Endurance and Gait in Children With Cerebral Palsy After Intensive Body Weight-Supported Treadmill Training

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Purpose: This study was designed to investigate changes in endurance, functional gait, and balance after intensive body weight-supported treadmill training in children with CP who were ambulatory. **Methods:** Six school-aged children with CP (four boys, two girls; age range: six to 14 years) participated in an intensive program of body weight-supported treadmill training 30 minutes twice daily for two weeks. **Results:** Statistically significant improvement in walking velocity and energy expenditure were observed. Variability of individual outcomes was observed with some children showing positive changes, and others no change or a decline in performance. Four children showed minimal detectable changes in a positive direction on both an endurance measure and a functional gait measure. Each endurance and functional gait measure included at least one child with a positive minimal detectable change. **Conclusion:** Intensive body weight-supported treadmill training may be an effective intervention for some children with CP who are ambulatory. **(Pediatr Phys Ther 2007;19:2–10)** *Key words: adolescent, child, female, gait, male, physical endurance, physical fitness, spastic CP, walking*

INTRODUCTION

The Summer Institute on Translating Evidence into Practice (III STEP Conference) was an intensive, multidisciplinary conference designed to catalyze the advancement of physical therapy for people with movement dysfunction by translating movement science research into effective clinical interventions. A list of "take-home messages" from the conference included the need for relevant and practical outcome measures, the need for algorithms to aid in making decisions about treatment options, as well as the need to define the optimal way for physical therapy clients/patients to "practice" in terms of such variables as intensity, specificity, dosing, motivation and feedback.[1] Body weight-supported treadmill training (BWSTT) currently is being used more frequently with adults and children with a variety of neurological impairments that affect mobility. Several studies have demonstrated the effectiveness of this intervention in adults with stroke and spinal cord injury.[2–7] BWSTT is a promising intervention for children, and some studies involving BWSTT have been conducted with children with CP. More research is needed to determine which children benefit in function and fitness from BWSTT, which outcome measures are most relevant, and what intensity and duration are optimal in the BWSTT protocol for children with CP.

Researchers have found BWSTT beneficial for young children who were infants or preschoolers and were not yet ambulating independently. Bodkin and associates[8]

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presented a case study of an infant at risk for neuromotor disabilities who received physical therapy twice weekly consisting of motor development activities and who also began treadmill training (TT) at five months adjusted age. The intensity and duration of the TT was four- to five-minute sessions conducted three to four times weekly and continued for 23 weeks. The infant progressed on the Alberta Infant Motor Scale (AIMS) at a steady rate, and his number of steps increased, with alternating steps almost exclusively by 10.5 months. Richards and colleagues[9] studied four children (age range, 1.7−2.3 years) with spastic CP who were nonindependent walkers. The children received a combination of conventional therapy and TT at an intensity of four times per week (two to three hours per week) for four months, with a total of approximately 10 to 15 hours on the treadmill per child. The Gross Motor Function Measure (GMFM) score changed from 8% to 23%, and mean gait velocity increased 12.0 cm/sec ± 16.8, with wide variability in the amount of change. All children improved on the Supported Walker Ambulation Performance Scale (SWAPS), with the two largest changes observed in the children with the highest and the lowest initial scores. Gait analysis of one boy showed hip and ankle movement patterns closer to normal. Dannemiller et al[10] researched parent-administered BWSTT with three young children with CP who were nonambulatory. After intervention of eight minutes per day, five times per week, lasting for two to four months, one child made positive changes on the SWAPS, and all three children made positive changes on the GMFM-88.

BWSTT studies also have reported clinical improvements in older children with cerebral palsy (CP), although most studies have predominantly included children who were nonambulatory. Schindl and colleagues[11] studied the effects of BWSTT on ten children (age range of six to 18 years) with CP who were nonambulatory (six children) or who ambulated for short distances with continuous physical help (two children), stand-by assist (one child), or independently (one child). The TT consisted of 25-minute sessions three times weekly for three months, in addition to other physiotherapy intervention for two to three 30-minute sessions per week. Group outcomes on the Functional Ambulation Category improved significantly from 1.1 to 1.9, and the standing and walking sections of the GMFM increased by 47% and 50%, respectively. Clinically relevant improvement in motor abilities was seen in eight of the 10 children, although two children who found the training exhausting did not improve.

