical, A-P and M-L directions, measured during wk 1 and 4 of intervention	Along M-L axis, stability of head was increased at wk 4 for first child, and stability of trunk was increased at wk 4 for second child
Therapeutic horseback riding				
Bertoti[5]	11 children with CP, age ≥2 y	10 wk, 2 times/wk, 60 min/session	Posture assessment scale (scored 0–3, severe–normal) at head/neck, shoulder, trunk, spine, pelvis, assessed before and after intervention	8 of 11 children significantly improved posture after intervention, evidenced by trunk elongation and more erect posture; improvements observed in all 5 areas measured
Mackinnon et al.[6]	19 children with CP, age ≥4 y; 10 in experimental group, 9 in control group	6 mo, 1 time/wk, 60 min/session	Similar to Bertoti[5]	No difference observed between experimental and control groups; in experimental group, those moderately affected showed gains, those mildly affected showed slight decreases in posture
MacPhail et al.[8]	6 children with CP, age ≥5 y; 7 able-bodied children, age ≥6 y	1 session	Lateral trunk displacement measured 3 times during riding using video motion capture	Mean displacement of trunk was significantly greater in the group with CP
MacKay-Lyons et al.[36]	10 adults with MS, age ≥25 y	9 wk, 2 times/wk, 30–45 min/session	Postural sway measured using a force platform and center of pressure before and after intervention	No significant changes from before to after intervention; trend toward a deviation in center-of-pressure displacement after intervention
Hippotherapy				
Ajzenman et al.[46]	6 children with ASD, age ≥5 y	12 wk, 1 time/wk, 45 min/session	Postural sway measured using motion capture before and after intervention	Significant decrease observed in postural sway after intervention

ASD, autism spectrum disorder.

direction of the horse are thought to increase the control of muscle fibers, thus improving balance through neuromuscular coordination.[38]

The effects of therapeutic horseback riding and hippotherapy on balance of participants with various disorders and healthy elderly individuals can be found in Table 4. In adults with MS, 20 weeks of therapeutic horseback riding can improve balance, assessed by the Tinetti performance oriented mobility assessment, by an average of 25%.[39] Additional anecdotal reports provide evidence for balance improvements after 10 weeks of therapeutic horseback riding.[38] Twenty-four weeks of therapeutic horseback riding can improve standing and quadruped balance by an average of 58% and 75%, respectively, in adolescents and young adults with DS.[34] Hippotherapy training can improve balance by 8%–11% in adults with CP and TBI after 8 weeks[10]; by 20%–23% in adults with MS after 4 months[40]; by 6% in adults following a stroke after 16 weeks[45]; by 3%–24% in healthy elderly individuals after 8 weeks[48,50]; and by 25% in children with intellectual disabilities after 10 weeks.[47]

In summary, short-term EAAT of as little as 8 weeks can acutely improve balance in adults of varying age and disability. At present, there is insufficient evidence to conclude that balance is improved after EAAT in children with varying neuromuscular disorders. It is not clear whether training duration is a critical factor, when balance may be influenced most, or how long balance improvements last after EAAT interventions. More research is needed, particularly with acute and chronic responses in children after an EAAT intervention.

Effects of EAAT on the pelvis and gait

The position of the pelvis is important in that it affects the alignment of the spine, head, and limbs.[69] The movement of the pelvis is involved in many ADLs, such as walking. Individuals who are diagnosed with some neuromuscular dysfunction likely experience hindered gait and abnormal pelvic kinematics, leading to increased resistance to movement throughout the ROM of the pelvis and trunk.[69]

The effects of a hippotherapy program on pelvic kinematics (i.e., pelvic displacement, ROM) in children with spastic CP have been investigated.[31,32] In one study, the authors evaluated the effects of hippotherapy on gait in children diagnosed with bilateral spastic CP.[31] An analysis of pelvic kinematics revealed a decrease in average pelvic tilt during gait after hippotherapy.[31] The authors hypothesized that the decrease in pelvic tilt may be related to an improvement observed in the balance of the participants.[31] Trunk, pelvis, and hip motion were also observed during the stance phase (i.e., the contact of a limb on the ground) of gait in 11 children with CP and other neurologic disorders after 10 weeks of hippotherapy.[32] Hip flexion decreased to match the values observed in controls after hippotherapy.[32] The investigators reported qualitative improvements; however, no significant change in trunk and pelvic positioning were observed. The authors concluded that the observed increase in postural control was likely influenced by improvements in trunk and hip alignments during gait.[32] These studies provide evidence that hippotherapy can improve some aspects of gait through an increase in postural control, balance, or a combination of the two.

