Hippotherapy Effects on Trunk, Pelvic, and Hip Motion During Ambulation in Children With Neurological Impairments

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Purpose: This study investigated the effects of a 10-week hippotherapy program on trunk, pelvis, and hip joint positioning during the stance phase of gait. **Methods:** Eleven children (6 boys and 5 girls; 7.9 ± 2.7 years) with neurological disorders and impaired ambulation participated. Joint range of motion data were collected via 3-dimensional computerized gait analysis before and after the program. Paired t tests were performed on kinematic data for each joint. **Results:** Significant improvements ($P \leq .008$) and large effect sizes (ESs) for sagittal plane hip positions at initial contact and toe-off were found. No differences in pelvic or trunk positioning were determined, although sagittal plane pelvic positioning displayed a trend toward improvement with large ESs. Several trunk variables displayed moderate ESs with a trend toward more upright positioning. **Conclusions:** Improvements in pelvic and hip joint positioning and more normalized vertical trunk position may indicate increased postural control during gait after 10 sessions of hippotherapy. **(Pediatr Phys Ther 2012;24:242–250)** *Key words: child, equine-assisted therapy, gait, hippotherapy, kinematics, neurologic disorders*

INTRODUCTION AND PURPOSE

Hippotherapy (HPOT) is a rehabilitation intervention that incorporates activities on horseback into a patient's plan of care and has been suggested to lead to improvements in righting and equilibrium reactions and postural control at the pelvis and trunk,[1-5] decreased hypertonicity at the hips,[6,7] increased pelvic and hip range of motion (ROM),[4,8] and improved general function,[9-11] all of which may affect ambulation. The 3-dimensional (3-D) movement of a horse's back, as it walks, imparts to the rider's pelvis a movement pattern that is similar to what occurs during walking.[2] Because of the benefits demonstrated in posture, tone, ROM, and function, and the similarity in pelvic movement during riding to that when ambulating, several authors have attempted to quantify improvements in gait post-HPOT.[8,11-14]

Trunk, pelvis, and lower extremity (LE) ROM in children during ambulation appears to stabilize and reach normal adult values by approximately age 3 to 4 years[15-17] and norms for ROM at each of the major joints of the trunk, pelvis, and LE for each part of the gait cycle have been determined for both healthy adults[18,19] as well as children up to the age of 7 years.[20] Excursion of the trunk, pelvis, or LE joints greater than or less than these normal values may indicate pathologies that affect the normal ROM of the limbs and/or motor control that contributes to the smooth and limited movement of the center of mass during ambulation.

Studies examining the effects of HPOT on ambulation have included measures of function often used in therapy clinics such as the Pediatric Evaluation of Disability

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Inventory and the Gross Motor Functional Measure, both of which have categories within them that also serve as tests of gait. These tools are somewhat limited, however, as tasks related to gait are rated on ordinal level scales, and specific changes in joint ROM, often a limiting factor in gait, cannot be identified. Kwon et al[8] objectively examined pelvic and hip kinematics during gait, using a 3-D motion analysis system in children with spastic cerebral palsy (CP) receiving conventional therapy plus HPOT as compared to a control group of children only receiving conventional therapy. The authors reported a decrease in average anterior pelvic tilt at initial contact (IC) and terminal stance in the children in the conventional plus HPOT group at posttesting after 8 weeks of twice-weekly HPOT sessions. Although hip joint kinematics were also examined, no significant differences pre to post were found in either group. The authors reported a limitation of their study as the lack of trunk motion analysis as pelvic motion and control is intricately related to lower trunk motion and control via the lumbosacral joint. The authors also were not able to examine the effects of HPOT only, as the experimental group received HPOT in conjunction with traditional therapy. Therefore, the aim of this quasi-experimental study was to determine via 3-D gait analysis if trunk, pelvic, and hip positions during gait in children with neurological disorders would more closely approximate normal ROM values after a 10-week period of HPOT only. Changes in trunk, pelvic, and hip positions in 3 planes at IC and toe off (TO) as well as the excursion of the segments/joints over the entire stance phase of gait were examined.

METHODS

Participants

Eleven children with neurological disorders that resulted in impairments in ambulation were recruited to participate in this study. Individual subject characteristics are provided in Table 1. Recruitment occurred via snowball and convenience sampling through contact with physical and occupational therapists that provided HPOT through a local hospital. Inclusion and exclusion criteria are presented in Table 2.

Once interest was expressed by the parents or guardians, the researcher then verbally explained the study in more detail and confirmed inclusion/exclusion criteria. Parents or legal guardians were informed of the basis and expectations of the study, including the possibility of future dissemination of the study results in a peer-reviewed journal and signed a written informed consent. Children who could sign their names were also asked to sign an assent form. Institutional Review Board approval of this study was obtained through The University of Toledo, The University of Findlay, and St. Vincent Mercy Medical Center of Toledo, Toledo, Ohio.

