THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE
Volume 0, Number 0, 2013, pp. 1–5

DOI: 10.1089/acm.2013.0207

Original Article

Therapeutic Horse Riding Improves Cognition, Mood Arousal, and Ambulation in Children with Dyspraxia

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Abstract

Objectives: The objectives of this study were to evaluate the effects of the physical motion of a horse (riding therapy) combined with the audiovisual perception of this motion on a group of children with dyspraxia in terms of cognition, mood arousal, and gait variability.
Design: The study design was a pretest/post-test.
Settings/location: The study was conducted at the Fettercairn Youth Horse Project, Fettercairn, Tallaght, Dublin.
Subjects: Forty (40) children ranging from 6 to 15 years of age with a primary diagnosis of dyspraxia were the study subjects.
Interventions: Children meeting inclusion criteria participated in six 30-minute horse-riding sessions and two 30-minute audiovisual screening sessions.
Outcome measures: A Standard Progressive Matrices test (also known as the Ravens test) was used to measure aspects of general intelligence. A Childhood Depression Inventory (CDI) questionnaire was used to assess cognitive, affective, and behavioral signs of depression. A GAITRite Pressure Mapping System analyzed foot function and gait variability by measuring single and double support, cycle time, cadence, toe in/out, and stride length.
Results: Significant improvements were evident on the Ravens test and the CDI by the end of the study period. The amount of both single and double support required while completing the walking task also was significantly reduced. Improvements were visible on toe in/out values, cycle time, and cadence. Changes in stride length did not reach statistical significance.
Conclusions: These findings support the theory that riding therapy and/or the perception of beat-based rhythms, as experienced by the rider on the horse, stimulates cognition, mood, and gait parameters. In addition, the data also pointed to the potential value of an audiovisual approach to equine therapy.

Introduction

Dyspraxia is a developmental disorder characterized by an impairment of the organization and planning of movement.[1] The condition is believed to be a result of a delay or disjoint in relaying information between the left and right cerebral hemispheres that would otherwise produce smooth, coordinated motor functions.[2] Individuals diagnosed with this disorder are not known to have other clinical neurological abnormalities in the brain but often display associated problems with language, thought, and perception.[2] Although at present there appears to be no official data identifying the number of children with dyspraxia in Ireland, according to the Dyspraxia Association of Ireland it is believed that approximately 6% of the population is affected, with cases appearing up to four times more prevalent in males than females.

The therapeutic value of horse-riding for children with special needs is well accepted and publicized widely.[3–7] However, there is a dearth of rigorous scientific evidence to support the many observations from case studies examining these therapeutic benefits. The reported physical benefits of riding therapy include increased trunk control and coordination, increased muscle tone, awareness of posture, balance and weight transference, and relaxation of tensed muscles.[3–6]

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Furthermore, the symmetrical and coordinated movement of the horse is believed to uniformly stimulate both the left and right hemisphere of the human cerebrum, a function that is impaired in dyspraxia.

For a rider, the horse's multidimensional movement closely mimics that of the human pelvis[8]; thus, it is used as a powerful physiotherapy tool for normalizing the human gait.[7] Rhythmic movement is perceived by the vestibular system,[9] which in turn stimulates the cerebellum and basal ganglia through its repetitive patterning motion.[10,11] These areas of the brain are responsible for motor control, learning, memory, attention, awareness, thought, and language.[12] Thus, cognition and movement are internally linked,[13] and studies confirm the theory that cognition conforms to the internalization of physical movement.[13,14]

Auditory rhythm perception has been shown to evoke physical movement[9,15] and is evident on a daily basis by the behavior of tapping in rhythm to music. The more predictable and regular the rhythm, the more activated the premotor and motor cortices and auditory prediction mechanism become, in order to continuously predict the rhythm and to prepare our bodies to move to it.[15] Therefore, areas of the brain activated during rhythm perception are also the same as those necessary for motion production.[10]

As auditory rhythm helps the body to synchronize its movements,[16] it can also increase the velocity of performance movement when the beat based perception is simple and regular,[17] such as that experienced by a rider on a horse.