Individual improvements in certain children were reported in gait measures (eg, walking forward and backward, stair-climbing) as well as in functions other than gait (eg, one-foot lifting while standing, transfers, rising). Day and coworkers[12] presented the case of a nine-year-old boy with spastic CP who was nonambulatory and who received BWSTT for two to three sessions per week over the course of 25 weeks (with some breaks). Results showed improvements of 7% on the GMFM total score and improvements on the mobility, functional skills, and caregiver assistance domains on the Pediatric Evaluation of Disability Inventory. McNevin et al[13] found that heart rate, blood pressure, and perceived exertion of an adolescent girl with spastic CP (who was a community ambulator with forearm crutches) were significantly lower during partial weight support, and her ambulation speed was higher. The authors concluded that partial unweighting generally improves gait efficiency up to a limit, which was about 2.7 km/h for their subject.

In general, the children studied for BWSTT have varied in age from infancy to adolescence. However, their levels of function have predominantly been nonambulatory, and there is a gap in the BWSTT research assessing children with CP who are independent in ambulation. This is in contrast to the BWSTT research involving adults with subacute or chronic stroke, in which a portion of the subjects were independent ambulators with or without assistive devices.[6,7,14,15] Children who are ambulatory may benefit from BWSTT for several reasons. Jahnsen et al[16] investigated locomotion skills in adults with CP and found that 44% reported deterioration in walking skills, mainly before 35 years of age. Self-reported causes of deterioration included fatigue and lack of adapted physical activity, which may be preventable if ambulatory children with CP engage in an ongoing program of effective treatment strategies such as BWSTT as they mature. In addition, conditioning programs are becoming increasingly important to improve fitness levels of children with disabilities,[17,18] and treadmill training with BWS may be an option to improve not only function but fitness including endurance levels of children with CP who are ambulatory.

Commonly used outcome measures in the BWSTT studies with children with CP include the GMFM, various gait measures including gait analysis, and measures of other clinical functions, including balance on one leg.[9–12] However, commonly used measures in studies that included ambulatory adults with subacute or chronic stroke include assessment of gait velocity and endurance such as the Ten-Meter Walk and the Six-Minute Walk.[6,7,14,15] These measures have not been used in children with CP after BWSTT. In addition, the Energy Expenditure Index (EEI) has been used in studies involving fitness with children with CP,[17,19–21] but has not been used to examine fitness in children with CP after BWSTT. Research is needed to determine whether outcome measures commonly used in studies with ambulatory adults poststroke or in fitness studies with children may be relevant outcome measures of BWSTT for children with CP who are ambulatory.

Protocols for BWSTT in the studies involving children with CP have varied in intensity and duration, with a range from approximately 20 minutes per week up to two to three hours per week, and have continued approximately two to six or more months. In addition, the BWSTT protocols have not included a control group and often have occurred in combination with conventional therapy, which can make it difficult to separate the effects of BWSTT alone. The studies of children, however, do suggest that the use of BSWTT over several months duration is effective for some children with CP, and programs that are similar to a typical therapy schedule seem to be quite feasible. Although research has shown greater improvement in certain children with CP with higher intensity of therapeutic treatments, including neurodevelopmental treatment,[22–24] there is little information regarding the effects of intensive BWSTT intervention. Intensive, short-term BWSTT may be a viable alternative in situations in which ongoing therapy is not economically or logistically possible. For example, it may allow children who live in rural areas without pediatric physical therapists to participate in intensive BWSTT in an urban rehabilitation setting during school vacations, or it may allow families busy with obligations during the school year to have their children participate in brief therapeutic "tune-ups" periodically when more convenient. In addition, conditioning programs are becoming increasingly important to improve fitness levels of children with disabilities.[17,18]

Little research has been done to investigate whether an increased intensity of BWSTT that is equal or more than the Centers for Disease Control and Prevention[25] suggested guidelines for physical activity in children (10 to 15 minutes or more of moderate-to-vigorous activity daily) and adolescents (moderate-to-vigorous levels of exertion for 20 minutes or more three or more times per week) may result in an increased fitness measure such as the energy expenditure index in children with CP. Although an intensive program for ambulatory children with CP can be developed using various methods of treatment including walking overground, BWSTT might be a more effective or efficient means for many ambulatory children with CP because of safety factors (eg, harness support eliminating fear/potential of falling, walking in the safe environment of the clinic), velocity factors for endurance (eg, treadmill speed maintains child's speed of walking), and facilitation of specific gait parameters (eg, heel-strike, hip extension, knee extension) during training.