Gait Analysis Protocol and Instrumentation

Study participants reported for gait analysis trials no earlier than 2 weeks prior to the initiation of a 10-week HPOT session. Retroflective markers were placed on anatomical landmarks according to the Helen Hayes Marker Set pattern[21] with the exception of head markers. During trials, an 8-camera 3-D motion capture system (Motion Analysis Corporation, Santa Rosa, California) was used to track the movements of the subjects as they ambulated at self-selected speeds. Data collection periods for each ambulation trial were between 5 and 10 seconds, depending on the ambulation velocity of each child across the 20-ft testing area. Subjects performed an average of 14 barefoot trials per testing session. EVaRT 7.0 software was used for video and analog data acquisition and processing and then exported to Orthotrak 6.5.1 software for quantification (Motion Analysis Corporation, Santa Rosa, California). The software allows the user to identify joint positions at every 1% of the gait cycle; thus, one can determine the points of IC and just immediately prior to TO, or the beginning and end points of

TABLE 1
Subject Demographics

Subject	Age, y	Gender	Height, cm	Weight, kg	Diagnosis
1	8	Male	133.4	32.7	Brain injury
2	5	Female	110.5	20.4	Guillain Barre syndrome
3	11	Female	130.8	33.3	Spastic diplegia
4	8	Male	129.3	30.9	Spastic hemiplegia
5	5	Male	109.2	20.4	Spastic diplegia
6	9	Male	108.0	18.2	Spastic diplegia
7	9	Male	137.8	34.2	Spastic diplegia
8	9	Male	141.0	33.6	Guillain Barre syndrome
9	12	Female	145.3	32.9	Spastic Hemiplegia
10	5	Female	99.1	18.4	Spastic diplegia
11	3	Female	70.0	14.0	Cerebrovascular accident

TABLE 2
Inclusion and Exclusion Criteria

Inclusion criteria
Physician approval to ride a horse
Age: 3 to 12 years
Neurological pathology affecting ambulation and gross motor control in standing as determined by physical therapy or occupational therapy evaluation
Ability to ambulate a minimum of 30 ft with or without assistive device
Passive bilateral hip abduction to at least 20° in the sitting position
Exclusion criteria
Cognitive or attentional disabilities that would limit involvement in HPOT and/or gait analysis sessions
Medical complications such as seizures that could increase risk of injury during HPOT
Orthopedic surgery within the past 6 months

the stance phase, and then determine the maximum and minimum values in degrees for each joint in between those 2 points. This would indicate the full ROM the segment traverses over the stance phase. Data on trunk, pelvis, and hip positions at the point of IC and TO of each LE were gathered and averaged across trials and subjects, as well as the values for the total ROM excursion of the trunk, pelvis, and right and left hips for the stance phase of each child. All 3 cardinal planes of motion (sagittal, frontal, transverse) were examined.

Identical posttesting gait analysis was performed within 2 weeks after completion of 10 sessions of HPOT. An average of 16 gait trials was performed by subjects at posttesting, and joint positions and ROM excursion for the trunk, pelvis, and hips were then compared pre- to post-HPOT across the group. These data were then compared with established norms to determine whether normalization, or improvement, in the segment/joint positions during gait had occurred within the group as well as individually.

Hippotherapy Intervention

Although each participant had individual needs and varying levels of involvement, many aspects of HPOT treatment interventions are similar among children with neurological diagnoses. All participants had personalized plans of care (POC) based on the PT and/or OT evaluations but focus on postural stability, balance, and gross motor control in sitting served as the common denominator during HPOT sessions. No participants were involved in any other type of PT or OT interventions during the study other than HPOT.

Participants attended once weekly 45-minute HPOT sessions for a total of 10 sessions under the supervision of therapists certified by the American Hippotherapy Association in provision of HPOT. The sessions were completed within an average of a 12-week time span. Actual riding time on the horse was approximately 35 minutes per session, with the remaining 10 minutes allotted to mounting, dismounting, and walking to and from the horse. All subjects wore riding helmets and gait belts when riding, and trained volunteer leaders and side walkers were used to promote safety of the subjects while riding. The therapists matched horses to participants on the basis of size of the children and horses to allow comfortable positioning on the horse during sessions. After children were initially matched with a specific horse, the same horse was used for the duration of the study. Riding equipment consisted of fleece bareback pads and surcingles and halters with lead ropes.

Since each participant's POC may have been slightly different according to level of involvement, specific areas of focus were emphasized in each of the HPOT sessions for all subjects. Participants rode astride and facing forward; however, occasionally, a participant performed a few minutes of riding facing backward. Proper posture in sitting was emphasized throughout the sessions and upper extremity (UE) exercises such as weight-bearing on the UE, reaching tasks, and general active ROM were incorporated along with LE exercises such as ankle pumps and the use of the LE to cue the horse. Trunk exercises included activities such as leaning forward or backward and rotating to pat the horse's neck or rump, or leaning side to side with or without UE support.