Table 5 summarizes the effect of EAAT on gait. Overall, no significant difference in the temporal-spatial gait parameters has been reported following an acute exposure to the therapies. However, training programs have yielded significant improvements in stride length by 17%[36] and by 29%.[31] Changes in gait velocity and cadence are mixed. Statistically significant differences are seen in ankle kinematics (i.e., improved ROM, improved gait cycle parameters), but not knee kinematics, after 13 weeks of hippotherapy in children with DS.[35]

ROM, body segment displacement, and muscle forces need to be characterized at the ankle, knee, and pelvis in individuals with neuromuscular disorders following EAAT. These variables should be investigated concurrently with temporal-spatial gait measures to help describe why these measures may improve.

Cardiovascular and metabolic benefits of EAAT

The cardiorespiratory and metabolic responses to therapeutic horseback riding[25,27] and hippotherapy[18,26] have been investigated in children with CP. Heart rate has been measured before, during, and immediately after the hippotherapy sessions.[26] These responses can be highly variable, in part because of anticipation felt by the participant, which may influence the measurement of change in the responses from rest to exercise, and the time at which the measurements are made during the therapy session. For example, mean systolic blood pressure (−5% change) and diastolic blood pressure (−2% change), heart rate (−8% change), and blood oxygen saturation (−1% change) were lower 5 minutes into hippotherapy compared with resting conditions before the session in 22 children with spastic CP.[26] In contrast, heart rate (14% change), oxygen consumption (41% change) and ventilation (45% change) were elevated after 20 minutes of therapeutic horseback riding in children with varying severity of CP.[27]

Heart rate has been used to calculate energy expenditure while walking before and during hippotherapy training.[18] In children with spastic CP, the energy expenditure index (EEI) while walking was assessed before and after an 8-week hippotherapy intervention in children with spastic CP.[18] The walking EEI is defined as (walking heart rate − resting heart rate)/walking velocity.[70] All five participants showed significantly decreased EEI (mean, 39%) after the hippotherapy compared with before the therapy.[18] Among children with varying severity of CP, 10 weeks of therapeutic horseback riding elicits a higher average resting heart rate and a higher median and peak heart rate during exercise in wheelchair-dependent participants compared with those who are more ambulatory.[25] The lower walking energy expenditure may reflect the fact that those who participate in EAAT are more comfortable with walking or can perform ADLs more easily or a combination of both. The limited results are promising, and further investigation is critically needed to determine whether the therapies have a sustaining effect with regard to energy expenditure while walking.

Cardiovascular responses to EAAT remain poorly defined. Heart rate and blood pressure responses may be influenced by anticipation of the riding because heart rate increases as a result of the anticipation or excitement of an unfamiliar event.[71] At present, there is insufficient evidence to suggest

Table 4. Effects of Equine-Assisted Activities and Therapies on Balance

Study	*Participants and groups*	*Duration/mode/frequency of therapy*	*Measures and methods*	*Outcomes*
Therapeutic horseback riding				
Biery and Kaufmann[34]	8 participants, age ≥12 y; 7 with DS, 1 with ID	24 wk, 1 time/wk, 20 min/session	SBT and QBT assessed 6 mo before, immediately before, and immediately after intervention	Significant improvement in standing and quadruped balance from immediately before to immediately after intervention
Hammer et al.[38]	11 adults with MS, age ≥35 y	10 wk, 1 time/wk, 30 min/session	BBS and TUG measured 4 times before, 5 times during, 4 times after intervention; walking a figure 8 3 times before, 4 times after intervention	4 participants significantly improved balance throughout intervention; 5 participants significantly improved balance from before to after intervention; 8 participants anecdotally improved from before to after intervention
Muñoz-Lasa et al.[39]	27 adults with MS, age ≥34 y; 12 in experimental group, 15 in control group	2 series of 10 weekly therapy sessions, separated by 4 wk; intervention lasted 30–40 min	POMA assessed before and after 24 wk protocol	Significant improvement observed in experimental group after intervention; no change in control group after intervention
Homnick et al.[49]	15 healthy adults, age ≥65 y; 9 in experimental group, 6 in control group	10 wk, 1 time/wk, 60 min/session	BBS and FABS assessed before and after intervention; same tests were assessed in controls	Small, nonsignificant increase in balance before and after intervention in both groups
Hippotherapy				
Silkwood-Sherer et al.[9]	16 children, age ≥5 y; 5 with CP, others with various disorders	6 wk, 2 times/wk, 45 min/session	PBS administered 2 times before, 1 time after intervention	Significant improvement in all 4 measures of the PBS after hippotherapy when compared with baseline for all participants
Sunwoo et al.[10]	8 adults with chronic brain disorders (e.g., CP, TBI), age ≥25 y	8 wk, 2 times/wk, 30 min/session	BBS and POMA assessed 8 wk before, immediately before, immediately after, and 8 wk after intervention	No change from 8 wk before to immediately before intervention; significant improvement immediately after intervention from baseline measures; significant improvement still evident 8 wk after intervention when compared to baseline measures
Kwon et al.[28]	92 children with CP, age ≥4 y; 45 in experimental group, 46 in control group	8 wk, 2 times/wk, 30 min/session; aerobic exercise of same frequency/duration in control group; 3 hours/wk of outside physiotherapy in both groups	PBS assessed before and after intervention	No difference in scores between groups at baseline; significant improvement in PBS score in experimental group after intervention; significant difference between groups after intervention
Kwon et al.[31]	32 children with CP, age ≥4 y; 16 in experimental group, 16 in control group	8 wk of hippotherapy (2 times/wk, 30 min/session) and conventional therapy (2 times/wk, 30 min/session) in experimental group; 8 wk of conventional therapy (2 times/wk, 30 min/session) in control group	PBS assessed before and after intervention	No difference in scores between groups at baseline; significant interaction effect between groups was observed