No research has been done on the effectiveness of BWSTT intervention on school-aged children with CP who are independent ambulators without assistive devices, nor on an intensive protocol without concurrent conventional therapy. If this approach is effective, intensive therapy with BWSTT for short periods of time may be an important treatment option for this specific group of children with CP. In addition, further information is needed on relevant outcome measures in endurance, functional gait and balance for ambulatory children with CP.

The purpose of this study was to examine the effects of a two-week program of intensive BWSTT on clinical measures of endurance, functional gait, and balance in ambulatory school-aged children with CP who are independent walkers. The study not only assessed the outcomes of the group but also of the individual children, in order to identify factors in various children that positively affected outcome. The research questions included the following: (1) Will the children as a group demonstrate statistically significant changes in clinical measures of endurance, functional gait and balance following an intensive BWSTT program? (2) Will individual children demonstrate important changes in clinical measures of endurance, functional gait and balance following an intensive BWSTT program? (3) What specific factors (eg, age and diagnosis of child, factors noted during clinical observations) contributed to the increased effectiveness of an intensive BWSTT program for particular children?

METHODS

Participants

Six ambulatory children with spastic CP (two girls, four boys) were recruited through the neurorehabilitation clinics at the University of New Mexico Hospital and from community referrals. Their age range was six to 14 years, with three children being in the younger group (six to nine years) and three children being in the older group (12 to 14 years). Four children had the diagnosis of hemiplegia, and two children were diagnosed with asymmetrical spastic diplegia. The diagnoses were confirmed by a pediatric neurologist. Inclusion criteria were: (1) able to ambulate independently without an assistive device, (2) able to actively dorsiflex the most involved ankle at least 10 degrees, and (3) able to follow verbal directions for standardized testing. Exclusion criteria were the following: (1) orthopedic surgery or neurosurgery in the past 12 months and (2) antispasticity medications orally or by injections in the past six months. Table 1 provides a summary of the demographic information for all six participants.

The six children with spastic CP were rated as Level I on the Gross Motor Function Classification System for children with CP.[26] They were able to walk independently indoors and outdoors, but experienced limitations in coordination, balance, and speed for advanced gross motor skills. This current study was part of a larger research project[27] and approval for the study was obtained from the University of New Mexico Institutional Review Board. Written informed consent was obtained from the parent(s)

TABLE 1
Subject Demographics

Subject	Age	Gender	Most Involved Side	Diagnosis	GMFCS Level
1	14	F	Left	Hemiplegia	I
2	14	F	Right	Hemiplegia	I
3	6	M	Right	Hemiplegia	I
4	12	M	Right	Asymmetrical diplegia	I
5	9	M	Right	Asymmetrical diplegia	I
6	8	M	Right	Hemiplegia	I

of each participant, and informed assent was obtained from the children.

Procedure

Pre- and Post-Training Clinical Assessments. Clinical assessments included two measures of endurance (Six-Minute Endurance Walk and Energy Expenditure Index), two functional gait measures (Ten-Meter Walking Velocity and Gross Motor Function Measure Dimension E), and one static balance measure (Single Leg Balance Test). All clinical assessments were conducted under the direction of an experienced pediatric physical therapist and occurred either at the child's school or a rehabilitation center. To provide as stable a measure of function as possible, a repeated-measures procedure was used when possible on the gait measures. Children performed the Ten-Meter Walking Velocity and Six-Minute Endurance Walk two to three times on separate days in the two-week period before BWSTT training, and two to three times in the two-week period after the training, with the exception of two children, who only received one post testing. Their repeated pre scores and post scores were averaged for analysis. Children were assessed on the Single Leg Balance Test and the GMFM one time in the two-week period before BWSTT training, and one time in the two-week period following the training.

