Changes in Dynamic Trunk/Head Stability and Functional Reach After Hippotherapy

Tim L. Shurtleff, OTD, OTR/L, John W. Standeven, PhD, Jack R. Engsberg, PhD


Objectives: To determine if hippotherapy (therapy using a horse) improves head/trunk stability and upper extremity (UE) reaching/targeting in children with spastic diplegia cerebral palsy (SDCP).

Design: Pre-postoperative follow-up with a 12-week intervention and 12-week washout period after intervention.

Setting: A human performance laboratory with 6 camera video motion capture systems for testing.

Participants: Eleven children (age 5–13y, average 8y) with SDCP, 8 children (age 5–13y, average 8y) without disabilities.

Intervention: Hippotherapy intervention performed at 3 therapeutic horseback riding centers.

Main Outcome Measures: Video motion capture using surface markers collecting data at 60Hz, a mechanical barrel to challenge trunk and head stability, and functional reach/targeting test on static surface.

Results: Significant changes with large effect sizes in head/trunk stability and reaching/targeting, elapsed time, and efficiency (reach/path ratio) after 12 weeks of hippotherapy intervention. Changes were retained after a 12-week washout period.

Conclusions: Hippotherapy improves trunk/head stability and UE reaching/targeting. These skills form the foundation for many functional tasks. Changes are maintained after the intervention ceases providing a skill foundation for functional tasks that may also enhance occupational performance and participation.

Key Words: Cerebral palsy, diplegic; Equine; Head movements; Horse; Occupational therapy; Physical therapy; Posture; Rehabilitation; Spastic; Upper extremity.

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In a hippotherapy session, a therapist uses a horse and its movement as well as the barn/farm/psychosocial environment to challenge multiple body systems in the client to accomplish specific therapeutic goals determined to be important during preintervention assessments. Hippos is the Greek word for horse, and hippotherapy is therefore defined as therapy using a horse.1,2 Children with SDCP often struggle with head/trunk stability, even during reaching and functional tasks3 and are frequent recipients of hippotherapy.

Beliefs about the positive effects of hippotherapy are strongly held.4,5 Anecdotal evidence and several studies support the benefits of hippotherapy for people with CP (eg, improvements in walking, gross motor improvements and reduction of motor disability,6 decreased energy expenditure and increased efficiency while walking,7 improvements in muscle symmetry,8 gross motor and functional performance,9 and gait speed and gross motor performance).10 Haehl et al11 showed improvement in the coordination of the movement of the upper and lower trunk in the sagittal plane with 2 children with CP after 12 weeks of hippotherapy. Bertoti12 showed improvements in trunk stability, strength, balance, and muscle tone after therapeutic horseback riding in 11 subjects. Our pilot study also found improvements in head and trunk control in 6 children with CP.13

CP refers to nonprogressive syndromes characterized by impaired voluntary movement or posture and resulting from prenatal developmental malformations or perinatal or postnatal central nervous system damage. Syndromes manifest before 5 years of age. CP causes nonprogressive spasticity, ataxia, or involuntary movements; it is not a specific disorder or single syndrome. CP syndromes occur in 0.1% to 0.2% of children and affect up to 15% of premature infants.14 In SDCP, the lower extremities are more involved than the UEs, and the trunk is often also affected. The degree of disability for children with CP is described by the GMFCS, a 5-level system in which GMFCS-V level cannot sit upright or ambulate independently.15

Children with spastic CP also have difficulties in fine-tuning postural muscle contraction to task specific conditions during reaching and show an excess of antagonistic coactivation and difficulties with subtle modulation of postural activity.16 This trunk instability contributes to the instability of the proximal foundation of the UEs of children with CP. This proximal instability at the shoulder may reduce their distal control, causing them difficulties with reaching and targeting during functional tasks. Clinical options to address UE control may use a stable seated position to isolate UE motor control and strength. Although UE control may improve, underlying prox-

List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>C7</td>
<td>cervical vertebrae 7</td>
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<tr>
<td>CP</td>
<td>cerebral palsy</td>
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<tr>
<td>GMFCS</td>
<td>Gross Motor Function Classification System</td>
</tr>
<tr>
<td>L5</td>
<td>lumbar vertebrae 5</td>
</tr>
<tr>
<td>OT</td>
<td>occupational therapy</td>
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<tr>
<td>PT</td>
<td>physical therapy</td>
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<tr>
<td>ROM</td>
<td>range of motion</td>
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<tr>
<td>SDCP</td>
<td>spastic diplegia cerebral palsy</td>
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<tr>
<td>T10</td>
<td>tenth thoracic vertebrae</td>
</tr>
<tr>
<td>UE</td>
<td>upper extremity</td>
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</table>

From the Human Performance Laboratory, Program in Occupational Therapy, Washington University School of Medicine, St. Louis, MO (Shurtleff, Standeven, Engsberg); and Therapeutic Horsemanship, Inc, Wentzville, MO (Shurtleff). Supported by the Horses and Humans Research Foundation (HHRF2006). No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated. Correspondence to Tim L. Shurtleff, OTD, OTR/L, Washington University School of Medicine, Program in Occupational Therapy, 4444 Forest Park, St. Louis, MO 63110; e-mail: shurtleff@wusm.wustl.edu. Reprints are not available from the author.