In light of the research that supports the theory that movement and cognition are internally linked[18] combined with the known characteristic physical and cognitive impairments associated with dyspraxia, this study investigates the effects of the physical motion of a horse (riding therapy) and the audiovisual perception of this motion on a group of children with dyspraxia in terms of cognition, mood arousal, and gait variability.

Materials and Methods

Subjects

A group of 40 children with a primary diagnosis of dyspraxia were selected for this study. The group consisted of 28 boys and 12 girls, ranging in age from 6 to 15 years, recruited from Dyspraxia Ireland and social media. A condition of inclusion in the study was that subjects had not participated in horse-riding or equine therapy in the previous 12 months. Parental written consent was obtained. The study was approved by The Standing Committee on Research Ethics at Limerick Institute of Technology. In respect of all the participants, all surveys remained anonymous and all test results were handled with strict confidentiality. The riding therapy sessions took place at Fettercairn Youth Horse Project in Tallaght, Co. Dublin. This equitation center is approved by AIRE (Association of Irish Riding Establishments). A British Horse Society certified riding instructor and a first-aid responder were present during all riding sessions.

Design

The study was conducted over an 8-week period beginning in January 2012. Children were randomly divided into eight groups of five and were all assessed over a 2-day period (Thursdays and Fridays) each week. On week 1, initial assessments evaluating cognition, mood arousal, and gait analysis using standard assessment tools described below were followed by 30 minutes of an audiovisual screening of equine motion and behavior. The audio component consisted of the rhythmical sounds of horses in motion, varying in tempo to mimic the horses' changing gait. Week 2 through to week 7 consisted of a weekly 30-minute horse-riding session. Each riding session consisted of a series of games and exercises, devised to assist with balance and engagement while riding, such as stretches, steering, and walking over poles. In week 8, the children again participated in the 30-minute audiovisual screening followed by the same final assessments on cognition, mood arousal, and gait analysis. In addition to the quantitative assessments, parents were also asked on a weekly basis to fill out a simple comment/report-card questionnaire that was designed to document any changes in their child/children at home and in school throughout the 8-week period. Individual scores from the Standard Progressive Matrices test (also known as the Ravens test) and The Childhood Depression Inventories (CDIs) were calculated by a qualified child psychologist familiar with these assessment tools.

Assessment tools

The Standard Progressive Matrices, the Childhood Depression Inventory, and GAITRite Pressure Mapping System were used to quantitatively assess cognition, mood arousal, and gait analysis, respectively.

The Ravens test is a visual, multiple-choice, pattern-based test used to measure two complementary aspects of general intelligence: Educative ability (i.e., the capacity to think clearly and make sense of complex data), and Reproductive ability (i.e., the capacity to store and reproduce information). This nonverbal assessment minimized dependence on language, literacy, and/or auditory skills and was therefore appropriate for the varying cognitive abilities characteristic of dyspraxia.

The CDI is a brief, 28-item, self-report questionnaire used to assess cognitive, affective, and behavioral signs of depression by asking children to choose from one of three statements that best describe their feelings. This test is suitable for children aged 6–17 years. The questions were read to each child by a certified psychologist, to minimize any difficulties with literacy or language.

The GAITRite is an 18-foot-long floor mat system that allows for multiple sequence footsteps to be quantifiably analyzed in terms of foot function and gait. Used barefoot, it provides automatic calculations for the gait parameters of a child, by assessing stride length, cycle time, single and double support, toe rotation (in/out), cadence, and velocity. Single and double support relates to the support (in seconds) required by one (single) or two (double) feet in completing a walking task and can indicate the stability of the participants' ambulation.

Data analysis

STATA (Stata Statistical Software: Release 11, StataCorp., College Station, TX) was used to complete all analyses. All tests for significance are based on paired-samples *t*-tests. A p-value of < 0.05 was considered statistically significant.