Six Minute Endurance Walk. The six-minute walk is a reliable and valid measure of walking endurance in children.[28] Measurement of walking for longer duration is more representative of a child's self-selected walking speed, which typically is used in the community,[29] and research studies with children have used this measure.[30–32] During the six-minute walk test, the total distance walked is recorded. For the Six-Minute Endurance Walk, the children were encouraged to walk without running for six minutes up and down an unobstructed hallway with a known distance. They were encouraged to cover as much distance as possible and were allowed to vary their pace and rest as needed. Orange cones were placed to mark for the children the designated turning points in the hallway, and the beginning of the course as well as the end points where the children stopped when the stopwatch showed six minutes were marked with tape. Overall distance was measured in feet with a measuring wheel.

Energy Expenditure Measurement. The Energy Expenditure Index (EEI) has been advocated as a means of using the heart rate response to assess energy cost during ambulation by relating changes in heart rate to velocity,[19,33] and has been used in studies with children with CP.[17,19–21] The EEI in beats/meter is calculated as the ambulation heart rate (beats/min) minus the resting heart rate (beats/min) divided by the ambulation velocity (meters/min). Normative values are available for children, and higher numbers indicate greater energy expenditure, while lower numbers reflect more energy efficiency.[34] For the EEI measurement, the baseline resting heart rate was taken before each walking session, and the exercise heart rate was taken immediately after walking and again one minute later to measure heart rate recovery. Ambulation heart rate was based on the average of the six highest exercise heart rate readings for the sessions on the first and last day of treadmill training. Velocity was converted from the miles per hour provided by the treadmill to meters per min for EEI calculation purposes. The average EEI on the first treatment day was compared to the average EEI on the last treatment day.

Ten-Meter Walking Velocity. Walking velocity is a valid and reliable measure of walking ability in children with or without neuromuscular disability.[35,36] This measure was identified as a primary outcome variable in a BWSTT study with adults post-stroke.[7] For the Ten-Meter Walking Velocity, the children were timed with a stopwatch as they walked a 10 meter walkway. The children were encouraged to walk as quickly as possible without running.

GMFM. The GMFM is a standardized observational instrument designed and validated to measure change in gross motor function over time in children with CP.[37] Two versions exist: the original 88-item measure (GMFM-88), used in this study, and the 66-item measure (GMFM-66). There is a four-point scoring system for each of the items on the GMFM, and the assessment is divided into five Dimensions: (A) Lying and Rolling, (B) Sitting, (C) Crawling and Kneeling, (D) Standing, and (E) Walking, Running and Jumping. The GMFM-88 item scores can be summed to calculate raw and percent scores for each of the five dimensions. Because all of the children were at Level I on the Gross Motor Function Classification System for children with CP, only the complete Dimension E (items 65–88) was administered and scored pre and post treadmill training to measures changes in walking, running and jumping.

Single Leg Balance Test. Timed single leg balance in standing is a commonly used measure to assess balance in adults and children. The measure can be used alone[38–40] or as part of a specific motor test, such as the Berg Balance Scale for adults,[41,42] the Peabody Developmental Motor Scales, Second Edition, for children,[43] or the GMFM for children with CP.[37] An individual is timed while standing on one leg without holding onto a support, and there is a ceiling of 10 seconds on some of the tests, including the GMFM. For the Single Leg Balance Test, items 57 and 58 from Dimension D of the GMFM were used to establish measurement protocols. Children were asked to stand on their most involved leg without holding onto a support, and the time in seconds was measured on a stopwatch, up to a maximum of 10 seconds.

BWSTT Apparatus and Protocol. A hydraulic weight-supported system was suspended over a motor-driven treadmill with variable speed control. Subjects were supported in an appropriately fitted harness suspended from the frame of the LiteGait I system (http://www.litegait.com). The LiteGait I apparatus included a Bisym attachment (http://www.litegait.com/BiSym.htm), a bilateral symmetry scale that measures and displays the amount of weight-bearing support provided on the right and left side in standing and as it changes throughout the gait cycle. Weight supported at onset was approximately 30% as measured by the Bisym attachment, with treadmill speed set at