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T R U N K  S T A B I L I T Y /  R E A C H I N G  P O S T  H I P P O T H E R A P Y ,  S h u r t l e f f

Imai stability is not targeted and will be only minimally affected if not challenged. As an example, a very common clinical option to address core strength and trunk stability for children with CP is to use Swiss ball exercises. Children often sit on the ball independently and perform exercises or task-related activities. They may also sit, lie prone, or supine across the ball while being moved by the therapist to build core strength and postural responses. Although this can be effective, the limitation in this application is that the time and repetitions typically last only a few minutes or a few sets of repetitions. Although such activities might address core strength and proximal stability, it would be rare indeed for a child to tolerate being moved about on a Swiss ball for 45 minutes or for a therapist to be able or willing to move a child rhythmically and consistently for such a long session in the clinic. In contrast to this, during a hippotherapy intervention, a mounted client experiences several thousand horse strides (3-dimensional challenges to trunk and head stability) in a 45-minute session. The child also typically changes positions during the session so different motor units can be targeted. During hippotherapy, in addition to this rhythmic movement of the horse’s gait, the horse also moves less predictably through space (eg, stopping and starting, turning circles, weaving cones, or negotiating terrain). This added vestibular and anticipatory challenge is further claimed by those who use horse movement for therapeutic effect to further challenge and train clients to improve motor control and functional ability. The motivation and the "fun" of riding a horse may be an even more important consideration. It is the addition of this meaningful and motivating aspect of hippotherapy to an intense exercise regimen that may contribute much of the power of the hippotherapy intervention.

Many sport-related activities are also available to children with CP and are also believed to help (eg, adapted skiing, sledge hockey, martial arts, and so on). Literature to date to support those beliefs is limited. However, it seems that any intervention that directly addresses postural stability, if effective, may also positively impact many aspects of functional competence and occupational performance.

No investigations have objectively quantified changes in both head/trunk control and in functional reaching/targeting as a consequence of hippotherapy. We believe that such objective data can augment the clinical rating scales and measures used in many of the previous investigations. As a primary research question, we wanted to provide objective evidence to support or refute efficacy of hippotherapy, an intervention that has been claimed for many years to address the basic problem of trunk/head instability, thus providing a foundation on which many other functional skills could be improved. The purpose of this investigation is to quantify changes in head/trunk stability and reaching speed/efficiency as a consequence of hippotherapy intervention.

METHODS

Participants

Eleven children with SDCP were recruited (table 1). Inclusion criteria included prior diagnosis of SDCP from their personal physicians, between 5 and 17 years old, able to sit up right unaided on a static surface, intact receptive communication, ability to follow directions, ability to abduct hips to sit astride a horse and the testing device, and available for up to 26 weeks. Participants’ personal physicians approved participation. The Human Studies Committee (Institutional Review Board) of Washington University School of Medicine and the Institutional Review Board of St. Louis University approved the study. All participants and parents signed assent or consent forms.

Excluded were children with any significant history of riding horses, defined as not having participated in hippotherapy, therapeutic riding or any riding lessons, or having frequently or regularly ridden horses in an informal/nonlesson setting. We did not exclude children who had taken 1 or 2 pony rides at a park or ridden briefly once or twice (ie, on a relative’s or family friend’s farm) because we believed that would make it too difficult to recruit sufficient subjects and we did not anticipate that such a limited exposure would make a real difference in the variables we were measuring. As it turned out, none of the children had ridden a horse in over a year, and most had never ridden horses. We also excluded other neuromuscular impairments; cognitive, attentional, sensory, or psychosocial diagnoses making them unable to follow direction; uncorrected visual impairments; and recent injection of botulinium toxin (6mo), surgery (1y), or any planned medical or surgical interventions to modify effects of CP during the period of the study. All participants were screened for precautions and contraindications for therapeutic riding listed by the North American Riding for the Handicapped Association and judged to be safe to participate in hippotherapy. Most study participants with CP were previously referred by their physicians for PT or OT and received therapy in other contexts that continued during the period of the study. They were recruited for the study and then approved by their physicians so hippotherapy could be performed after a new evaluation by a physical therapist or an occupational therapist familiar with hippotherapy.