Results

Of the 40 children who were enrolled in this study, one girl, aged 11, did not participate in the horse-riding sessions and therefore was not included in any analyses. Physical difficulties in one other girl, aged 9, did not allow for measurement of gait-related items. The mean age of the group was 8.8 ± 1.8 years. There was no significant gender difference in age ($t_{(37)} = 0.91$, $p > 0.05$).

Quantitative results

Significant improvements were noted in several domains, as shown in Table 1. Intelligence, as measured by the Ravens test, increased 39% from baseline and was highly significant at the $p < 0.0001$ level. The reliable change index, a function of the Ravens test, categorized individuals into reliably improved (51.3%) and unreliably changed (48.7%) groups. No individuals reliably deteriorated. There was no significant difference in the proportion of boys who reliably improved (57.1%) and the proportion of girls who reliably improved (36.4%) ($\chi^2 = 1.36$, $p > 0.05$).

The CDI showed significant decreases in overall scores over the 8-week period, dropping by 19% from the baseline score. Clinical cut-off scores are often used as a means of defining cases of clinical depression. Ivarsson (2006)[19] reports that cut-off points of >20 for girls and >15 for boys are indicative of depression. The present study shows that according to these cut-off points, the number of children categorized as clinically depressed fell from 4 to 2.

The main findings revealed an increase in confidence and self-worth as well as a decrease in anxiety. Distinct improvements relating to school and homework were evident, such as improved attitude and behavior, along with increased concentration and attention. Related factors such as social interaction and enjoyment also appeared to be enhanced. These findings supported the qualitative data received from the parents' weekly report questionnaire.

The GAITRite revealed that the amount of both single and double support required by the children while completing the walking task reduced significantly by the end of the study period (single, left $p = 0.0132$, right $p = 0.0046$; double, left $p = 0.0066$, right $p = 0.0093$). The angle of the foot while walking was significantly improved, in the case of the left foot ($p = 0.0410$), but this change did not reach statistical significance in relation to the right foot ($p = 0.4637$). The stride length of the right leg did significantly increase ($p = 0.0409$), and the increase in the stride length of the left leg was similar in degree to the right leg, but did not reach statistical significance ($p = 0.0517$). The time between strides (the cycle time) significantly reduced over the study period ($p = 0.0035$ and $p = 0.0064$; left and right, respectively) and the number of steps per minute, or cadence, increased significantly ($p = 0.0039$).

Qualitative reports

Weekly reports from parents revealed improvements in self-esteem, confidence, self-worth, self-awareness, anxiety, social skills, focus, empathy toward others, coordination, core stability, flexibility, mood, behavior, and motivation. Improved self-worth, motivation, and self-awareness were noted as being the most common reoccurring themes.

Parents reported an increased sense of pride and self-worth exhibited by their children through their involvement in the study and their ability to handle such large animals. In turn, a degree of increased sociability and confidence with their peers, when talking about their participation in the study, was also recorded. Parents further noted an increased motivation for participating in and attempting new tasks and hobbies, which they felt the children would not have attempted previously.

Parents also noted that children reflected an increasing degree of self-awareness and self-regulation throughout the study, with many reporting a reduction in their child's reactivity to situations that would normally spark a negative emotional reaction. According to parents, children appeared more rational and less temperamental or tearful, both at school and at home. Although parents also reported children as being calmer and less anxious following the equine sessions, this effect was only noted to last for 2–3 days.

Finally, parents also reported considerable improvements regarding behavior and attitude in school. In particular,

Table 1. Mean Scores and Mean Difference of All Measures Taken at the Start and at the End of the Study Period in All 39 Children Who Completed the Therapeutic Riding and Audiovisual Screening Sessions

