R A T E

Effectiveness of a low-cost body weight support training device in the rehabilitation of cerebral palsy

Deepak Sharan, Joshua Samuel Rajkumar, Rajarajeshwari Balakrishnan, Amruta Kulkarni, Kalpana Selvakumar, Sivakrishna Gampa, Mathankumar Mohandoss and Rameshkumar Ranganathan

Abstract

Background: Body weight supported treadmill training (BWSTT) has been proven to be effective in rehabilitation of persons with cerebral palsy (CP). However, it has still not found widespread usage, especially in industrially developing countries, due to its high cost. Treadmill training promotes a rhythmical movement of the lower extremities through motor learning, which can be enhanced by BWSTT for persons with CP. Hence, the research and development team of a tertiary level neuromusculoskeletal rehabilitation center designed a low-cost body weight support training (BWST) device. The aim of this study was to evaluate the effectiveness of the BWST device on gait and ambulation in persons with CP post single-event multilevel surgery (SEMLS) of the lower extremities.

Method: A randomized controlled trial was conducted in 50 persons with CP aged between 5 and 20 years, who underwent a type of SEMLS called single-event multilevel lever arm restoration and anti-spasticity surgery (SEMLARASS). They were randomly assigned to two groups: group A ($n = 25$) received gait training and treadmill training with the BWST device, and group B ($n = 25$) received gait training and treadmill training without the BWST device. The designed BWST device was manually operated and based on an un-weighing principle in which a vest of different sizes un-weighed 10–30% of the individual's weight transmitted to the ground by means of adjustable counterweights fixed on a movable metallic frame which had an adjustable top lever (holding the vest) and a handle bar for the patient to hold. The entire cost for the finished BWST device was estimated around 700 USD. The study duration was 5 weeks with 1 h of intervention per day for 6 days per week. Physician Rating Scale (PRS), Dynamic Gait Index (DGI) and Functional Mobility Scale (FMS) were the primary outcome measures.

Results: Group A showed significant positive differences in the scores of PRS ($p < 0.001$), DGI ($p < 0.001$) and FMS ($p < 0.01$) when compared with group B, 5 weeks after the intervention, and the results were maintained at a follow-up of 12 months.

Conclusion: The low-cost BWST device was found to be clinically effective in improving gait and ambulation in persons with CP following SEMLARASS.

Keywords

Body weight support treadmill training, gait training, cerebral palsy, SEMLS, SEMLARASS

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Introduction

Cerebral palsy (CP) is a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, by epilepsy and by secondary musculoskeletal problems.[1] A common functional goal in rehabilitation of persons with CP is the attainment of upright locomotion (i.e. walking).[2]

RECOUP Neuromusculoskeletal Rehabilitation Centre, Bangalore, Karnataka, India

Corresponding author:
Deepak Sharan, RECOUP Neuromusculoskeletal Rehabilitation Centre, 312, 10th Block, Further Extension of Anjanapura Layout, L.B. Shastri Nagar, Bangalore-560108, India.
Email: drdeepaksharan@yahoo.com

Persons with CP who are between Gross Motor Function Classification System (GMFCS) levels III to V have major limitations in ambulation.[3] Treadmill training has shown positive outcomes in improving ambulation in neurological disorders such as stroke, spinal cord injuries and CP. Animal studies of supported treadmill training have demonstrated restoration of coordinated stepping movements in spinalized cats.[2,4] Consequently, body weight supported treadmill training (BWSTT), which is a method of task-oriented ambulatory training using an overhead suspension system and harness to support a percentage of the patient's body weight as the patient is walking on a treadmill, has emerged as an important tool in neuro-rehabilitation as it aids in reducing the weight from the lower extremities symmetrically as the patient tries to walk.[5] BWSTT addresses the problem of gait limitations at multiple levels of the International Classification of Functioning, Disability and Health (ICF), which makes it an important tool in neurological rehabilitation of gait.[6] The use of BWSTT is based on current motor learning theories specifying active engagement in task performance over time for neural plasticity to occur.[7] Several studies specific to the use of BWSTT for pediatric neuro-rehabilitation have been published (Table 1).

Recent systematic reviews of BWSTT in children describe weak evidence with no reported randomized clinical trials.[6,8,9] However, the evidence for BWSTT varies by diagnosis, with the strongest evidence suggesting positive outcomes in children with Down syndrome and limited evidence for children with CP.[10–16]

Table 1. Positive outcomes of using BWSTT.