To add challenges to the subjects' balance, horses were led in serpentine, figure-8, or circular patterns during some activities instead of only a straight line. Half halts and varying walking speeds were also incorporated into the sessions to add further challenges. Activities such as assisted mounting and dismounting from a mounting block and ambulation in the arena to and from the horse were also incorporated into the participants' POC.

Data Analysis

Because clinicians often compare measurements of clients' joint ROM from pretherapy intervention with measures obtained in a subsequent session of intervention several weeks later, joint positions and ROM excursion were analyzed according to average change of degrees from pretest to posttest to provide data that are clinically relevant. To determine changes and possible normalization of joint positions during gait for the group, joint position data in degrees in all 3 planes for trunk, pelvic, and hip positions at IC and TO, as well as total ROM excursion from IC to TO for each joint, were grouped into 10 families of comparisons: (1) data for trunk positions at IC, (2) data for trunk positions at TO, (3) data for pelvic positions at IC, (4) data for pelvic positions at TO, (5) data for hip positions at IC, (6) data for hip positions at TO, (7) data for trunk ROM excursion in all 3 planes over the stance phase from IC to TO, (8) data for pelvic ROM excursion in all 3 planes over the stance phase from IC to TO, (9) data for right hip ROM excursion in all 3 planes over the stance phase from IC to TO, and (10) data for left hip ROM excursion in all 3 planes over the stance phase from IC to TO. Two-tailed paired *t* tests were run for each segment/joint position in all 3 planes at IC and TO, as well as for total ROM excursion of each segment/joint over the stance phase. A pairwise error rate (α_{PC}) was set at 0.008 per comparison within each family of trunk, pelvis, and hip data, as each family involved 6 mean comparisons. Standardized ESs, using the Cohen's *d*, were calculated for each paired *t* test to measure the magnitude of the treatment effect. It is common to consider a Cohen's *d* of 0.2 as a small ES, 0.5 as medium, and 0.8 as large.[22] Effect sizes allow quantification of the size of the difference between pre- and posttest values, without confounding the difference with sample size.[23] Large ESs are associated with clinical changes that are grossly observable, while moderate effects are still sizeable enough to be perceived by the viewer.[22] The *t* statistics from independent *t* tests (pre to post) for each variable were used in the formula to provide more conservative estimates of ESs.[24] In addition to group data analysis, changes in joint positions from pretest to posttest for each child, individually, were compared with previously established norms to determine whether changes in the child's ROM were progressing toward or away from normal values.

RESULTS

Trunk Position at IC and TO and Total Trunk ROM Excursion

Group Results. No statistically significant changes in trunk position were found for any of the 3 planes of motion (sagittal [flexion/extension], frontal [lateral side-bending], or transverse [rotation]) at ipsilateral LE IC or TO. Effect size was calculated for each of the trunk positions in all planes at IC and TO of the ipsilateral LE, and the ROM excursion of the trunk over the stance phase (Table 3). A small ES was found for each variable, except for a large ES associated with trunk frontal plane position at left TO (d = 1.27, 95% CI = −1.72 to 0.69) and a moderate ES associated with trunk sagittal plane position at left TO (d = 0.50, 95% CI = −1.84 to 5.58). Effect sizes for trunk sagittal plane position at IC for both right and left lower extremities approached a moderate ES (d = 0.48, 95% CI = −1.26 to 5.50, and d = 0.40, 95% CI = −2.08 to 6.38, respectively), as did trunk rotation position at left IC (d = 0.43, 95% CI = −4.50 to 2.24). All effects were toward more normal values.

TABLE 3
Statistical Summary of Trunk Variables (n = 11)

	LE Mean Change in Degrees and SD	Cohen's d
Initial contact		
Right LE	2.12 ± 5.03	0.48
Trunk sagittal plane[a]		
Left LE	2.15 ± 6.30	0.40
Right LE	1.22 ± 4.74	0.26
Trunk frontal plane[b]		
Left LE	− 1.84 ± 5.42	0.15
Right LE	2.62 ± 5.07	0.29
Trunk transverse plane[c]		
Left LE	− 1.13 ± 5.02	0.43
Toe-off		
Right LE	1.79 ± 4.60	0.28
Trunk sagittal plane[a]		
Left LE	1.87 ± 5.19	0.50[d]
Right LE	− 0.03 ± 3.88	0.01
Trunk frontal plane[b]		
Left LE	− 0.52 ± 1.80	1.27[d]
Right LE	0.41 ± 5.35	0.04
Trunk transverse plane[c]		
Left LE	− 2.00 ± 4.93	0.37

Abbreviation: LE, lower extremity.
[a]Positive numbers represent trunk flexion, and negative numbers represent trunk extension.
[b]Positive numbers represent ipsilateral lean, and negative numbers represent contralateral lean.
[c]Positive numbers represent anterior rotation, and negative numbers represent posterior rotation.
[d]Moderate or large effect toward normalization of joint position.