Measure	n	*Pretest (SD)*	*Post-test (SD)*	*Difference (SD)*	*Significance*
Raven (Progressive Matrices)	39	24.3 (9.1)	33.7 (9.2)	9.4 (7.6)	**0.0000**
CDI (Childhood Depression Inventory)	39	7.7 (5.6)	6.2 (4.5)	1.5 (4.1)	**0.0267**
Single support left (GAITRite)	38	0.39 (0.05)	0.37 (0.04)	0.02 (0.04)	**0.0132**
Single support right (GAITRite)	38	0.40 (0.06)	0.37 (0.04)	0.02 (0.05)	**0.0046**
Double support left (GAITRite)	38	0.21 (0.05)	0.19 (0.05)	0.02 (0.04)	**0.0066**
Double support right (GAITRite)	38	0.02 (0.05)	0.19 (0.04)	0.02 (0.05)	**0.0093**
Toe in/out left (GAITRite)	38	1.09 (7.8)	−0.34 (8.0)	1.43 (4.15)	**0.0410**
Toe in/out right (GAITRite)	38	1.62 (8.0)	1.14 (7.7)	0.48 (4.0)	0.4637
Stride length left (GAITRite)	38	109.2 (16.7)	113.6 (17.0)	4.4 (13.5)	0.0517
Stride length right (GAITRite)	38	109.3 (16.9)	113.9 (16.9)	4.5 (13.2)	**0.0409**
Cycle time left (GAITRite)	38	1.00 (0.14)	0.93 (0.11)	0.06 (0.13)	**0.0035**
Cycle time right (GAITRite)	38	1.00 (0.14)	0.94 (0.11)	0.06 (0.13)	**0.0064**
Cadence (GAITRite)	38	122.1 (17.0)	130.0 (15.2)	7.9 (15.8)	**0.0039**

All tests for significance are based on paired samples *t*-tests. Significant changes at $p < 0.05$ level appear in bold.
SD, standard deviation.

lower anxiety levels and more focused attitudes were evident in both school activities and homework.

Discussion

This study set out to investigate the effects of the physical motion of a horse (riding therapy) and the audiovisual perception of this motion on the cognition, mood arousal, and gait variables within a dyspraxic test group. Importantly, this is the first study to examine the combined effects of equine therapy and audiovisual beat-based perception on the characteristic symptoms of dyspraxia in Irish children. We show for the first time that such equine therapeutic intervention quantitatively improves multiple components of these variables in a subset of children diagnosed with dyspraxia in Ireland.

Within the available literature there are numerous aspects of the horses' unique motion that potentially account for the significant findings observed in this study. By nature, the horses' ambulation is rhythmical and beat based, either by a two-beat, three-beat, or four-beat motion. Grahn and Brett (2007)[10] determined that perception of a regular beat-based rhythm has an effect on the brain by activating the basal ganglia (learning, memory, awareness), the supplementary and presupplementary motor area (control of movement), the cerebellum, the insula (integrates autonomic information to the limbic system), and the superior temporal gyrus (involved in the perception of emotions in facial stimuli). This activation was also confirmed in studies by Bengtsson et al. (2008).[15] The ability of the human brain to perceive time-based stimuli is fundamental for a wide range of behaviors such as prediction of movement, performance, and language,[15] and the perception of beat-based rhythms stimulate this timing mechanism.[15] Fundamentally, the presence of a beat in learning can influence the ability of an individual to remember and perform a task.[10]

Considering that horse-riding is a physical intervention, which delivers its impact directly to the human pelvis, and in light of the highly significant findings obtained from the Ravens test, it appears this study further supports an internal link between movement and cognition.[13]

The primary stimulation for brain maturation comes from the vestibular system.[9] As one of the oldest cerebral systems, both in phylogeny[20] and ontogeny,[21] the vestibular system is the first system to develop in the cerebrum of an embryo and therefore plays a major role in the development of the other senses.[9] Furthermore, because hearing a rhythm evokes a physical movement and stimulates the vestibular system[10] and rhythmic perception stimulates the areas of the brain that are necessary for motor function,[11] it further subscribes to the generally understood internal link between movement and cognition. In addition, rhythmical movement influences memory and cognition[18]; thus, the perception of beat-based rhythms not only stimulates time-based movement[15] and performance velocity,[10] but it also plays an important role in learning.