Positive outcomes	Reported by
BWSTT is a dynamic task-specific repetitive activity, incorporating weight bearing, stepping and balance functions	Kleim JA et al., 2008[7] Dodd KJ et al., 2007[13]
BWSTT allows for early ambulation and can discourage compensatory gait patterns from developing	Visintin M et al., 1998[5]
BWSTT encourages users to practice gait as a whole task	Hesse S et al., 1999,[21] Ada L et al., 2007[22]
BWSTT improves cardio-vascular endurance	Provost B et al., 2007,[7] Hesse S, 2008[23]
BWSTT provides improved safety and reduces risk of falls	Dodd KJ et al., 2007[13] Hesse S, 2008[23]

The limitations of BWSTT include the high cost of equipment and being labor intensive, usually involving two or three staff. Companies such as Biodex, Lode, Glidetrak, LiteGait, Second Step and Rifton sell BWSTT devices at a cost ranging from around USD 10,000 to USD 15,000. The treadmill and body weight suspension system alone may cost up to a maximum of USD 180,000.[17] The outcome of two systematic reviews conducted in 2009 also confirmed the above factors, along with the need for large-sized randomized controlled trials.[6,8] Single-event multilevel surgery (SEMLS) refers to the correction of all orthopedic deformities in one session, which has the advantage of requiring one hospital admission and one period of rehabilitation.[18,19] BWSTT is one of the most common gait training programs followed in the rehabilitation period post SEMLS.[20] However, no studies have been reported yet in the literature studying the effectiveness of BWST among persons with CP after SEMLS. Hence, the objective of our study was to develop a BWST device at low cost and to evaluate its effectiveness among persons with CP after SEMLS on the parameters of gait and ambulatory function.

Methodology

A randomized controlled trial was conducted among 50 children and adolescents with CP, from a single multi-disciplinary rehabilitation center, who were in their post-operative rehabilitation period after SEMLS. The SEMLS was more specifically called single-event multilevel lever arm restoration and anti-spasticity surgery (SEMLARASS). The surgical procedures included intramuscular release and controlled tendon lengthening using the principles of orthopedic selective spasticity control surgery and simultaneous restoration of lever arm dysfunctions, which was followed by plaster immobilization of both lower limbs for 6–10 weeks, and then protocol-based, sequenced multidisciplinary rehabilitation.[20]

Selection criteria

The inclusion criteria for the study were as follows: (a) male or female gender, (b) age 5–20 years, (c) diagnosis of spastic or dyskinetic CP, (d) participants post SEMLARASS were in the ambulatory phase of rehabilitation, (e) able to understand commands, (f) GMFCS level 3–5 before SEMLARASS, (g) no other previous orthopedic or neuro surgeries, (h) no previous treatment with botulinum toxin injections or other types of invasive treatments.

Intervention program

After providing informed consent, the participants were randomly assigned to group A (experimental) and
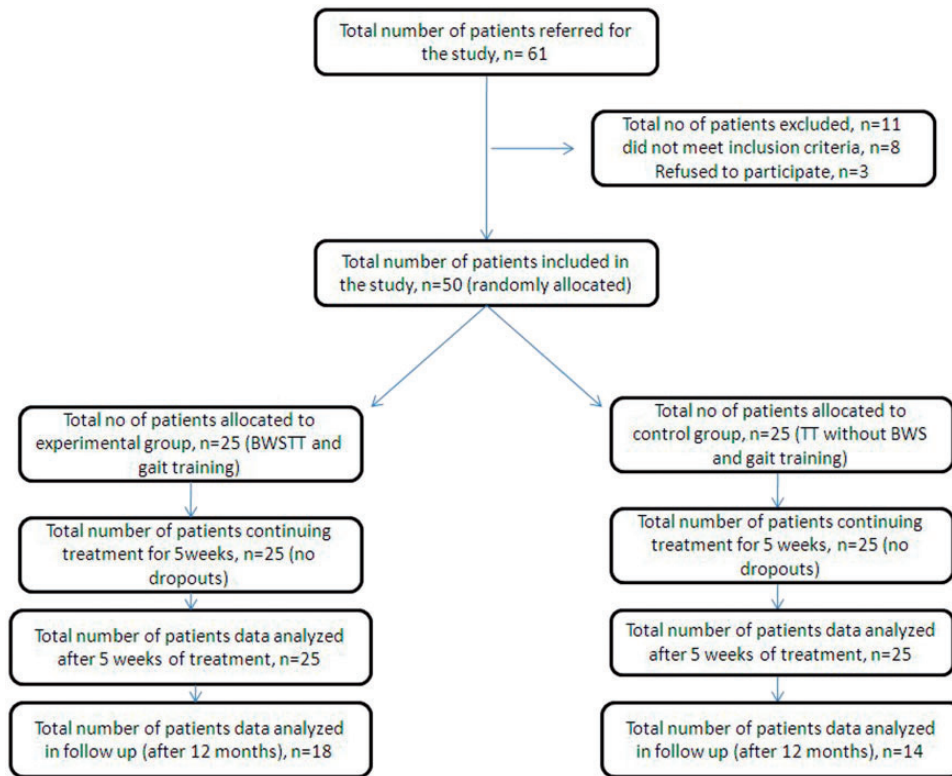
Figure 1. Flowchart of the study participant selection process.