Individual Results. Eight of the 11 subjects displayed some degree of more normal positioning of the trunk at IC and TO in the sagittal plane, even though ROM excursion of their trunks across the stance phase remained the same from pre- to posttest (Table 4). Individual changes in the trunk position in the frontal and transverse planes were quite variable with no specific trends in changes identified.

Pelvic Position at IC and TO

Group Results. No statistically significant changes in pelvic position in any of the 3 planes of motion (sagittal [anterior/posterior tilt], frontal [lateral tilt], or transverse [rotation]) were identified at ipsilateral LE IC or TO. However, a large effect toward normalization in pelvic sagittal plane tilt (anterior/posterior tilt) was determined at right and left IC (d = 1.31, 95% CI = −0.82 to 16.03, and d = 1.22, 95% CI = 2.42-15.45, respectively) (Table 5). A large ES was also associated with sagittal plane pelvic tilt at right and left TO (d = 0.72, 95% CI = −0.41 to 13.36, and d = 0.91, 95% CI = 0.18-15.65, respectively). Moderate ESs were associated with pelvic lateral tilt during left IC (d = 0.56, 95% CI = −5.49 to 1.79) and pelvic rotation at left TO (d = 0.51, 95% CI = −7.65 to 0.39).

Individual Results. Ten of the 11 subjects experienced some degree of normalization in pelvic position in the sagittal plane (Table 6). Individual results regarding the frontal and transverse planes were quite variable and no trends in changes could be identified.

Hip Position at IC and TO

Group Results. Two-tailed paired t tests revealed significant changes for pre- to post-HPOT intervention for right and left hip sagittal plane position (flexion/extension) at IC ($t_{(10)} = 3.65$, P = .004, and $t_{(10)} = 3.43$, P = .006, respectively) (Table 7). At TO, a significant change was also found for the left LE ($t_{(10)} = 3.98$, P = .003). No other statistically significant changes were determined for hip position at IC or TO. Large ESs were associated with right and left hip sagittal plane position at IC (d = 0.98, 95% CI = 4.56-18.80, and d = 0.84, 95% CI = 4.47-21.10, respectively) and left hip frontal plane position (abduction/adduction) at TO (d = 0.81, 95% CI = −0.66 to 16.36). Change in right LE position at IC in the frontal plane was associated with a moderate ES (d = 0.57, 95% CI = −11.56 to 1.82), as was left hip transverse plane position (rotation) at TO (d = 0.51, 95% CI = −7.65 to 0.39).

Individual Results. Nine of 11 subjects had some degree of normalization in either unilateral or bilateral hip joint sagittal plane positioning post-HPOT (Table 8). Six of 11 subjects demonstrated normalization in hip frontal plane positioning of the right and/or left LE, and 6 of 11 subjects demonstrated normalization in hip transverse plane positioning and/or more symmetrical positioning left to right over the stance phase of gait.

TABLE 4

Subject Trunk Positioning in Sagittal Plane at Bilateral Lower Extremity Initial Contact and Toe Off and Total Trunk Range of Motion Excursion in Sagittal Plane Over Stance Phase[a]

		Trunk Position at IC (Norm = −5.00°)[b]		Trunk Position at TO (Norm = −5.00°)[b]		Total Trunk ROM (Norm = ~2.00°)[b]
Subject	Test Session	Right LE	Left LE	Right LE	Left LE	Stance Phase
1	Pretest	8.54	11.86	9.22	8.18	3.68
	Posttest	1.95[c]	8.12[c]	4.40[c]	3.41[c]	4.71
2	Pretest	.20	− 2.19	− 11.88	1.37	11.68
	Posttest	− 1.32[c]	− 5.92[c]	− 14.79	− 3.38[c]	13.47
3	Pretest	4.38	4.20	5.23	2.02	2.18
	Posttest	0.33[c]	− 0.88[c]	1.99[c]	− 1.44[c]	1.66
4	Pretest	− 1.65	3.40	1.55	− 2.31	5.71
	Posttest	3.53	9.66	7.69	3.34	6.32
5	Pretest	2.46	1.74	2.08	0.57	1.17
	Posttest	− 1.34[c]	− 3.76[c]	− 3.06[c]	− 4.36[c]	1.72[c]
6	Pretest	16.03	17.83	14.20	19.47	1.64
	Posttest	6.99[c]	4.97[c]	9.39[c]	8.99[c]	2.40[c]
7	Pretest	1.72	8.58	7.00	9.01	3.72
	Posttest	7.23[c]	5.02[c]	3.76[c]	4.20[c]	3.47[c]
8	Pretest	3.37	3.75	1.37	1.99	1.76
	Posttest	2.74[c]	1.59[c]	2.53	3.50	1.91[c]
9	Pretest	2.89	− 1.44	− 2.46	2.36	5.35
	Posttest	8.75	8.46	1.47	6.98	1.48[c]
10	Pretest	7.78	5.70	7.69	11.71	6.01
	Posttest	− 0.18[c]	− .32[c]	− 1.46[c]	0.30[c]	1.28[c]
11	Pretest	− 2.08	− 1.64	− 2.86	− 3.86	2.22
	Posttest	0.61	1.22	− 0.42	− 1.14	2.36

Abbreviations: IC, initial contact; LE, lower extremity; ROM, range of motion; TO, toe off.