After the subjects with SDCP were recruited, 8 children without disabilities were recruited to match the ages of the

<table>
<thead>
<tr>
<th>Table 1: Participant Recruitment Table</th>
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<tr>
<td><strong>Participants</strong></td>
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<tr>
<td><strong>CP Group</strong></td>
</tr>
<tr>
<td><strong>Participants</strong></td>
</tr>
<tr>
<td>1 M 5 II</td>
</tr>
<tr>
<td>2 F 5 IV</td>
</tr>
<tr>
<td>3 M 5 I</td>
</tr>
<tr>
<td>4 F 6 III</td>
</tr>
<tr>
<td>5 M 7 I</td>
</tr>
<tr>
<td>6 M 8 II</td>
</tr>
<tr>
<td>7 M 8 II</td>
</tr>
<tr>
<td>8 F 9 III</td>
</tr>
<tr>
<td>9 M 12 II</td>
</tr>
<tr>
<td>10 F 12 III</td>
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<tr>
<td>11 F 13 IV</td>
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<tr>
<td><strong>Total in CP group</strong></td>
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<tr>
<td>6 boys 8.18 average age 2.994 SD</td>
</tr>
<tr>
<td>5 girls</td>
</tr>
<tr>
<td><strong>WD</strong></td>
</tr>
<tr>
<td><strong>Participants</strong></td>
</tr>
<tr>
<td>12 M 5 WD</td>
</tr>
<tr>
<td>13 M 5 WD</td>
</tr>
<tr>
<td>14 F 7 WD</td>
</tr>
<tr>
<td>15 M 7 WD</td>
</tr>
<tr>
<td>16 M 7 WD</td>
</tr>
<tr>
<td>17 M 9 WD</td>
</tr>
<tr>
<td>18 F 12 WD</td>
</tr>
<tr>
<td>19 F 13 WD</td>
</tr>
<tr>
<td><strong>Total in WD group</strong></td>
</tr>
<tr>
<td>5 boys 8.13 average age 2.997 SD</td>
</tr>
<tr>
<td>3 girls</td>
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</tbody>
</table>

Abbreviation: WD, without disability.
children with CP (see table 1). They each completed the test battery once. Their results provided data for typically developing children as a normative comparison with the CP group. They were compensated for their participation ($25) but received no intervention because they did not have the impairment that the intervention was intended to address and an intervention would have little meaning.

**Intervention**

The intervention (45 minutes on a horse, 1 time/wk for 12 weeks) began with an OT/PT evaluation to identify specific impairments and develop a unique treatment. The intervention was conducted by licensed occupational or physical therapists experienced with hippotherapy. Horses were selected for size and movement characteristics to challenge participants but not overwhelm them. Interventions were performed by physical therapists, occupational therapists, or certified occupational therapy assistants at 3 local therapeutic riding centers. All of them received training from the American Hippotherapy Association to become registered with the North American Riding for the Handicapped Association as level II hippotherapy therapists. All 3 therapeutic riding centers are Premier Accredited Centers with the North American Riding for the Handicapped Association. In the local centers in which hippotherapy was performed, physical therapists and occupational therapists have trained together and have developed a broad overlap in the use of intervention tools for hippotherapy. In this context at these centers, it is difficult to distinguish a PT from an OT treatment, and both used tools from either specialty to give these children what they needed, based on their initial evaluation and goal setting. The common denominator between all of the treatment plans was 45 minutes mounted on a moving horse in walk and/or trot performing various positions (eg, forward astride, side sit, tall kneel, reverse astride, quadruped), often with transitions between positions and sometimes while the horse was moving. This was not a riding lesson, and the participant had no control of the horse. Horses were led by an experienced leader. The therapist and trained side walkers walked alongside assisting and coaching the child in positions and activities and ensuring safety. UE activities, stretches, cognitive games, and exercises were included. As a few examples, stretches might include reaching forward up the neck to place clips in the mane or rings on the horse’s ears. The child might also stretch down to touch his/her feet or back to touch the horse’s tail. Activities and games included catching, throwing, and placing balls, rings, and toys as directed by the therapist. Reaching to grasp objects while sitting or kneeling on a moving horse and then placing them onto a stationary surface, or to/from a therapist (who may be using a reacher) further challenges reaching into all planes while riding. Cognitive games might include memory or recognition games in which the child would identify; search for and find objects, letters, and/or toys around the arena; and remember where they were so he/she could go back to find them. They might change gait or position while moving toward each new object. All of these and other activities were performed while on a moving horse. The horse varied speed and gait during the activity or perform a school figure (circle, weave cones, and so on) while the child was engaged in a fun and meaningful task. This integrates the effect of the rhythmic movement and the vestibular effect of the school figures with UE tasks while responding to a cognitive challenge.

Hippotherapy is believed by those who do it to integrate these basic skills of stability and balance with the more refined skills (functional and cognitive tasks). This integration is considered by those who do hippotherapy to be one of its strengths. Therefore, there was no attempt to separate training that targeted only stability from the UE tasks that might affect the functional reaching test because both were considered goals of the hippotherapy treatment and were most effectively targeted simultaneously. Even the school figures consisting of straight lines, large and small circles, weaving cones, and riding on challenging terrain were performed with transitions between gaits and speeds. This further challenged the children to integrate their motor abilities with meaningful tasks and fun experiences.