group B (control) based on a computer-generated permuted allocation of 25 children in each group. The experimental group underwent the gait training program over-ground and on the treadmill with the low-cost BWST device, whereas the control group underwent the same training program without the BWST device. The training was given for 1 h per day for 6 days in a week, for a total of 5 weeks. The methodology is described in Figure 1, which shows the flowchart of the study process. The gait training protocol provided for both the groups is displayed in Table 2.

Construction of the low-cost BWST device

The BWST device was constructed with stainless steel (SS), and was designed by some of the authors and constructed by a rehabilitative and assistive devices manufacturer who had experience in making various rehabilitation devices with SS material. The entire cost of the finished BWST device was approximately 700 USD. The BWST device consisted of the following components, shown in Figure 2, showing the lateral view of the BWST device with a suspended model: vertical SS frame (a), which was fixed to a 3-sided platform base (b). There were two movable segments which ran up and down on the vertical SS frame: segment 1 (c) overhead top lever system (refer to Figure 3, showing the top view of the overhead system): Y-shaped

(the width of the "Y" spanned the average shoulder width such that the user, after suspension, remained un-twisted) adjustable recoiling top lever to which the loaded weights were suspended by a metallic rope which ran through a pulley fitted at the top end of the vertical SS frame, and segment 2 – (d) Y-shaped adjustable handle bar or hand rail. The other external components were (e) body vest (available in three different sizes) for holding and suspending the patient with the top lever by means of dog clips and (f) removable weights of 500 g per unit which could be added up based on the user's body weight.

Measurements of the low-cost BWST device

The measurements (refer to Figure 2 and 3) of the BWST device are as follows: (a) to (b) (distance of the pulley bar which holds the overhead pulley to the vertical frame) = 14 cm; (b) to (c) (distance between the top to bottom of the vertical frame) = 158 cm; (c) to (d) (ground clearance distance from the bottom of the vertical frame, which is fixed to the platform base to the floor) = 15 cm; (e1) to (f1) = (e2) to (f2) (distance of the horizontal bars of the platform base) = 120 cm; (e1) to (e2) = (f1) to (f2) (clearance distance between the two horizontal bars of the platform base) = 80 cm; (g1) to (h1) = (g2) to (h2) (distance of the length of the hand rails) = 95 cm; (i1) to (j1) = (i2) to (j2) (distance of the

Table 2. Gait training protocol provided for the experimental and control group.