[a]Positive numbers represent trunk flexion, negative numbers represent trunk extension.

[b]Data from Sartor et al.[26]

[c]Shift towards normalization of trunk position/ROM occurred.

TABLE 5

Statistical Summary of Pelvic Variables (n = 11)

Initial Contact	LE Mean Change in Degrees and SD	Cohen's *d*
Right LE	8.43 ± 11.32	1.31[d]
Pelvis sagittal plane[a]		
Left LE	8.94 ± 9.70	1.22[d]
Right LE	1.22 ± 4.74	0.30
Pelvis frontal plane[b]		
Left LE	− 1.84 ± 5.42	0.56[d]
Right LE	1.76 ± 5.55	0.26
Pelvis transverse plane[c]		
Left LE	− 1.68 ± 6.66	0.35
Toe-off		
Right LE	6.48 ± 1.24	0.72[d]
Pelvis sagittal plane[a]		
Left LE	7.91 ± 11.51	0.91[d]
Right LE	1.90 ± 4.79	0.37
Pelvis frontal plane[b]		
Left LE	− 0.44 ± 5.47	0.12
Right LE	− 2.35 ± 7.20	0.33
Pelvis transverse plane[c]		
Left LE	− 3.63 ± 5.99	0.51[d]

Abbreviation: LE, lower extremity.

[a]Positive numbers represent anterior pelvic tilt, and negative numbers represent posterior pelvic tilt.

[b]Positive numbers represent superior pelvic tilt, and negative numbers represent inferior pelvic tilt.

[c]Positive numbers represent anterior pelvic rotation, and negative numbers represent posterior pelvic rotation.

[d] Moderate or large effect toward normalization of joint position/ROM.

Total Joint ROM Changes in Stance Phase

No statistically significant changes for total ROM were determined pre- to posttest; however, several large and moderate effects toward normalization were found. A large ES was associated with joint ROM excursion changes of the right hip in the transverse plane (d = 1.31, 95% CI = −3.62 to 0.73) and moderate ESs of the left hip in the sagittal plane (flexion/extension) (d = 0.79, 95% CI = −11.56 to 1.86) and the left hip joint in the transverse plane (rotation) (d = 0.65, 95% CI = −2.71to −0.55) were found.

DISCUSSION

Trunk and Pelvic Positions at IC, TO, and ROM Excursion Over the Stance Phase

It is common in studies that analyze gait to correlate measurements of joint position from IC of a reference foot to IC of that same foot again.[25] However, as it was the intention of the current authors to analyze only the stance phase of the gait cycle, obtaining ROM measurements at IC and the end of preswing, or TO of the same foot, allowed identification of possible deviations from normal joint positions at the beginning and the end of the stance phase for each LE. This method also allowed analysis of the excursion of the joints across the stance phase between IC and TO.

Pre-HPOT, the subjects were relatively flexed at the trunk relative to the pelvis at IC rather than the norm of slight extension of 5°.[26] Normal pelvic position in the sagittal plane at IC is neutral[16,20,27]; however, this group of subjects presented with pelvic positioning at IC of approximately 12° of anterior tilt at pretesting. Excessive anterior pelvic tilt is a common deviation in children with CP and other spastic conditions. This tilt of the pelvis could have led to the decreased amount of extension that was found in the lumbar spine at IC if the children were unable to disassociate the trunk from the pelvis, which is often the case in children with CP or other conditions that may be associated with spasticity.

Statistically significant differences may not have been distinguished because of the small sample size, heterogeneity, and large standard deviations in data, or because of the fact that trunk motion during gait is very minimal. The 1° of ipsilateral lateral flexion that is the norm at IC[26] is so minute that movements of the retroflective markers on the skin could contribute to changes or lack of changes seen in this variable in individuals, or in the group as a whole. Several moderate and large ESs associated with normalization in trunk position at both IC and TO in this sample, however, provide information that clinically observable positive changes occurred in the group and thus warrant further investigation with a study using a larger sample size.

Pelvic position in the sagittal plane at IC improved bilaterally in subjects by approximately 8.5° (Table 5). These results are similar in scope to the pelvic position changes found in the study by Kwon et al.[8] This tilting of the pelvis posteriorly toward the norm of 0³ resulted in improved sagittal plane posture at the pelvis and, concurrently, the trunk at IC. This supports the suggestion of Kwon et al[8] that pelvic kinematics may be affected by changes in trunk control and the relationship between the 2 segments after several weeks of HPOT.