This not only potentially accounts for the significant improvements in cognition as evident by the findings of the Ravens test, but it also further supports the results of the CDI, which revealed an overall significant decrease in indicators of depression by the end of the study period, with the main findings indicating an increase in confidence and self-worth as well as a decrease in anxiety. Distinct improvements relating to school and homework were evident, such as improved attitude and behavior, along with increased concentration and attention. Related factors such as social interaction and enjoyment also appeared to be enhanced.

Perception of beat-based rhythms not only helps the body to synchronize its movements[16] and increase performance velocity,[10] it also stimulates memory and cognition to continue to restimulate the correct motion pattern.[22] In this experiment, significant reductions in single and double support were evident. The angle of the foot while walking improved, as did cycle time and cadence, indicating improved balance.

It is possible that the stimulation to the vestibular system as experienced during the riding sessions not only improved balance and stability, but the movement of the horse also stimulated a more "normal" walking pattern. Gait velocity is a recognized clinical measurement and is determined by both physical motor function[23] and cognitive ability,[24] and it has been determined that attention is needed in order to control gait variability and speed.[14] The significant cognitive improvements and the increase in gait velocity as seen in this study correlates with this theory and supports the concept that an improvement in cognitive ability can generate an improvement in physical abilities.

It is known that the sensory experience of hearing a rhythm can evoke physical movement,[10,16] and the presence of a beat in a learning context may influence the ability of an individual to remember and perform a task.[10] It is therefore reasonable to suggest that the use of audiovisual stimulation in this study may have contributed to the considerable increase in both gait velocity and cognitive ability observed. However, limited numbers prevented the separation of audiovisual treatment and riding therapy test groups, so it was not possible to quantify the relative contribution of each stimulus in this study. While the audiovisual potentially confound the results, the authors are currently planning an additional, more comprehensive study to differentiate potential contributions from beat perception via audiovisual stimuli alone.

Nevertheless, Trainor et al. (2008)[9] determined that only a "sense" of movement, and not actual physical bodily movement, is sufficient to stimulate the vestibular system and that the encoding of a rhythm can also be influenced and stimulated by passive motion through auditory or visual perception of that motion.[18,25] Thus, there is strong evidence to support the potential for an audiovisual approach to equine therapy.

Future studies are warranted to determine the effectiveness of audiovisual equine movement stimuli alone on cognition, mood, and gait variability in children with dyspraxia. If shown to be effective, an audiovisual therapeutic equine intervention could potentially contribute greatly to the education system for children with disabilities by providing cognitive, physical, behavioral, and emotional benefits.

Conclusions

The perception of beat-based rhythms is thought to stimulate memory, attention, and cognition,[10,15] as well as performance velocity[10] and correct motion pattern synchronization.[16,22] The significant increase in cognitive functioning evident in this study, as a result of combined

natural beat-based rhythms of equine motion and audiovisual stimulation, supports these hypotheses. Furthermore, improvements in gait, with reduced single and double support along with increased cadence and cycle time, also conform to the beat-based perception theory. Combined with supported theories of the internal link between cognition and movement,[18] there is considerable support for the potential of equine therapy in the treatment of both gait and cognitive disabilities/illnesses.

Acknowledgments

The authors wish to thank Laurence McFerran and Fettercairn Youth Horse Project for their help and support in providing the use of their venue, staff, and horses in the implementation of this experiment. A sincere thank you is extended to David Watterson, (clinical manager of Merlin Park Podiatry Clinic and honorary clinical NUIG fellow) on providing the gait analysis software and equipment; Dyspraxia Ireland; the volunteers; and all the parents and children who participated in the study.

Disclosure Statement

No competing financial interests exist.