**Outcome Assessment Testing**

Outcome testing was performed within 2 weeks before beginning the hippotherapy intervention, within 2 weeks after completion, and 12 to 14 weeks postintervention. During the washout period, the children did not ride horses but continued any other ongoing activities or therapies.

**Video Motion Capture Data Collection**

**Barrel test.** A mechanical barrel (fig 1) was used to assess the control of head and trunk movement. The barrel was an 18-gal plastic drum covered with 1-inch thick neoprene, a wool saddle blanket, and 2-inch strips of Velcro, giving a finished diameter of 18 inches. Foam blocks were affixed to the Velcro strips around the hips and thighs to stabilize the pelvis for positioning and safety. The barrel had 1 translational degree of freedom with an amplitude of 16cm. It moved on wheels in an internal steel track that was supported on inverted T-legs and was powered by a variable speed 0.25 horsepower, DC, variable speed gear motor. The reciprocating speed was variable from 0 to 1Hz. A spotter sat on each side of the barrel during each test to ensure participant safety. The mechanical barrel

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**Fig 1. Child with surface markers sitting on testing barrel with spotters low on side. One (of 6) cameras in the background.**

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provided a precisely replicable testing motion to challenge and test trunk/head stability in a reliable manner.

Nineteen reflective surface markers (4mm) were placed on the head and trunk of each participant (table 2) for video motion capture. Four markers were placed on the barrel to establish a barrel frame of reference. Each subject rode the barrel in the astride position for 2 trials at a reciprocating speed of 1Hz. A 6-camera video motion capture system (EvaRealTime® V. 5.0.4 using MAC Eagle Digital Cameras®) captured the movement of the surface markers during 15-second interval trials. The video motion capture software created a stick figure or “tinkertoy” image (fig 2) that could be rotated in all planes to observe recorded movement during a testing time series from any viewpoint. To ensure consistent marker placement on trunk and UEs, markers were placed on bony landmarks or placed proportionately between bony landmarks per our lab protocol. Marker placement reliability in our laboratory for a single person applying the markers during an investigation has been shown to be excellent (r = 0.95). Test-retest reliability within a single session for the video motion capture barrel test was also excellent (r = 0.94).

During testing, the child was given a ball or small stuffed toy and asked to hold it with both hands in front of the abdomen. This put the arms in adduction with elbows flexed and slightly internally rotated. This put all children into a similar arm position, kept them from supporting themselves with UEs, and reduced protective extension when barrel movement started. It also avoided random arm movements from blocking reflective markers. The child was asked to look at a target (a drawing of a stick figure or “tinkertoy” image) that could be rotated in all planes to observe recorded movement during a testing time series from any viewpoint. To ensure consistent marker placement on trunk and UEs, markers were placed on bony landmarks or placed proportionately between bony landmarks per our lab protocol. Marker placement reliability in our laboratory for a single person applying the markers during an investigation has been shown to be excellent (r = 0.95). Test-retest reliability within a single session for the video motion capture barrel test was also excellent (r = 0.94).

Data Analysis

Surface marker data were tracked and edited to produce 3-dimensional coordinates as a function of a time series. Approximately 15 cycles were obtained for each trial yielding about 30 cycles of data for a test. However, only the last half (7.5s) of each trial was used after the barrel had reached a constant reciprocating speed of 1Hz. Data were imported into a spreadsheet for analysis.

Dynamic stability in the sagittal plane was defined as the ability to keep the head and trunk relatively stable while the pelvis was in motion. Two sets of sagittal plane variables were determined from the tracked data: (1) head angle and (2) anterior posterior translation of the spine and head. Five markers on the head and trunk (see fig 2) and 2 on the barrel were used for this anterior/posterior head angle and translation analysis (Vertex, Cyclops, C7, T10, L3, horse left fore, horse left hind).

Table 2: Anatomic Landmarks for Head/Trunk Markers for Barrel Test

<table>
<thead>
<tr>
<th>Vertex</th>
<th>R Zygomatic Arch</th>
<th>L Zygomatic Arch</th>
<th>R Acromion</th>
<th>L Acromion</th>
<th>Offset R Scapula</th>
</tr>
</thead>
<tbody>
<tr>
<td>C7</td>
<td>Sternum</td>
<td>T4</td>
<td>T7</td>
<td>T10</td>
<td>R midclavicle</td>
</tr>
<tr>
<td>L midclavicle</td>
<td>L1</td>
<td>L5</td>
<td>R iliac crest</td>
<td>L iliac crest</td>
<td>R midclavicle</td>
</tr>
<tr>
<td>L greater trochanter</td>
<td>Horse RF</td>
<td>Horse LF</td>
<td>Horse RH</td>
<td>Horse LH</td>
<td>L greater trochanter</td>
</tr>
</tbody>
</table>

Table 3: Additional Markers for Upper-Extremity Functional Reach Placed on Both Right and Left Upper Extremity