Parameter	Experimental group	Control group
Type of program	Gait training (with a BWST device)	Gait training (without a BWST device)
Duration of program	60 minutes per day with adequate breaks	60 minutes per day with adequate breaks
Number of sessions	6 days per week for 5 weeks	6 days per week for 5 weeks
Physical support	Physical support provided for unloading and safety mostly by the BWST, guidance during initial completion of task	Physical support provided for unloading, safety and guidance during initial completion of task
Orthosis	Ankle Foot Orthosis ($n = 17$) or Foot Reaction Orthosis ($n = 8$) (if needed)	Ankle Foot Orthosis ($n = 19$) or Foot Reaction Orthosis ($n = 6$) (if needed) and walker, elbow crutch or sticks
Unloading amount of weight	10–30% of body weight by the counterweights on BWST	No unloading as BWST not used
Speed of treadmill	Initially at a minimal speed of 0.1 m/s with a gradual increment of 0.1 m/s once the participant is comfortably walking without missing the steps and able to take a few steps without the help of staff. The average maximal speed reached by the study participants $= 0.5$ m/s	Initially at a minimal speed of 0.1 m/s with a gradual increment of 0.1 m/s once the participant is comfortably walking without missing the steps and able to take a few steps without the help of staffs. The average maximal speed reached by the study participants $= 0.3$ m/s
Gait training program	Includes two methods of training: 1. Over-ground walking training (30 min with a BWST device): short or long straight walks, obstacle crossing (using bars/cones/circles as obstacles to enhance the difficulty level), transitional tasks in walking (sit to stand; stand to walk; walk to turn; turn to stand), steps (a rectangular piece of wood), ramps and curbs. 2. Treadmill walking training (30 min with a BWST device): treadmill walking with gradually increasing speeds and decreasing the BWS	Includes two methods of training: 1. Over-ground walking training (30 min without a BWST device): Short or long parallel bar walking and walking with assistive devices progressively reducing the assistance (walker to elbow crutches to sticks) in obstacle crossing, transitional tasks in walking (sit to stand; stand to walk; walk to turn; turn to stand), steps, ramps and curbs. 2. Treadmill walking training (30 min without a BWST device): treadmill walking with gradually increasing speeds

long stem of the Y-shaped overhead system) $= 55$ cm; (k1) to (l1) $=$ (k2) to (l2) (distance of the short extended split stem of the Y-shaped overhead system) $= 28$ cm; (k1) to (k2) $=$ (l1) to (l2) (clearance distance between the two short extended split stem of the Y-shaped overhead system) $= 35$ cm; the breadth and width of the vertical frame is 10 cm $\times 10$ cm; the breadth and width of the overhead and platform horizontal bars are 5 cm $\times 2.5$ cm; the breadth and width of pulley bar is 14 cm $\times 2.5$ cm; the diameters of the hand rail and the rod connector from the vertical rod to the platform base are 8 cm.

Specific features of the low-cost BWST device

The whole BWST unit had four lockable wheels fixed to the four ends of the three-sided platform base and could be easily moved. The device was also constructed with the following major considerations: (a) allowed movement in and out and also fitted around the average sized treadmill, (b) one-sided open platform base so that there was access for the participant to be positioned inside without restriction for leg space or wheelchair entry, (c) the system could lift the patient to standing (by means of the recoiling top lever), (d) vest that snugly fitted around the trunk and provided an appropriate vertical unloading, (e) different sized vests (small, medium, large) to accommodate participants with various size ranges, (f) the treadmill would run with a starting low speed of 0.1 m/s, (g) the overhead system was springy and allowed for minimal vertical movements to give way to vertical displacement of the body while walking and at the same time, the unloading was maintained. The other key factors of the low-cost
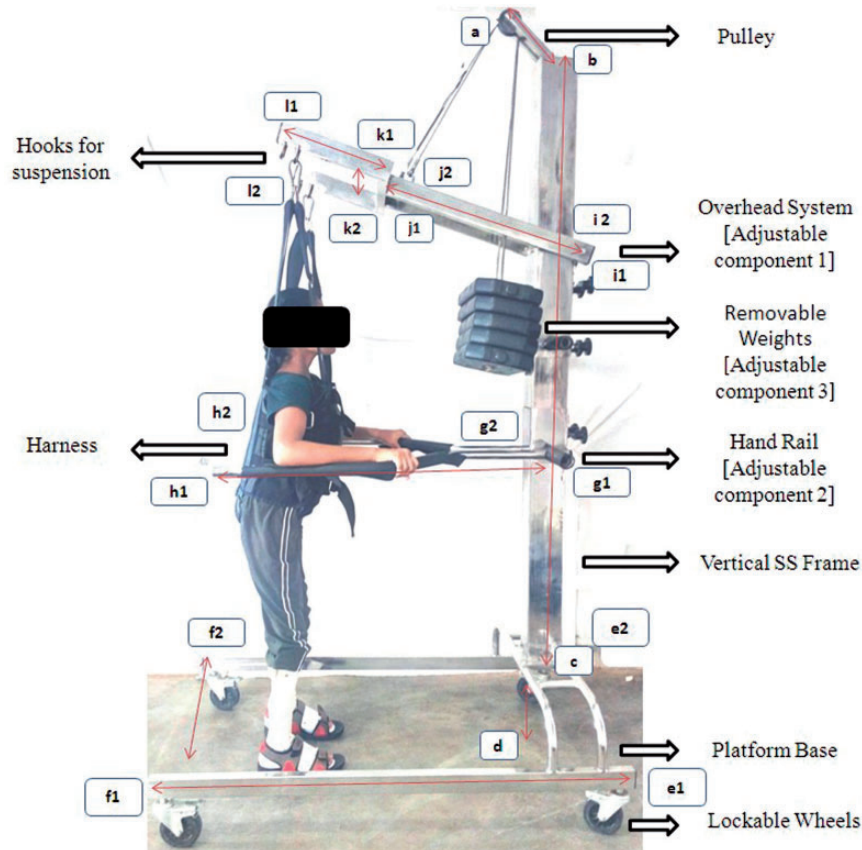
Figure 2. Lateral view of the BWST device with a suspended model.