1.5 to 1.9 mph. In all subjects, weight support was gradually decreased to 0% or as close to 0% as possible during the intervention, and treadmill speed gradually increased to 2.3 to 3.1 mph by the end of the two-week training. Treadmill training with the LiteGait I took place over two consecutive weeks, six days a week. Children walked on the treadmill for 30 minutes twice daily, once in the morning and again in the afternoon. Subjects' initial treatment sessions generally consisted of three 10-minute walking sessions interspersed with five-minute rest periods. However, if the subjects needed to rest at any time they were allowed to stop and rest. As the study progressed, rest breaks were more individualized, and subjects were allowed to continue walking on the treadmill as long as they desired, up to the 30 minute limit. In all cases total walking time totaled 30 minutes, with a maximum of two rest periods.

A licensed physical therapist and two research assistants facilitated the children's gait patterns on the treadmill during the training sessions. The treatment goal was to reproduce a normalized gait cycle throughout the sessions; attention was paid to appropriate gait kinematics, emphasizing heel strike at initial contact, knee extension at stance phase, and hip extension at terminal stance. One training facilitator was positioned behind the child to provide stabilization at the hips while the other facilitators assisted leg movement as needed in order to assist the child to achieve normal gait kinematics. As gait patterns improved for each child through the two-week training, facilitators were able to decrease the amount of assistance provided during the gait cycles.

Data Analysis

To assess the group differences between pre and post measurements, paired *t* tests were used to compare the means of the outcome measures. In addition, to assess changes in individual children, two approaches were used: (1) calculation of the percent change from pretest to posttest for each child on each of the assessments and (2) calculation of the minimal detectable change (MDC) for each measure, for which there were test–retest data and comparison of the MDC to each child's individual change. The MDC, the magnitude of change over and above measurement error of two repeated measures at a specified confidence level, is a technique that has been used in research with children with developmental disabilities.[17] To estimate test–retest reliability for the Six Minute Endurance Walk, the Energy Expenditure Index, and the Ten Meter Walking Velocity, the within-study preintervention data (the first two repeated measures) was used, while the previous published reports of test-retest data was used for the GMFM. The MDC was not calculated for the Single Leg Balance Test since no test-retest reliability data was available from the study.

RESULTS

Group Differences

Table 2 presents the results of the clinical measures for the group. Paired *t* tests showed significant differences between the pre- and post-measures on the walking velocity for the Ten-Meter Velocity Walk (t [5] = −2.80, $p = 0.038$) and on the EEI (t [5] = 3.04, $p = 0.029$). Paired *t* tests did not show significant differences between the pre and post measures for the group on the Six-Minute Endurance Walk (t [5] = −0.20, $p = 0.851$), on the Single Leg Balance (t [5] = −1.40, $p = 0.221$), or on the GMFM Percentage Scores for Dimension E (t [5] = 2.27, $p = 0.72$).

Individual Children

Table 3 shows the calculations for the MDCs for this study. Table 4 presents the scores and changes from pre- to post-testing, including fulfillment of MDC criteria for the individual children on the endurance, functional gait, and balance measures. Variability of outcomes was observed, with some of the children showing positive changes, and others having no change or a decline in performance. All

TABLE 2
Comparison of Group Means on Pre- and Postclinical Measures

	Mean	SD	Range	*p* Value
10-Meter walking velocity (m/sec)				
Pre	1.47	0.32	1.10–2.00	
Post	1.66	0.41	1.20–2.26	0.038*
EEI				
Pre	0.68	0.30	0.38–1.10	
Post	0.39	0.10	0.23–0.52	0.029*
Six-minute endurance walk (feet)				
Pre	1480	316	1051–1856	
Post	1501	274	1195–1918	0.851
GMFM percentage scores for dimension E				
Pre	92.53	5.96	80.6–97.2	
Post	95.20	3.89	87.5–98.6	0.072
Single leg balance on most involved leg (sec)				
Pre	3.67	3.14	2–10	
Post	5.00	3.16	3–10	0.221

* Significant at $p < 0.05$.