(*continued*)

Table 4. (Continued)

Study	Participants and groups	Duration/mode/frequency of therapy	Measures and methods	Outcomes
Silkwood-Sherer et al.[37]	15 adults with MS, age ≥24 y; 9 in experimental group, 6 in control group	14 wk, 1 time/wk, 30 min/session	BBS and POMA administered before, 7 wk into, and after intervention	Experimental group significantly improved after intervention from baseline; no change in experimental group after intervention from 7 wk into intervention; control group did not change after intervention from baseline; significant difference observed between groups after intervention
Menezes et al.[40]	11 adults with MS, age ≥32 y; 7 in experimental group and 4 in control group	4 mo, 2 times/wk, 50 min/session	Balance and stability measured using stabilometry before and after intervention	Experimental group significantly improved in postural balance after intervention with greatest reduction of oscillations occurring in A-P direction
Choi et al.[41]	10 adults with incomplete cervical SCI, age ≥27 y	Similar to Lechner et al.[42]	Static standing balance assessed using IBS before and after intervention	No significant difference after intervention compared to baseline
Giagazoglou et al.[47]	19 children with ID, age 15.3 ± 2.1 y; 10 in experimental group, 9 in control group	10 wk, 2 times/wk, 30 min/session	Double-leg stance with eyes open and eyes closed, 1-leg stance with eyes open while standing on pressure pad, assessed before and after intervention	Significant improvement observed with 1-leg stance and eyes open condition in experimental group after intervention
Beinotti et al.[45]	20 adults post-stroke, age ≥30 y; 10 in experimental group, 10 in control group	16 wk (1 time/wk) and conventional therapy (2 times/wk) in experimental group; 16 wk of conventional therapy (3 times/wk) in control group	BBS measured before and after intervention	Greater improvement observed in experimental group after intervention
de Araujo et al.[48]	17 healthy adults, age ≥60 y; 7 in experimental group, 10 in control group	8 wk, 2 times/wk, 30 min/session	Stabilometry and TUG test assessed before and after intervention	No significant difference observed in stabilometry variables in either group after intervention; significant improvement observed with TUG test performance in experimental group after intervention
de Araujo et al.[50]	28 healthy adults, age ≥60 y; 12 in experimental group, 16 in control group	Similar to de Araujo et al.[48]	BBS and TUG test assessed before and after intervention	Significant improvement observed with BBS assessment observed with experimental group after intervention; no change in TUG test performance in either group after intervention

ID, intellectual disability; SBT, standing balance test; QBT, quadruped balance test; BBS, Berg balance scale; TUG, timed up and go; POMA, performance-oriented mobility assessment; FABS, Fullerton advanced balance scale; PBS, pediatric balance scale; TBI, traumatic brain injury; IBS, interactive balance system.