BWST device are explained in Table 3. The major unloading parameter was that the BWST device unweighed about 10 to 30% of the participant's weight.

Assistance requirements in the low-cost BWST device

Assistance by physiotherapists was required in training to facilitate correct kinematics for swing and stance. One therapist usually stood behind the participant, to facilitate trunk alignment (trunk and hip extension) and weight shifting. The second therapist or caregiver sat beside the participant to facilitate the knee and foot position for weight bearing or limb loading and swing during stepping of the legs, to ensure heel strike at initial contact and prevent knee hyperextension. A third person or assistive straps might be required to support hemiplegic arm or assist with trunk control.

Outcome measures

The outcomes of control group and experimental group were measured before and after the 5 weeks of intervention. A follow-up measurement was performed 12 months after the intervention. The outcomes measures used were the Dynamic Gait Index (DGI), Physician Rating Scale (PRS) and Functional Mobility Scale (FMS). DGI measures the mobility function and dynamic balance in walking and stair climbing. There are eight items on the DGI and each item was scored on a 4-point scale as (3) Normal; (2) Mild impairment; (1) Moderate impairment; (0) Severe impairment, with a maximum score of 24. The eight items include walking, walking with speed changes, walking with vertical and then horizontal head turns, walking with a quick pivot stop, walking over objects, walking around objects and walking up and down stairs.[24] PRS is an observational clinical evaluation of gait in the sagittal plane on the parameters of foot contact, crouch, hip flexion, knee flexion and dorsiflexion.[25,26] The FMS is a six-level clinician-administered self-report ordinal scale that rates mobility within the different environmental settings of the home, school and community based on the assistance persons with CP require.[27]

Statistical analysis

Descriptive statistics were reported using mean and 95% CI for continuous variable and numbers and percentages for categorical variables. Independent *t*-test and paired *t*-test were used to analyze the significant
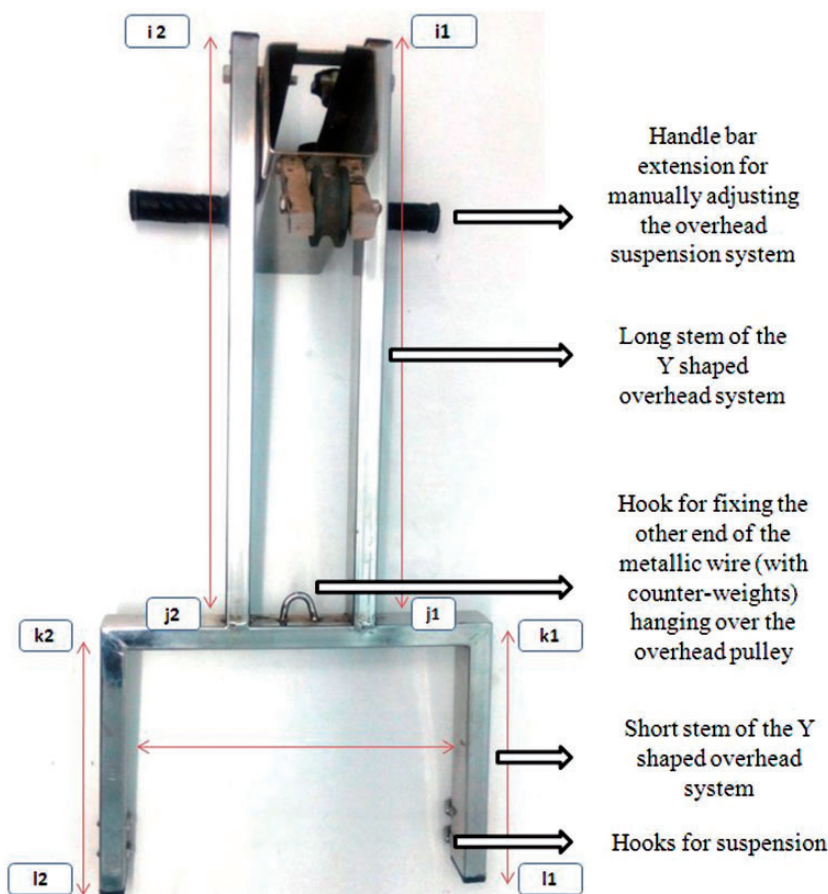
Figure 3. Top view of the overhead system of the BWST device.