<table>
<thead>
<tr>
<th>Proximal Humerus (middeltoid)</th>
<th>Lateral Epicondyly</th>
<th>Medial Epicondyly</th>
<th>Mid Humerus (biceps)</th>
<th>Radial Styloid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnar styloid</td>
<td>Distal 3rd metacarpal</td>
<td>Distal 1st metacarpal</td>
<td>Distal 2nd phalange (index fingertip)</td>
<td></td>
</tr>
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</table>

Fig 2. Markers as seen in video capture software in computer, showing markers used for analysis.
The head angle analysis compared the maximum and minimum angle of the head relative to the horizontal over a time series. Head angle was the angle of the Vertex-C7 line compared with a horizontal line represented by a front and back barrel marker (horse left fore and left hind). The maximum angle was the largest angle over several movement cycles (most vertical head or beyond vertical into extension), and the minimum was the least angle over the same time series (most flexion). The difference was described as the ROM of the head over the 7.5-second time series of the test. The standard deviation of all of the angle measurements over the 7.5-second time series was also used as a variable itself because it effectively described the degree of variability of head angle over several (7–9) movement cycles.

Translation was quantified by using the markers at the vertex, a virtual marker calculated between the eyes (the “Cyclops eye”), and markers at C7, T10, and L5 (top, middle, and bottom of spine) (see fig 2). The average horizontal translation of these markers was determined. One barrel marker quantified the movement of the barrel (horse) as the challenge to the subject. Differences in barrel movement noted are within the precision of the video motion capture measurement tool (±0.5mm). The specific variables were the maximum amplitudes of horizontal translations of each marker averaged across a 7.5-second movement cycle.

For the reaching test, every child performed 3 reaches forward (see fig 3) and 3 to the side (see fig 4) with each arm at the “easy reach” distance (no trunk movement required) and the “extended reach” distance (plus 10 or 15cm). This yielded 24 reaching trials at each testing time. In a few cases, trials were thrown out when data were not clear or the child used a different movement than that requested. The elapsed time was calculated as the time from the beginning of movement from resting position to first touch. Reach/path ratio was calculated as the sum of the distances moved by the index finger marker between all observations (60 frames per second) from rest to touch and divided by the straight line distance from the initial resting position to the target. The elapsed time and reach path ratio were averaged for all of the good trials. Those 2 average numbers aggregated the elapsed time and reach path ratio for that testing period for each child. These numbers were used for statistical analysis between pretest, the first postintervention test immediately after hippotherapy intervention ceased, and the second postintervention (washout) test 12 weeks after hippotherapy ceased and were averaged for the groups of subjects for each testing time for graphics. The group without disability was only measured once. A horizontal dashed line was placed on the graphs indicating the without disability result as a “typically developing” normative comparison.
Statistical Analysis

Results were entered into SPSS V16. A repeated-measures analysis of variance was used to compare absolute head angle, translation, and functional reach variables at 3 time points before and after hippotherapy for the group with CP with an a priori significance level of $\alpha=0.05$. The same variables were determined for the without-disability participants. The 1-time without disability baseline results were compared with pretest, the first postintervention test immediately after hippotherapy intervention ceased, and the second postintervention (washout) test 12 weeks after hippotherapy intervention ceased for the participants with CP by using independent samples $t$ tests.

Effect sizes (Cohen’s $d$) were calculated by using a pooled standard deviation to compare the results of the intervention between test times. The effect size interpreted as $d=0.2$ is a small change, $d=0.5$ is a moderate change, and $d>0.8$ is a large change and is described as “grossly observable” and can be interpreted to indicate clinical change. Positive effect sizes are movements in the anticipated or positive direction. Negative effect sizes indicate regression.

RESULTS

Eleven children with SDCP completed the intervention and the pretest and first postintervention test. Ten children with SDCP completed the second postintervention (washout) test. One child failed to return; the family did not respond to several contact attempts. His data were kept in the results for the pre-first postintervention test, but the washout results were calculated without him.

Head Angle

The head angle results showed a significant change in head control between pre- and posttests that was maintained after the washout period. The significant changes in SD, ROM, and minimum head angle were maintained after the washout period (figs 5–7). There were no significant changes between the first postintervention test and the second postintervention tests on these variables. The changes in the average minimum angle between the pretest and first postintervention test were significant with a large effect size, but they were not significantly different between the first postintervention test and the second postintervention test. The significant changes in SD and ROM also showed very large effect sizes (table 4). The first postintervention/second postintervention differences that were not significant also showed very small effect sizes.