References

1. McKinlay I. Foreword: What is "dyspraxia"? In: Hunt R, ed. Praxis Makes Perfect II. Hitchin, UK: Dyspraxia Foundation, 1998:9.
2. McCance KL, Huether SE. Pathophysiology, The Biological Basis for Disease in Adults and Children. St. Louis, MO: Mosby, 1994.
3. Cuypers K, De Ridder K, Strandheim A. The effect of therapeutic horseback riding on 5 children with attention deficit hyperactivity disorder: A pilot study. J Altern Complement Med 2011;17:901–908.
4. Casady RL, Nichols-Larsen DS. The effect of hippotherapy on ten children with cerebral palsy. Pediatr Phys Ther 2004;16:165–172.
5. McGibbon NH, Andrade CK, Widener G, Cintas HL. Effect of an equine-movement therapy programme on gait, energy expenditure and motor function in children with spastic cerebral palsy: A pilot study. Dev Med Child Neurol 1998;40:754–762.
6. Yack H, Bartels C, Irlmeier J, et al. The effects of therapeutic horseback riding on the quality of balance control in children with attention disorders. Sci J Ther Riding 1997;3:3–9.
7. Benda W, McGibbon NH, Grant K. Improvements in muscle symmetry in children with cerebral palsy after equine-assisted therapy (hippotherapy). J Altern Complement Med 2003;9:817–825.
8. Fleck CA. Hippotherapy: Mechanics of the human walking and horseback riding. In: Engel B, ed. Rehabilitation with the Aid of a Horse: A Collective of Studies. Durango, CO: Barbara Engel Therapy Services, 1997:153–176.
9. Trainor L, Gao X, Lei J, Lehotovaara K. The primal role of the vestibular system in determining musical rhythm. Cortex 2009;45:35–43.
10. Grahn J, Brett M. Rhythm and beat perception in the motor areas of the brain. J Cogn Neurosci 2007;19:893–906.
11. Lewis PA, Wing AM, Pope PA, et al. Brain activity correlates differentially with increasing temporal complexity of rhythms during initialisation, synchronisation and continuation phases of paced finger tapping. Neuropsychologia 2004;42:1301–1310.
12. Doya K. Complementary roles of basal ganglia and cerebellum in learning and motor control. Curr Opinion Neurol 2000;10:732–739.
13. Middleton F, Strick F. Cerebellar output: Motor and cognitive channels. Trends Cogn Sci 1998;2:348–354.
14. Yogev G, Giladi N, Peretz C, et al. Dual tasking, gait rhythmicity, and Parkinson's disease; which aspects of gait are attention demanding. Eur J Neurosci 2005;22:1248–1256.
15. Bengtsson SL, Ullén F, Ehrsson H, Hashimoto T, et al. Listening to rhythms activates motor and premotor cortices. Cortex 2009;45:62–71.
16. Kwak EE. Effect of rhythmic auditory stimulation on gait performances in children with spastic cerebral palsy. J Music Ther 2007;44:198–216.
17. Grahn J. The role of the basal ganglia in beat perception. Neurosci Music III Disord Plasticity 2009;1169:35–45.
18. Phillips-Silver J, Trainor L. Hearing what the body feels: Auditory encoding of rhythmic movement. Cognition 2007;105:533–546.
19. Ivarsson T, Svalander P, Litlere O. The Children's Depression Inventory (CDI) as measure of depression in Swedish adolescents: A normative study. Nord J Psychiatry 2006;60:220–226.
20. Walls GL. The evolutionary history of eye movements. Vision Res 1962;2:69–79.
21. Romand R, ed. Development of Auditory and Vestibular System. New York: Elsevier, 1992.
22. Desmond J, Fiez J. Neuroimaging studies of the cerebellum: Language, learning and memory. Trends Cogn Sci 1998;2:355–362.
23. Gerin-Lajoie M, Richards CL, McFadyen BJ. The circumvention of obstacles during walking in different environmental contexts: A comparison between older and younger adults. Gait Posture 2006;24:364–369.
24. Persad CC, Jones JL, Ashton-Miller JA, et al. Executive function and gait in older adults with cognitive impairment. J Gerontol A Bio Sci Med Sci 2008;63:1350–1355.
25. Phillip-Silver J, Trainor L. Vestibular influence on auditory metrical interpretation. Brain Cognition 2008;67:94–102.

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