difference between and within the experimental and control before, after 5 weeks and 12 months of intervention. A *p*-value less than 5% was considered statistically significant. The data were analyzed using SPSS version 17.

Results

The demographic details of the study participants are presented in Tables 4 and 5. Ages, gender and type of CP were found to be equally distributed among both the study groups. The mean scores of all the outcome parameters studied are exhibited in Table 6. The independent *t*-test results, presented in Table 7, showed that there was a significant difference in the outcomes of PRS Right ($t = 13.20$, $p < 0.001$), PRS Left ($t = 11.91$, $p < 0.001$), DGI ($t = 13.52$, $p < 0.001$) and FMS ($t = 12$, $p < 0.001$) after 5 weeks of intervention among the experimental group in comparison with the control group. The paired *t*-test results, presented in Table 8, showed that both the groups showed significant difference in the pre–post outcome parameters. However, the experimental group showed highly significant levels on PRS Right ($t = 32$, $p < 0.001$), PRS Left ($t = 25.41$, $p < 0.001$), DGI ($t = 59.71$, $p < 0.001$) and FMS ($t = 26.94$, $p < 0.001$) compared with only significant levels on all the pre–post outcome parameters of the control group. No falls or adverse events were reported in either group. The follow-up data of the experimental group participants who were available for repeat measurements ($n = 18$) were extracted on an average of 12 months' post test, which also showed that there was still a significant difference for the experimental group in the parameters of PRS Right ($t = 11.49$, $p < 0.001$), PRS Left ($t = 14.39$, $p < 0.001$), DGI ($t = 5.74$, $p < 0.001$) and FMS ($t = 8.24$, $p < 0.001$) compared with outcome from the participants ($n = 14$) of the control group (Table 9). The obtained results were maintained in the experimental group on the post-test follow-up test parameters, with a significant difference on PRS Right ($t = 8.44$, $p < 0.001$), PRS Left ($t = 5.29$, $p < 0.001$), DGI ($t = 4.67$, $p < 0.001$) and FMS ($t = 6.44$, $p < 0.001$), but were not maintained in the control group with a non-significant difference on PRS left ($t = 0.80$, $p = 0.43$), PRS Right ($t = 0.80$, $p = 0.43$), DGI ($t = 1$, $p = 0.33$) and FMS ($t = 1.88$, $p = 0.08$) (Table 10).

Table 3. Key factors of the BWST device.