The shift toward more normal sagittal plane pelvic positions, or decreased anterior pelvic tilt, at IC as well as TO after HPOT may indicate the improved postural control of the lumbopelvic region of the subjects as the body progressed over the stance limb. These results support the work of Bertoti[1], Quint and Toomey[4], and Kuczynski and Slonka,[5] among others who have investigated changes in posture after HPOT or the use of a saddle shaped seat. The slope of the horse's back promotes proper sagittal plane alignment at the lumbopelvic region, while the movement of the horse imparts 3-D movement to the rider's pelvis that has been identified in previous research[2] as being very similar to that which occurs during gait. As the horse walks, the rider's trunk changes position in response to the horse's movements to maintain the center of mass over the shifting pelvis.[28] The stimuli that occur during HPOT, such

TABLE 6

Subject Pelvic Positioning in Sagittal Plane at Bilateral Lower Extremity Initial Contact and Toe Off and Total Pelvic Range of Motion Excursion in Sagittal Plane Over Stance Phase[a]

		Pelvis Position at IC (Norm = 0.00°)[b]		Pelvis Position at TO (Norm = 0.00°)[b]		Total Pelvic ROM (Norm = 4.00°)[b]
Subject	Test Session	Right LE	Left LE	Right LE	Left LE	Stance Phase
1	Pretest	13.05	18.44	3.26	5.73	9.79
	Posttest	− 1.82[c]	2.17[c]	− 0.50[c]	0.38[c]	1.32[c]
2	Pretest	0.75	1.71	− 7.73	− 0.37	8.48
	Posttest	− 1.26	− 7.26	− 2.33	− 11.43	9.97
3	Pretest	9.19	9.47	11.00	7.85	1.81
	Posttest	− 4.82[c]	− 3.99[c]	− 0.76[c]	− 6.62[c]	4.06[c]
4	Pretest	3.34	1.01	8.23	2.98	4.89
	Posttest	9.19	9.47[c]	22.24	15.38	6.31
5	Pretest	12.57	11.50	11.60	1.87	0.97
	Posttest	0.16[c]	− 0.31[c]	0.37[c]	− 0.03[c]	0.21
6	Pretest	26.70	26.78	19.85	3.33	6.85
	Posttest	4.86[c]	2.98[c]	2.56[c]	3.83[c]	2.30[c]
7	Pretest	16.84	16.25	13.45	13.05	3.01
	Posttest	4.52[c]	4.24[c]	0.61[c]	0.68[c]	3.85[c]
8	Pretest	8.49	12.23	9.23	7.67	0.74
	Posttest	2.29[c]	2.74[c]	2.56[c]	2.03[c]	1.65[c]
9	Pretest	11.49	3.54	5.07	13.70	11.49
	Posttest	9.29[c]	0.00[c]	12.93	19.47	3.36[c]
10	Pretest	23.16	2.07	23.02	26.12	0.14
	Posttest	0.13[c]	7.17[c]	5.52[c]	4.77[c]	5.39[c]
11	Pretest	6.11	7.33	5.11	3.55	1.00
	Posttest	7.97	8.09	5.66	5.91	2.31[c]

Abbreviations: IC, initial contact; LE, lower extremity; ROM, range of motion; TO, toe off.
[a]Positive numbers represent anterior pelvic tilt, and negative numbers represent posterior pelvic tilt.
[b]Data from Murray et al[18,19] and Perry[27]
[c]Shift towards normalization of pelvic position/ROM occurred.

as the movement of the horse and the changes in speed of the horse, are challenges to the subject's lumbopelvic neuromuscular control. Opportunities for the rider to respond to and correct postural disturbances via feedback from and cooperation among the visual, auditory, vestibular, and somatosensory systems may lead to improved feed forward and feedback neuromuscular responses and improved lumbopelvic control in this dynamic sitting posture on the horse. Development of feed-forward control promotes modification of strategies for enhanced postural control, and postural control is essential for higher-level actions such as gait.[29] This improved postural control and pelvic alignment in dynamic sitting, then, may transfer to static and dynamic standing, resulting in the improved lumbopelvic alignment in the sagittal plane during ambulation in this group.

Regarding total ROM excursion between IC and TO, although the excursion of the trunk and pelvis did not show statistically significant changes from pre to post and in fact remained quite consistent and essentially within normal limits, what did change is the trunk and pelvic positions in regard to vertical. In essence, the trunk became more upright and normalized in the sagittal plane over stance post-HPOT instead of being relatively flexed as was seen at pretesting, while still displaying relatively normal excursion.