Anterior Posterior Translation

The results for the translation analysis show a reduction in movement for all participants as the markers moved away from the barrel and toward the head (fig 8). Thus, $L_5$ only varied a small amount compared with the translation of the barrel because it is so close to the barrel. At $T_{10}$ and $C_7$ and the markers on the head (Cyclops and Vertex), there was much more reduction in translation between the pre- and posttests. There are 2 key results. The first key result is that there was a significant reduction in horizontal translation at $C_7$, at the Cyclops eye, and the Vertex in the CP group after the hippotherapy intervention. This change was maintained in the second intervention test after the washout period. The second key

![Fig 5. Movement variability (SD) of head angle compared with horizontal indicating that changes from pre-post1 and pre-post2 are significant ($P<.05$), and no significant change occurred post1-post2 indicating that changes were maintained. Abbreviations: post1, first postintervention test; post2, second postintervention (washout) test.](image1)

![Fig 6. Range of motion of head angle comparing pre-post changes to washout period. Pre-post1 and pre-post2 changes are both significant ($P<.05$), but post1-post2 is not significant, showing that changes are maintained. Abbreviations: post1, first postintervention test; post2, second postintervention (washout) test.](image2)

![Fig 7. Minimum head angle in the sagittal plane indicating improved ability to hold the head more upright while moving after hippotherapy, it is significant between pre and post ($P<.05$). The change is maintained after washout (post1–post2 not significant). Abbreviations: post1, first postintervention test; post2, second postintervention (washout) test.](image3)
result was that the change in the CP group after the intervention brought their results closer to that of the without disability group. The average amplitude at C7, the Cyclops eye, and the Vertex for the CP group were significantly different from the without disability group before the intervention. These 3 markers remained significantly different from the without-disability group after the intervention. There were no significant differences between the first postintervention and the second postintervention test on these variables for the CP group.

Functional Reach

Results showed that both the reach path ratio (fig 9) and the elapsed time (fig 10) decreased from the pretest to the posttest and continued to decrease to the third test. Both variables were significant for the children with CP at the second postintervention test measurement after the washout period, but only the elapsed time was significant immediately after the intervention. The reach path ratio was also significantly different between the first postintervention and second postintervention test. Between the pre- and first postintervention tests, both of these measures for the children with CP moved toward results for the children without disabilities. Between the first postintervention and second postintervention test, they continued to move toward the without-disability baseline but remained significantly different.

DISCUSSION

The purpose of this investigation was to objectively evaluate the efficacy of hippotherapy in improving head/trunk stability and functional reaching in children with SDCP. Three published studies focus attention specifically on trunk stability and hippotherapy. Our objective results reinforce Bertotti’s conclusions about improvements in trunk control and sitting balance after hippotherapy, including the ability to right the trunk after displacement.12 Haehl et al11 showed improvement in the coordination of movement with the horse of the upper and lower trunk in the sagittal plane with 2 children with CP after 12 weeks of hippotherapy. They used kinematic measurements with 3 markers each on both the child’s and a live horse’s spine.11 The results of the present investigation support Haehl et al’s conclusions that hippotherapy improved trunk coordination by showing a reduced translation of the upper trunk and head and reduced variability of the head angle in response to an external perturbation at the pelvis. However, we have included additional subjects and anatomic markers allowing the calculation of translation and rotation variables at several levels. MacPhail et al24 measured kinematic postural responses of 6 without-disability children and 6 with CP to horse movement in the coronal plane. They reported differences between children with no disabilities, those with diplegic CP, and those with quadriplegic CP. They concluded that kinematic measurements would be a sensitive and effective means to measure change over time resulting from horseback riding.24 This study responds to their recommendation by applying video motion capture tools to enable kinematic measurement to understand the effect of a hippotherapy intervention on children with CP.
To do so, we defined improved trunk stability as reduced movement at the top of the spine in response to perturbation at the pelvis. We believe it is good that translation decreases as we move our measurement up the spine. The results in our video motion capture barrel test show this as a good thing because the children with CP have shown that they can better absorb external perturbations with reduced movement distally (upward from pelvis) and have become more like their peers without disability on this measure.

In our pilot study, we recruited 6 children with SDCP and a without-disability comparison group (n=6). Results of the pilot study showed significant changes between pre- and postresults in both head angle and head/upper trunk translation, which moved toward the results of the without-disability group. After a 12-week hippotherapy intervention, the CP group was no longer significantly different from the without-disability results on the trunk and head translation variables. The current group of 11 children with CP did not achieve the result of no significant difference between the without-disability and CP groups at the top of the spine after the hippotherapy intervention as in our pilot study. We explain this because the current group started out more impaired in stability by our measure but improved about the same absolute amount. Because they had farther to go, they did not achieve the “no significant difference” result like the pilot CP group did. We think that this raises the question of dosage and whether more intervention might have taken them to that point or if the hippotherapy intervention only goes so far. Maybe it reaches a plateau at some point.

To fully use the precision of the 3-dimensional video motion capture testing process (±0.5mm at 60Hz), the challenge to trunk stability to which the subject responds for testing needed to be a constant, not a variable. With real horses, replication of the same testing movement after 3 and 6 months also becomes even more problematic. We believed that it would obscure the measurement of changes in the subjects’ ability to respond to the trunk challenge. Therefore, the advantage of using such a precise measurement tool would be diminished. Because our results support previous reports in which data were collected from participants riding horses, it would appear that our artificial environment of the mechanical barrel did not prevent changes from occurring. Future work should compare these methods.