Key factors	Explanation
Usage of stainless steel as the raw material	Superior properties such as stiffness, non-corrosiveness and ability to be welded easily in comparison with other materials. In addition, we have not yet observed any wear and tear or damage despite using the device for more 5 years. This adds to the safety aspect of the device.
Recoiling phenomenon	Recoiling means to pull back, which is the effect with which the BWST device can lift and hold the individual being treated in an upright position. This recoiling effect is through the top lever which gets pulled back due to the added weights that runs across a pulley through the metallic rope. With the help of this recoiling phenomenon, the top lever system propels the patient to attain an upright standing position with the minimal help of the therapist or by self with hand support on the hand rails in the BWST device.
Maneuverability	With the help of lockable wheels fixed to the platform base, the BWST device can be easily moved by both the therapist and the patient. The device is easy for the therapist to use by moving it across the therapy area for over-ground walking and fitting it back to the treadmill during the treatment session, and for the participant during over-ground walking.
Adjustability	The three adjustable components of the BWST device are as follows, and the adjustments are done uniformly for all the study participants: 1. Overhead top lever system: Runs vertically up and down through the full length of the vertical SS segment. It can be adjusted through knobs located on the posterior movable component 1. Criteria: The adjustments are made by the training therapist based on the two criteria that the overhead system must be clear of the participant's head and also should hold the harness system in a taut manner. 2. Hand rails: Runs vertically up and down through the full length of the vertical SS segment. It can be adjusted through knobs located on the posterior movable component 2. Criteria: The adjustments are made by the training therapist based on the criteria that for quadriplegia/triplegia the hand rail is fixed at elbow level, and for diplegia the hand rail is fixed at the trochanteric level. 3. Counterweights: Weights are adjusted manually based on the patient's body weight. They can be adjusted only manually by a therapist. The fixed end of the metallic wire to the top lever is removed (by dog clips) and after the weights are removed or added, the metallic wire can be fixed again. Criteria: Adjustment to the weights are made by the training therapist based on two criteria: that initially 20% of the patient's body weight is added as the counterweight, and difficulty is increased by reducing 3.5% of the counterweight once the patient has reached a speed of 0.2 m/s and is able to take clear steps for two subsequent training days without any difficulty.

Table 4. Mean age and weight of participants in the study.

	Group	N	Minimum	Maximum	Mean $\pm$ Std. Deviation
Age	Experimental	25	10	18	13.84 $\pm$ 02.51
	Control	25	7	19	12.84 $\pm$ 03.15
Weight	Experimental	25	19	51	33.32 $\pm$ 08.88
	Control	25	12	54	30.00 $\pm$ 12.53

Discussion

The addition of the low-cost BWST device to conventional gait and treadmill training provided significant improvements in the specific gait and mobility parameters when compared with conventional gait and treadmill training only. The maintenance of the positive outcomes for the participants who underwent BWST at a follow-up of 12 months showed that the effect of training was long lasting. The amount of weight used for unloading is dependent on the ability of the participant to carry body weight on the affected legs during single limb stance while maintaining proper trunk and limb alignment. Gradually, the unloading weight was

Table 5. Frequency distribution of demographic profile of the participants.

	Groups		Frequency (n = 25)	Percent (%)
Gender	Experimental	Female	14	46.7
		Male	11	55
	Control	Female	16	53.3
		Male	9	45
Type of cerebral palsy	Experimental	Spastic hemiplegia	4	50
		Spastic quadriplegia	15	60
		Spastic diplegia	6	35.3
	Control	Spastic hemiplegia	4	50
		Spastic quadriplegia	10	40
		Spastic diplegia	11	64.7
Type of SEMLARASS	Experimental	VDRO (proximal femur) + OSSCS of lower limbs	13	52
		FDRO (distal femur) + OSSCS of lower limbs	8	32
		Only OSSCS of lower limbs	4	16
	Control	VDRO (proximal femur) + OSSCS of lower limbs	9	36
		FDRO (distal femur) + OSSCS of lower limbs	12	48
		Only OSSCS of lower limbs	4	16

VDRO: varus derotation osteotomy; FDRO: femoral derotation osteotomy; OSSCS: orthopedic selective spasticity control surgery

Table 6. Mean scores of all the outcome measures used to examine the BWST device.

Outcome parameters		Experimental group		Control group	
		N	Mean ± Std. Deviation	N	Mean ± Std. Deviation
PRS right	Pre test	25	7.04 ± 1.20	25	6.76 ± 2.04
	Post test	25	13.44 ± 1.26	25	10.20 ± 2.08
	Follow-up	18	14.94 ± 0.87	14	9.42 ± 1.78
PRS left	Pre test	25	7.04 ± 1.92	25	7.12 ± 1.20
	Post test	25	13.72 ± 2.17	25	10.36 ± 1.07
	Follow-up	18	15.22 ± 0.80	14	10 ± 1.24
DGI	Pre test	25	11.08 ± 2.17	25	10.92 ± 2.64
	Post test	25	19.44 ± 1.80	25	16.28 ± 2.86
	Follow-up	18	21.11 ± 2.60	14	15.5 ± 2.90
FMS	Pre test	25	2.00 ± 0.81	25	2.08 ± 0.81
	Post test	25	4.20 ± 0.76	25	3.08 ± 0.75
	Follow-up	18	5 ± 0.59	14	2.92 0.82