TABLE 7

Statistical Summary of Hip Variables (n = 11)

	LE Mean Change in Degrees and SD	Cohen's *d*
Initial contact		
Right LE	11.68 ± 1.60[e]	0.98[d]
Hip sagittal plane[a]		
Left LE	12.79 ± 12.37[e]	0.84[d]
Right LE	− 4.87 ± 9.96	0.57[d]
Hip frontal plane[b]		
Left LE	3.81 ± 16.11	0.33
Right LE	1.76 ± 5.55	0.26
Hip transverse plane[c]		
Left LE	− 1.68 ± 6.66	0.35
Toe-Off		
Right LE	1.55 ± 16.31	0.72[d]
Hip sagittal plane[a]		
Left LE	16.04 ± 13.69[e]	0.81[d]
Right LE	− 0.61 ± 6.95	0.12
Hip frontal plane[b]		
Left LE	7.85 ± 12.67	0.81[d]
Right LE	− 2.35 ± 7.20	0.33
Hip transverse plane[c]		
Left LE	− 3.63 ± 5.99	0.51[d]

Abbreviation: LE, lower extremity.

[a]Positive numbers represent hip flexion, negative numbers represent hip extension.

[b]Positive numbers represent hip adduction, negative numbers represent hip abduction.

[c]Positive numbers represent hip internal rotation, negative numbers represent hip external rotation.

[d]Moderate or large effect toward normalization of joint position/ROM.

[e]$P \leq .008$.

Hip Positions at IC, TO, and Total ROM

If one examines the changes in hip flexion at IC for the group, one is led to believe that the hip joint position at IC became less normal at posttesting. However, examining individual subject changes paints a much clearer picture of the changes and actual improvements in hip flexion position at IC. Five of the 11 subjects presented at pretesting with much greater hip flexion at IC than normal, either bilaterally or unilaterally, skewing the mean at pretesting (Table 8). All 5 of these subjects' hip joints positions at IC had decreased to more normal values at posttesting, resulting in a lower group mean. Possible explanations for the improved hip flexion in these 5 subjects may be explained by the fact that each of these subjects also displayed more normalized sagittal plane positioning of the pelvis at IC. As the pelvis rotates posteriorly, the angle between the pelvis and the femur decreases, which would be confirmed by their lower posttest values. These subjects also may have benefited from the stretching of the adductors that also aid in hip flexion, and decreased tone in these muscles that may have occurred from the HPOT sessions. One additional subject (9) demonstrated more normalized hip flexion at IC. This subject has spastic hemiplegia and presented with essentially normal hip flexion at IC on the noninvolved (right) side at pretesting, but the involved (left) side displayed much less than normal flexion at IC at pretesting. At posttesting, this subject's left hip flexion had improved and was essentially symmetrical to the right LE. The focus on symmetrical posture on the horse, and the improvements in sagittal plane pelvic position at IC for these subjects, may have contributed to the improvements in hip joint position at IC.

Normal frontal plane position for the hip at IC is 10° of adduction.[18,19,27] Because the subjects presented with varying degrees of spasticity in one or both LE, and generally speaking, those with spasticity in the LE typically present with some adduction of the limbs, and the positioning at IC was relatively normal across the group, leading to the lack of statistically significant results and small ESs. However, 6 of the 11 subjects presented with frontal plane hip joint positions of the right LE that were closer to the norm at posttesting than at pretesting, and 6 of the 11 showed improvements on the left side, which may indicate that HPOT may aid improving some clients' LE positioning in the frontal plane at IC.

Although statistically significant differences in hip transverse plane position at IC for the group were not identified, a trend toward improvement was noted. Eight of the 11 children presented at pretest with excessive internal rotation (IR) of one or both hips at IC perhaps due to spasticity and/or tight hip musculature. Sitting astride a horse passively positions the hip joints in neutral to mild hip external rotation in conjunction with abduction, which may have promoted stretching of tight hip internal rotators/adductors such as the adductor longus/brevis and pectineus. Of the 8 subjects who demonstrated excessive hip IR at pretesting, 3 normalized to a less IR position at

TABLE 8

Subject Hip Joint Positioning in Sagittal Plane at Bilateral Lower Extremity Initial Contact and Toe Off and Total Hip Joint Range of Motion Excursion in Sagittal Plane Over Stance Phase[a]