Table 5. Effects of Equine-Assisted Activities and Therapies on Gait

Study	*Participants and groups*	*Duration/mode/frequency of therapy*	*Measures and methods*	*Outcomes*
Therapeutic horseback riding				
Winchester et al.[19]	5 children, age ≥6 y; diagnoses include spina bifida, autism, DS, and TBI	7 wk, 1 time/wk, 60 min/session	Gait speed assessed 2 times before, immediately after, 7 wk after intervention	No significant differences observed from before to immediately after or from before to 7 wk after intervention
MacKay-Lyons et al.[36]	10 adults with MS, age ≥25 y	9 wk, 2 times/wk, 30–45 min/session	Gait speed, stride time, stride length at free pace, fast pace assessed before and after intervention	Gait speed, stride length significantly greater at normal pace with no change in stride time in 7 participants after intervention
Hammer et al.[38]	11 adults with MS, age ≥35 y	10 wk, 1 time/wk, 30 min/session	Maximum velocity during 10-m walking test assessed before and after intervention	One participant significantly increased gait velocity after intervention
Hippotherapy				
Sunwoo et al.[10]	8 adults with chronic brain disorders (e.g., CP, TBI), age ≥25 y	8 wk, 2 times/wk, 30 min/session	10-m walking test, assessed 8 wk before, immediately before, immediately after, 8 wk after intervention	No change observed from 8 wk before to immediately before intervention; significant improvement observed from immediately before to immediately after intervention; no change observed from immediately after to 8 wk after intervention
McGibbon et al.[18]	5 children with CP, age ≥9 y	8 wk, 2 times/wk, 30 min/session	Stride length, cadence, gait velocity, assessed 8 wk before, immediately before, immediately after intervention	No significant differences were observed at any time point; a trend toward increased stride length, decreased cadence was observed
McGee et al.[23]	9 children with CP, age ≥7 y	1 session, 30–45 min	Time in swing, stance, single and double support, step length, stride length assessed before and after intervention	No significant differences observed after intervention compared with baseline
Kwon et al.[31]	32 children with CP, age ≥4 y; 16 in experimental group, 16 in control group	8 wk of hippotherapy (2 times/wk, 30 min/session) and conventional therapy (2 times/wk, 30 min/session) in experimental group; 8 wk of conventional therapy (2 times/wk, 30 min/session) in control group	Cadence, single-limb support, stride length, gait velocity assessed before and after intervention	Gait velocity increased in both groups after intervention; significant increase in stride length with no change in cadence observed in experimental group after intervention; increase in cadence observed with control group after intervention
Copetti et al.[35]	3 children with DS, age 7.3 ± 2.08 y	13 wk, 1 time/wk, 50 min/session	Angular kinematics of ankle and knee measured before and after intervention	Significant differences in ankle dorsiflexion ROM, observed in balance phase of gait after intervention
Beinotti et al.[45]	20 adults post-stroke, age ≥30 y; 10 in experimental group, 10 in control group	16 wk of hippotherapy (1 time/wk) and conventional therapy (2 times/wk) in experimental group; 16 wk of conventional therapy (3 times/wk) in control group	Cadence and gait speed measured before and after intervention	Significant improvement observed in both groups with cadence after intervention; no differences observed between groups before or after intervention

that EAAT has a residual or training effect similar to the effects generally expected from training to improve cardiovascular fitness.[72] Limited information exists on the cardiorespiratory responses to horseback riding, particularly in those with physical disabilities, in part because of a host of factors that confound measurement precision. Movements of the rider in response to the horse augment the variability. Environmental conditions, such as temperature and humidity, and the logistics of collecting respiratory data as the horse and rider move throughout a large space, add to the difficulties in characterizing the physical responses to horseback riding. Even if most of these factors are controlled for during a single measurement session, reproducing the same conditions becomes almost impossible in attempts to obtain pre and post-training measurements, which are often separated by many sessions and several weeks.

Nonetheless, because cardiovascular fitness is a central measure of physical fitness and is an independent predictor of chronic health conditions, more studies are needed to investigate whether horseback riding at a walking pace stimulates the cardiovascular system, including studies that provide data on a dose-dependent response (i.e., different walking intensities) and more measurements taken throughout the therapy.

It may be of tremendous value to clinicians to understand cardiovascular responses to various horseback riding intensities in order to compare to other ADLs and to ascertain whether cardiovascular adaptations result from EAAT as they do from consistently practiced ADLs (e.g., walking, running, and jumping). Careful planning and thoughtful control of environmental factors are critical because a variety of factors conspire to prevent reliable cardiovascular measurements during EAAT.