The results of this investigation add to the body of knowledge in several ways. This study extends our pilot work with a larger sample of children with CP. It also recruited and tested an age-matched without-disability comparison group and added a measure of UE distal control. The measure of UE control could be affected by the proximal improvements in trunk and head stability. Most importantly, this study added a 3-month washout period during which subjects did not ride horses. Our results showed that the increased level of control persisted after the intervention ceased. The results of this current study further support the notion that meaningful data can be conveniently collected in the laboratory instead of the riding arena.

The reduction in translational movement at the upper trunk and head along with the decreased angle variation of the head also effectively stabilizes the visual and vestibular systems, both of which are resident in the head and are 2 primary sensory systems providing input to control posture and functional movement. This improved stability might also contribute to the improvement we measured in gross movement of the UE that may enable improved functional competence. Additional work is needed to isolate, define, and quantify relationships between increased stability in these sensory systems because of hippotherapy and improvements in functional competence.

Results indicate that hippotherapy improves the ability of children with CP to control the movement of their trunk and head as a result of learning to respond to rhythmic movement. The prepost changes for the minimum angle, ROM, and SD (see figs 5–7) are all significant. Effect sizes are very large indicating that these changes should be visible to casual observation and are likely indicative of clinical change. The small changes between the first postintervention test and the second postintervention test are not significant, with low effect sizes indicating that little change occurred and that prepost changes were maintained for at least 3 months after the intervention ceased.

“Forced use” has been established as an effective approach to deal with childhood hemiparesis secondary to CP. The concept of forced use is also applied to treadmill training for gait training for children with CP because a patient must step forward to keep up with the treadmill. It is not a long leap to apply the same concept to a child’s trunk that has decreased strength and motor control mounted on a rhythmically moving horse. Thus, hippotherapy becomes a “forced-use” head/trunk exercise while mounted because the child must respond to the movement of the horse’s back imparted to the pelvis as each step of the horse thrusts him/her mostly forward but with some movement in other planes/axes as well.
Furthermore, neuroscientists who study motor learning have concluded that both massed practice and variable practice are very effective practice conditions to reinforce new motor learning. Changes in speed, gait, and direction and position changes during a hippotherapy session create variability while the child is experiencing the rhythmic movement. Therefore, the experience of riding a horse can be thought of as a massed but variable practice of 3000 to 5000 repetitions of a forced-use postural challenge and trunk/head righting exercise per 45-minute hippotherapy session.

Although we recognize that there are differences between CP and stroke, there are also many parallels, both in etiology (often caused by ischemia/hypoxia) and in treatment (focus on motor learning, reduction in abnormal and asymmetric tone and strengthening). Therefore, some of the literature regarding stroke recovery and treatment may apply here and help to explain these results. Lang et al reported that typical numbers of repetitions for PT and OT sessions for neurorehabilitation after stroke average from 34 to 39 repetitions with only 12 for purposeful movements and 292 steps for interventions addressing gait. However, animal models showing motor recovery after ischemic lesions included 400 to 600 repetitions before results were conclusive. In this context, hippotherapy could be considered as a rhythmic trunk challenge/recovery and core-strengthening exercise. Thus, the extremely large numbers of repetitions per hippotherapy treatment session (ie, 3000–5000) exceed typical OT/PT treatments in numbers of repetitions by an order of magnitude. They also far exceed animal models of motor learning. This intense practice condition may begin to account for the results we have measured here in the improvement of dynamic stability.

It was interesting to note that the without-disability children had more lumbar mobility than the children with CP. This is likely desirable because much of the movement of a horse, the testing barrel, or the forward pelvic movement from walking/running with one’s own lower extremities represent challenges to trunk stability and balance that are typically absorbed in the lumbar spine so as not to be transmitted to the upper spine and head. Thus, lumbar mobility enables reduced movement at the top of the trunk. The initial response to new postural demands for children with CP is to respond as a much younger typical child, to cocontract to improve stability, and as they mature to use more typical patterns as motor learning and strength improve. Our children without disability were likely well past the trunk contraction stage in which a child with CP might move stiffly, like a mast on a ship, either on a horse, on the testing barrel, and even while ambulating. The SDCP children may still be stuck in or moving through this early stage of strengthening/motor learning as they begin to learn to respond to the rhythmic movement of a horse.

The change in the reach path ratio in the reaching test was not significantly different from preintervention to the first postintervention test. However, it was significant between the preintervention test and the second postintervention washout test. This was initially a bit perplexing. The explanation might be that the improvements that stabilized the trunk also stabilized the proximal foundation for the upper extremities. Because proximal stability enables distal control, we hypothesize that this may have facilitated better functional use of the hands in everyday activities. As the children became more effective and efficient with daily functional tasks, they might have done even more with their hands, maybe with more success or less effort, moving their measured improvement further by the time of the third test. Thus, initial improvements may have initiated a virtuous cycle that reinforced itself without more intervention. It would be worthwhile to determine if this trend continues over longer time periods. It would also be worthwhile to determine if additional intervention would accelerate the improvement.