TABLE 3

Calculation of MDC

Outcome Variable	Test-Retest Data; Data Source; n for SD Baseline	Calculation for MDC 95 = SD × Square Root of 1 – r × 1.96 × Square Root of 2	MDC 95
10-Meter walking velocity (m/sec)	r = 0.88; current study; n = 6	0.32 × sqrt (1 – 0.88) × 1.96 × sqrt2	±0.31
EEI	r = 0.69; current study; n = 6	0.30 × sqrt (1 – 0.69) × 1.96 × sqrt2	±0.46
Six-minute endurance walk (feet)	r = 0.93; current study; n = 6	316 × sqrt (1 – 0.93) × 1.96 × sqrt2	±227
GMFM	ICC = 0.99, Russell et al, 2000; n = 4	5.96 × sqrt (1 – 0.99) × 1.96 × sqrt2	±1.65

children improved on the EEI, and the majority improved on the Ten-Meter Walking Velocity (five of the six children) and the GMFM (four of the six children). Half of the subjects showed no change or a decline in performance on the Six-Minute Endurance Walk and Single Leg Balance. On the other hand, certain individual children made impressive positive percent changes in some clinical measures, such as Subject 1's 22.8% improvement in velocity and 300% improvement in single leg balance, Subject 6's 29.9% improvement in endurance, and Subject 4's 59% improvement in energy expenditure. Four children showed MDCs in a positive direction on both an endurance measure and a functional gait measure, and each of the endurance and functional gait measures had at least one child with a positive MDC. Two children made these minimal detectable changes in a positive direction on the Six Minute Endurance Walk and the EEI, and three children (half the sample) made these positive changes on the GMFM. One child showed a minimal detectable change on the Six Minute Endurance Walk in a negative direction.

DISCUSSION

As a group, the ambulatory children with CP in this sample made statistically significant improvements in a measure of endurance (energy expenditure) and a measure of functional gait (walking velocity) after the intensive BWSTT. This result is particularly impressive not only because of the small sample size but also because one participant was an "outlier" who actually decreased her speed on the Ten-Meter Walking Velocity. We believe this was because of her attention, after training, to her gait pattern rather than to her speed. Group results for the other three measures spanning endurance, functional gait, and balance, however, were not statistically significant. The mixed results for the group as a whole appear to be attributable to the wide variation of responses along the continuum from positive to negative results in the individual children. Because the sample size was small, with only six subjects, each individual strongly affected the overall group results. Although the answer to first question of this study, related to group results, was mixed, answers to the remaining questions of the study related to individual children may provide more helpful and clinically relevant information for therapists to assess potential use of BWSTT for specific children on their caseload.

Similar to the results in other BWSTT studies with children with CP,[9,11] the children in this sample showed marked differences among themselves, with a range from decreased scores to no score change to improved scores on the various clinical measures. Because of this wide range in opposite directions, many of the individual children's differences cancelled out when assessed as a group. However, when viewed individually, certain children did demonstrate important clinical changes in only a two-week period in some of the measures of endurance, functional gait and balance. It is important to determine which children benefited from the

TABLE 4

Comparison of Pre and Post Assessments for Individual Children

	Six-Minute Endurance Walk		EEI		10-Meter Walking Velocity		GMFM		Single Leg Balance	
Subject	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	1856 ft	1918 ft	1.03	0.52	1.62 m/sec	1.99 m/sec	97.2	97.2	2 sec	8 sec
Direction, % change, and MDC		+3.3		+50*		+22.8*		0		+300
2	1841 ft	1467 ft	0.51	0.23	1.31 m/sec	1.20 m/sec	97.2	97.2	3 sec	3 sec
Direction, % change, and MDC		−20.3*		+55		−8.4		0		0
3	1336 ft	1195 ft	0.38	0.34	1.30 m/sec	1.54 m/sec	93.1	94.4	3 sec	3 sec
Direction, % change, and MDC		−10.6		+11		+18.5		+1.4		0
4	1466 ft	1426 ft	1.10	0.45	1.51 m/sec	1.68 m/sec	93.1	95.8	2 sec	3 sec
Direction, % change, and MDC		−2.7		+59*		+11.3		+2.9*		+50
5	1051 ft	1278 ft	0.49	0.35	1.10 m/sec	1.28 m/sec	80.6	87.5	2 sec	3 sec
Direction, % change, and MDC		+21.6*		+29		+16.4		+8.6*		+50
6	1329 ft	1727 ft	0.59	0.44	2.00 m/sec	2.26 m/sec	94.4	98.6	10 sec	10 sec
Direction, % change, and MDC		+29.9*		+25		+13.0		+4.4*		0

* MDC occurred.