		Hip Joint Position at IC (Norm = 30.00°)[b]		Hip Joint Position at TO (Norm = 0.00°)[b]		Total Hip ROM, Stance Phase (Norm = 40.00°)[b]	
Subject	Test Session	Right LE	Left LE	Right LE	Left LE	Right LE	Left LE
1	Pretest	37.97	47.76	14.20	9.86	27.27	30.99
	Posttest	19.24	− 8.55 [c]	30.99 [c]	39.48 [c]	32.87 [c]	4.71[c]
2	Pretest	13.45	11.56	− 22.84	− 11.63	40.49	40.22
	Posttest	7.04	− 2.69	− 30.58	− 30.85	40.22 [c]	36.74
3	Pretest	44.40	49.03	15.99	23.60	31.91	30.16
	Posttest	26.27 [c]	29.56 [c]	− 1.59 [c]	0.01 [c]	30.16	32.77 [c]
4	Pretest	21.75	23.38	− 16.47	− 22.64	39.82	20.24
	Posttest	21.85 [c]	11.19	6.61[c]	− 23.86	20.24	38.25 [c]
5	Pretest	13.24	7.42	− 7.73	− 20.69	23.57	38.06
	Posttest	− 3.37	− 6.66	− 31.09	− 42.70	38.06 [c]	51.96
6	Pretest	49.42	5.62	14.96	31.88	36.56	23.58
	Posttest	18.81[c]	24.75[c]	− 1.87[c]	− 23.58	31.50 [c]	3.55 [c]
7	Pretest	47.66	45.06	5.87	6.66	43.20	42.07
	Posttest	28.23 [c]	23.38[c]	− 9.94	− 13.63	42.07[c]	41.11[c]
8	Pretest	25.47	28.78	− 4.02	− 8.10	31.97	30.61
	Posttest	22.05	20.15	− 6.26	− 6.84[c]	30.61	29.89
9	Pretest	29.88	12.97	− 12.72	− 15.30	45.70	36.30
	Posttest	31.29	28.58 [c]	− 1.81 [c]	− 36.30 [c]	38.11[c]	6.33[c]
10	Pretest	46.72	54.22	28.20	20.87	21.82	36.87
	Posttest	28.46[c]	33.32[c]	− 6.01 [c]	− 9.96[c]	36.87[c]	44.68
11	Pretest	13.84	24.16	− 20.39	− 19.27	37.33	45.77
	Posttest	14.55[c]	24.87[c]	− 45.77	63.22	19.88[c]	− 18.73[c]

Abbreviations: IC, initial contact; LE, lower extremity; ROM, range of motion; TO, toe off.
[a]Positive numbers represent hip flexion, and negative numbers represent hip extension.
[b]Data from Murray et al[18,19] and Perry.[27]
[c]Shift toward normalization of hip position/ROM occurred.

IC, and 3 who had excessive unilateral hip IR at IC, or who were asymmetrical from left to right, progressed to a more normal, symmetrical position at posttesting. One factor that was not addressed before the initiation of the study that may have led to limited improvements in hip transverse plane measurements is the fact that many children with CP present with anteversion of the hip. Oftentimes, those with excessive anteversion ambulate with internally rotated hips possibly to increase stability at the joint, as the joint becomes unstable the more it moves into external rotation.[30] This may be one reason the subjects presented with excessive IR group means at both pre- and posttesting, as most of the children had CP.

Analysis of individual changes as well as group changes in a heterogeneous sample presents a more comprehensive picture of possible treatment effects, than if presenting only group changes. Because no 2 individuals with neurological diagnoses present exactly alike, what benefits one may not necessarily benefit another. Also, as mentioned, there may have also been some individual variances in biomechanical or neuromuscular conditions and responses that limited the treatment effect of HPOT in 1 or more joint or plane of motion. Although aggregate data support the use of HPOT to positively affect pelvic and hip positioning and ROM as demonstrated by several moderate and large ESs, one must consider that HPOT did not benefit all subjects individually, although a majority of subjects had several positive gains in joint motion.

Statistical significance is not the final litmus test of a study's value. Clinical or practical significance as related by ES is also very important especially in studies examining rehabilitation strategies and in studies with limited sample sizes and a heterogeneous sample. Several variables examined in this study demonstrated large or moderate ESs, and when individual changes were examined in more detail, it appears that clinically relevant improvements in ambulation in terms of trunk, pelvis, and hip joint positioning and ROM over the stance phase were made in most of the subjects as denoted by these large and moderate ESs.

A strength of this study is that subjects were involved in only HPOT and no other therapy over the course of 10 weeks. Inclusion of a control group of children involved in traditional therapy would reduce the threats to internal validity, as well as allow a comparison between the 2 types of therapy. Future studies may want to examine the possibility of changes in joint kinematics during the swing phase of gait to determine whether HPOT has an effect on control of the patterns and arc of motion that limbs traverse. It may be valuable to analyze potential changes in ROM of the knee and talocrural joints as well, as the ROM of these joints are often affected in children with neurological diagnoses and play a large role in gait deviations.

CONCLUSIONS

This study is the first study to attempt to quantify changes in kinematics of the trunk, pelvis, and hips at IC, TO, and across the stance phase of gait using 3-D gait analysis after HPOT-only intervention. A trend toward more normalized sagittal plane pelvic position during gait was observed in this group after 10 weeks of HPOT and most likely influenced the corresponding improvements in alignment of the trunk and hips in the sagittal plane during gait.

Because the pelvis is kinematically linked to both the spine and the hips, it stands to reason that improvements in alignment and control at the pelvis may translate to corresponding improvements in trunk and hip arthrokinematics as well. Improved pelvic postural control in sitting can theoretically transfer to improved standing postural control and lead to improvements in ambulation as proximal stability allows for enhanced distal movement and control.

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