Considerations of the horse

The effect of EAAT on the horses is an often overlooked, but important, aspect that may affect changes observed in the rider. Although horses are typically chosen for health, passive and tractable behavior, or quality of gait, it is important to identify horses that are at risk for high levels of stress during the therapy session, leading to health and behavioral problems.[73–75] A horse used for EAAT that should be gentle and pleasant, a temperament that will have a calming effect on the rider. However, horses are social animals and respond to external stimuli that may go unnoticed by the riders or handlers, resulting in increased stress that may lead to the horse exhibiting noncompliance during EAAT sessions.[76]

Discussion

EAAT is a broad term that includes hippotherapy and therapeutic horseback riding. These forms of therapy improve gross motor function (particularly walking, running, and jumping), spasticity, and muscle asymmetry in individuals with various disorders, including CP. These physical benefits can lead to improvements in posture and balance. EAAT can also elicit modest, acute cardiovascular responses and improve components of gait, including walking velocity, stride length, and cadence. The improvements observed in gait of those who regularly engage in EAAT are thought to be related to the similarities between the motion of the rider's pelvis while sitting on a walking horse, the motion of the rider's pelvis while ambulating along a level surface, and the motion of the horse's pelvis while walking.[51,52,77]

While most studies have focused on the noticeable, physical benefits of EAAT, the literature lacks evidence as to why the benefits occur. Very little evidence exists regarding the physiologic responses to EAAT, which need to be investigated concurrently with functional testing. For example, improvements in an individual's circulatory system could affect exercise performance and thus gross motor function. Improvements in an individual's respiratory system could affect walking velocity and duration. Improvements in neuromuscular function could decrease spasticity and lead to a lower energy expenditure and less stress placed on the cardiovascular system while performing ADLs.

The existing literature have several limitations. Anestis et al. recognized and discussed many of these limitations in their recent systematic review of equine-related treatments for mental disorders.[78] Although some assessments exist, more validated, standardized, and quantitative evaluative instruments are needed, particularly for balance and posture. More stringent control over the existing instruments that rely on subjective measures is also needed (e.g., gross motor function measure, Ashworth scale). Those performing assessments using these instruments should have formal training or a form of certification before administering the tests. Inter- and intratechnician reliability measures should be reported.

Although electromyography data have been used during hippotherapy to assess activation,[22] more studies must be performed to investigate exactly which muscles are being activated and to what degree, using electromyography and motion capture. Experimental protocols and interventions during EAAT should be described in more detail. In particular, the activities performed on the horse during therapeutic interventions must be specified relative to the severity of the participant's chronic disability. For the studies that analyze cardiorespiratory data, a more comprehensive cardiorespiratory profile is needed to investigate chronic adaptive changes. Cardiorespiratory data need to be integrated with variables related to functional testing in order to improve understanding of physical changes with EAAT from a dynamic standpoint.

Control groups are not included in much of the related current literature. Future protocols should include more within-group crossover designs and more randomization of participant populations with the same chronic condition if separate groups are studied. Control groups might also be composed of those with similar disorders assigned to standard or conventional therapy.

Additional studies should provide data on children and adults with varying neuromuscular disorders and varying severity of their respective conditions, longer treatment protocols, and follow-up assessments (e.g., at least up to 1 year after therapy).

A common weakness that exists for most treatment/intervention programs is also true of equine-related programs. The differences in equine-related programs are across facilities pose a major obstacle for establishing generalizable benefits. To promote generalizability in this field, practitioners should be aware of and document how their particular programs and the measurements they obtain to establish efficacy are modified from those described in the literature.[79] Interested readers are referred to excellent discussions on the topic of program fidelity.[78,79]

In conclusion, the present body of literature provides evidence that EAAT is an effective means of improving many measures of physical health. The benefits of EAAT appear to be greatest after a multiweek intervention in which the participant rides one or more times per week. Any improvements generally begin to decrease and return to preriding levels several weeks after the riding has stopped. At present, the primary need is the undertaking of controlled trials to firmly establish the efficacy of EAAT in order to continue the promising results suggested from the limited evidence presented herein. Evidence for the efficacy of EAAT might lead to a more widespread acceptance by healthcare practitioners and therapists. This may lead to a greater demand for EAAT to be recognized as beneficial by health insurance providers and ultimately result in EAAT becoming more affordable and accessible.

Acknowledgments

All work was completed in the Baylor Laboratories for Exercise Science & Technology, Department of Health, Human Performance, and Recreation, Baylor University, Waco, TX.

Author Disclosure Statement

No competing financial interests exist.

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