Single leg balance = on most involved leg.

intensive BWSTT program, which outcome measures showed changes, and what specific factors might have contributed to the positive changes that occurred in some children. That is, why did some ambulatory children improve after an intensive BWSTT program and others did not?

In general, both younger and older children in both the hemiplegic and the asymmetrical diplegic diagnostic categories showed some improvement on some of the measures used in this study for endurance, functional gait, and balance after an intensive two-week BWSTT program. Each of the measures had positive percent changes for at least half the sample, and each measure also had at least one child who made a positive MDC. On the basis of positive percent change, all children improved on one of the endurance measures, the EEI, and the majority improved on the functional gait measures, the Ten-Meter Walking Velocity (five of the six children) and the GMFM (four of the six children). However, although half of the subjects improved, the other half showed no change or a decline in performance on the Six-Minute Endurance Walk and Single Leg Balance. In addition, based on the more stringent criteria of the MDC changes, four of the six children in this sample, with an age range from eight to 14 years old, had positive MDC changes in both an endurance measure and a functional gait measure. It is interesting to note that none of these children improved an MDC on both endurance measures simultaneously, or on both functional gait measures simultaneously. This may be due to differences in factors related to the measures themselves as well as to differences in characteristics of the children.

Regarding the endurance measures, the measurements for energy expenditure were dependent not only on the children's heart rates but also on their speeds on the treadmill, which was externally controlled and consistent. However, the measurements for the endurance walk were dependent on the distance covered and therefore also on the child's speed of walking (eg, faster equaled further) over six minutes, and these factors were entirely self-chosen by the children, and therefore were more prone to variability based on aspects such as the child's attention, intention and fatigue. Another factor influencing the results involved the initial assessment scores of the children. Because the children in the study were all community ambulators, perhaps the children who showed the least change may have already been at their maximum potential before trial onset. However, the children who improved the most on each endurance measure and who also met the MDC criteria had the poorest initial scores. For example, two children who had initial EEI scores higher than the norms actually improved enough to have final EEIs within the normal range. Not only function but fitness is an important consideration for children and adults with disability, and this study suggests that an intensive BWSTT program may also contribute to improved endurance on some measures in certain individuals.

Three of the four children who showed minimally detectable changes in the functional gait measures made them on the GMFM, while the other child had an MDC on the Ten-Meter Walking Velocity. This may likewise be the result of differences in factors related to the measures themselves as well as to differences in factors related to the children. The GMFM Section E measures several functional activities besides walking, such as kicking, jumping, and stair climbing, while the Ten-Meter Walking Velocity measures only walking speed; therefore, more opportunity for improvement existed throughout the different items on the GMFM. The two children that did not show improved scores on the GMFM had an original score of 70, which is just two points lower than the maximum score attainable, and they may have already initially been at their maximum potential. Although the three children who exceeded the MDC change in a positive direction were from both the younger and older groups, with both hemiplegic and diplegic diagnoses, their ages ranged from eight to twelve years, and they may have been old enough to be attentive and to benefit from the training but young enough to not have yet reached their maximum potential. The child with the lowest initial score on the GMFM showed the most improvement post training.

Regarding balance, no child showed a decrease in their balance skills, and half of the children increased their single leg balance time markedly. These three children, spanning the younger and older groups, had a variety of diagnoses but had the lowest initial scores, and therefore perhaps had the most opportunity for improvement. Because the maximum score used for this study was 10 seconds, and testing was discontinued after that time, it might be that the child who demonstrated the maximum score both in pre and post testing might have also improved post-training if the maximum time tested was increased past 10 seconds.