Even with only a 12-week intervention, these children with CP appear to have moved closer to a typical range of head, trunk, and UE control. The lack of significant change in trunk/head stability and in these basic UE skills between the first postintervention and second postintervention test (the final test after the washout period) indicates that the changes measured immediately after a series of therapist-directed hippotherapy sessions persisted with these children for at least 3 months after the intervention ceased. This is important because it indicates that this improvement in dynamic trunk stability and functional reach is not transitory and not limited to the period of active therapy. This new stability may provide a permanent platform on which these children can continue to develop functional and mobility skills to improve their occupational performance and participation in other activities of everyday life.

Results from this study leave questions unanswered about the effects of dosage. No studies measured varying levels of dosage objectively as a factor in determining how much improvement comes from different levels of intervention over varying periods of time. Knowing this could be a significant factor in providing additional evidence of efficacy for hippotherapy to the medical and funding communities, and could provide valuable information to support treatment planning to therapists who perform hippotherapy.

Study Limitations

One limitation of this study was the short time of intervention. The intervention lasted only 12 weeks (amounting to 8 hours on a moving horse). Many children with CP experience much longer therapy interventions over months and even years. However, there is no literature addressing the effects of varying levels of dosage of hippotherapy, either by varying intensity or duration of the therapy.

A methodologic limitation of this study was the lack of 2 preintervention baseline assessments. These assessments would have quantified any changes in the outcomes that might have occurred over time and could have assisted in factoring out any effect of maturation and other ongoing therapies. However, Palisano et al found that “by middle childhood, children with CP do not make substantial changes in the gross motor abilities measured by the Gross Motor Function Measure” (which includes measures of trunk stability). Their results showed the improvement curves of children at each of the 5 GMFCS levels plateauing after approximately 60 months. This published evidence suggested that the significant postintervention improvements, with large effect sizes, found in our pilot study with a group of children who were older than 60 months likely represented real change and were not simply a result of maturation. Our sample in this investigation also started at 60 months and had an average age of 8 years. The grant supporting this effort also required that we complete the study in 1 year. Therefore, we had to make a tradeoff between a prebaseline and a washout period test. Our choice, therefore, for this investigation was to investigate persistence of any change that might occur after hippotherapy intervention ceased because this would become new information.

The UE Functional Reach test is not a true functional test because it only involves reaching and touching a target, and no complete functional task is performed. However, these 2 measurements (the ability to move the UEs quickly [elapsed time] and efficiently [reach/path ratio]) quantify improvement in the ability to get the hands to the task. They measure very basic components that are necessary to perform almost all functional
tasks using the UE. An improvement in these impairment level components should predict improved performance at the task itself. In other work (UE recovery of function after stroke), these components of the task (reach path ratio and elapsed time) are considered essential to many functional activities, and, thus, our results are interpreted in that context. Further work should include tests that assess changes in the ability to complete whole functional tasks as a consequence of hippotherapy. In addition, further analysis of our data quantifying any changes in trunk stability that might have occurred during the reaching tasks from pre- to postassessment might offer additional insight regarding the mechanism of reaching improvement.

CONCLUSIONS

The purpose of this investigation was to objectively evaluate the efficacy of hippotherapy in improving head/trunk stability and functional reaching in children with SDCP. We used a motorized barrel and kinematic measurements to quantify motor learning affecting dynamic stability of the head/trunk and the speed and efficiency of functional reaching that occurred in children with CP resulting from a therapist using the rhythmic movement of a horse as a treatment tool. These changes were compared with a baseline of the same movement patterns measured in an age-matched group of children without disabilities. Subjects were also tested after an additional 12 weeks to determine if changes persisted after the intervention ceased. Results indicated that children with SDCP responded to a series of weekly experiences with the rhythmic movement of the horse by increasing motor control of their trunk and head. This improved control of the trunk stabilized the proximal foundation of the UEs and may account for the improvements we measured in the functional reach test. Changes in trunk/head stability and in reaching/targeting persisted for at least 3 months after the intervention ceased. These objective improvements in dynamic stability suggest that hippotherapy can provide a valuable therapeutic tool in the practice of OT and PT that may enable improved function in many activities of everyday life for children with CP. It appears that further use of this measurement model and further development of additional systematic and objective data about the results of hippotherapy intervention will further inform physicians, therapists, and third-party payers about the benefits of hippotherapy as an effective treatment strategy in the context of OT or PT for children with CP.

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References


Suppliers
a. EvaRealTime V. 5.0.4 and MAC Eagle Digital Cameras; Motion Analysis Corp, 3617 Westwind Blvd, Santa Rosa, CA 95403.
b. SPSS V16; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.