The children in this sample who improved the least, with no positive MDC changes in any measure, included a teenage girl with right hemiplegia, and the youngest boy, age six years, also with right hemiplegia. The teenager was at an age during which she appeared to be very conscious of her appearance, and clinical observations were that she paid particular attention to her gait pattern during the training. During the post-testing, her increased attention to foot placement of her involved extremity during the endurance and functional gait measures slowed her pace, because she appeared to be using cognitive motor planning to improve her heel strike with each step. Her intention and demonstration of improved gait quality superseded any other goals of increased speed or endurance. Although her pattern of increased awareness decreased her speed on the walking velocity and also decreased her endurance on the six-minute walk, this result could be considered a positive outcome for this individual because her awareness of her gait was heightened with the BWSTT intervention. A clinical therapist might be pleased by the teenager's improvement in gait quality, even though she did not improve significantly on the measured outcomes of this research project. Therefore, her lack of improvement should not be construed as lack of all clinical benefit for this teenager, but rather a lack of benefit on the measures used in this study. In contrast, the youngest child had less focused attention than the older children both during the assessments and the training. Initially, he had difficulty walking fast without running, which may have inflated his initial scores on some measures; in addition, at the end of the training, he appeared more fatigued than the older children from the intensity of the BWSTT, which may also account for less improvement in his final scores. A clinical implication of this finding is that therapists need to recognize that a child's decreased attention, interest and motivation for the training, whether due to age or other factors, may impact their participation and potential benefit from an intense program.

Because younger and older children with both hemiplegia and asymmetrical diplegia showed some improvement on some of the measures used in this study, neither age nor diagnostic category suggests preclusion from consideration of an intensive BWSTT program for an ambulatory child with CP. In addition, each of the outcome measures was appropriate for use with the children in this study, and all measures showed positive percent changes for at least half the sample. Similar to another study,[9] children in this study with the lowest initial scores improved the most in several of the measures.

Limitations

A major limitation of this study was the lack of a control group to determine whether the changes made in this sample of ambulatory children with CP were truly a result of the BWSTT or were the result of other factors that occurred within the two-week period. Because of this limitation, the findings are only preliminary and cannot be generalized. The issues of intensity and practice are important ones, and future research is needed to determine whether the key ingredient facilitating clinical changes in children with CP is the intensity of the repetitive training rather than either the body weight support and/or the treadmill training. Recent literature involving ambulatory patients with chronic stroke suggests that groups showed the same improvement with equal amounts of practice in BWST training compared to overground walking exercise.[14] Perhaps if the children in our sample practiced walking overground without the treadmill or engaged in a different repetitive activity, such as cycling with the same protocol intensity, they would have had similar improvements.

Another limitation of the study was the lack of objective measurements of the quality of the children's gait patterns before and after training, because BWSTT involves facilitators to improve gait parameters such as heel strike and hip extension during the gait cycle. Because BWSTT protocols usually include several facilitators to ensure practice of a normal gait pattern in the subjects, suggestions are to include formal gait analysis measures before and after training to determine actual differences in gait parameters as well as to help determine the optimal number of facilitators required to change gait patterns in subjects using BWSTT protocols. The issue of retention of changes observed after the intervention was not addressed in this study, and future research should consider long-term follow-up data which would provide critical information to determine how often children with CP who are ambulatory might need intensive intervention "tune-ups." In addition, several authors[8,10] recommend that treadmill apparatus and training be done in the home for convenience and cost-effectiveness, and future studies comparing a home-based vs clinic-based program would provide important information about these different settings.

CONCLUSIONS

Many children with CP do not have easy access to pediatric physical therapists and rehabilitation centers, making it difficult to participate in long-term interventions. In some cases it may be easier for children and their families to participate in brief, intensive therapeutic programs. This study found that a short, intensive course of BWSTT improved measures of endurance, functional gait, and balance in a small sample of ambulatory school-aged children with CP who were in different diagnostic categories and age groups. Both younger and older children in both the hemiplegic and the asymmetrical diplegic diagnostic categories showed improvement after an intensive two-week BWSTT program, and there was a trend for greatest improvement among the children with the lowest initial scores. All children improved on the EEI, and the majority improved on the Ten Meter Walking Velocity (five of the six children) and the GMFM (four of the six children). Half of the subjects improved and half showed no change or a decline in performance on the Six-Minute Endurance Walk and Single Leg Balance. Further study with children with CP and various intensities of BWSTT will continue to help identify specific clinical characteristics that may assist therapists in predicting which children will respond best regarding functional and fitness outcomes.

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