reduced to reduce the support as the participant was able to tolerate loading the legs in stance without the knee buckling, maintaining the ability to swing the leg independently and maintaining hip extension in weight bearing.[13,15,28,29] The speed of treadmill was kept as slow as possible in the initial phase to maintain the integrity of gait pattern, namely maintaining adequate step length and swing through, which was also supported by previous studies.[6,8,16,23] The duration of treadmill training was not determined in previous studies.[8] In this study, the duration of treadmill training was set at approximately 30 min (in a 60-min session which included another 30 min of over-ground walking) with adequate breaks in between. Our BWST device had a handrail which has been shown to increase single limb support and improve gait symmetry, but

Table 7. Independent *t*-test between the experimental and control group on all the studied outcome parameters.

Outcome parameter	Group	N	Mean ± Std. Deviation	t-test	Level of significance
PRS right	Experimental	25	6.40 ± 1.00	13.20	0.001**
	Control	25	3.44 ± 0.50		
PRS left	Experimental	25	6.68 ± 1.31	11.91	0.001**
	Control	25	3.24 ± 0.59		
DGI	Experimental	25	8.36 ± 0.70	13.52	0.001**
	Control	25	5.36 ± 0.86		
FMS	Experimental	25	2.20 ± 0.40	12.00	0.001**
	Control	25	1.00 ± 0.28		

**Denotes highly significant difference

Table 8. Paired *t*-test between pre test and post test between the experimental and control group on all the studied outcome parameters.

Group	Outcome parameter	N	Mean ± Std. Deviation	t-test	Level of significance
Experimental	PRS right Pre test – post test	25	6.40 ± 1.00	32.00	0.001**
	PRS left Pre test – post test	25	6.68 ± 1.31	25.41	0.001**
	DGI Pre test – post test	25	8.36 ± 0.70	59.71	0.001**
	FMS Pre test – post test	25	2.20 ± 0.40	26.94	0.001**
Control	PRS Right Pre test – post test	25	3.44 ± 0.50	23.95	0.010*
	PRS Left Pre test – post test	25	3.24 ± 0.59	17.12	0.010*
	DGI Pre test – post test	25	5.36 ± 0.86	21.15	0.020*
	FMS Pre test – post test	25	1.00 ± 0.28	7.32	0.040*

**Denotes highly significant difference, *Denotes significant difference

Table 9. Independent *t*-test between the experimental and control group on all the studied outcome parameters: follow-up test data.

Outcome parameter (12 months follow-up)	Group	N	Mean ± Std. Deviation	t-test	Level of significance
PRS right	Experimental	18	14.94 ± 0.87	11.49	0.001**
	Control	14	9.43 ± 1.79		
PRS left	Experimental	18	15.22 ± 0.80	14.39	0.001**
	Control	14	10.00 ± 1.24		
DGI	Experimental	18	21.11 ± 2.60	5.74	0.001**
	Control	14	15.50 ± 2.90		
FMS	Experimental	18	5 ± 0.59	8.24	0.001**
	Control	14	2.93 ± 0.83		

**Denotes highly significant difference

Table 10. Paired *t*-test between post test and follow-up test between the experimental and control group on all the studied outcome parameters.

Group	Outcome parameter (12 months follow-up)	N	Mean ± Std. Deviation	*t*-test	Level of significance
Experimental	PRS right Post test – follow-up	18	14.94 ± 0.87	8.44	0.001**
	PRS left Post test – follow-up	18	15.22 ± 0.80	5.29	0.001**
	DGI Post test – follow-up	18	21.11 ± 2.60	4.67	0.001**
	FMS Post test – follow-up	18	5 ± 0.59	6.64	0.001**
Control	PRS Right Post test – follow-up	14	9.42 ± 1.55	0.80	0.434[NS]
	PRS Left Post test – follow-up	14	10 ± 1.24	0.80	0.434[NS]
	DGI Post test – follow-up	14	15.5 ± 2.90	1	0.335[NS]
	FMS Post test – follow-up	14	2.92 ± 0.82	1.88	0.082[NS]

**Denotes highly significant difference; [NS]Denotes no significant difference

ultimately the arms should swing as part of the normal gait pattern, as supported by previous studies.[28] This study further adds to the rationale behind the use of BWST for persons with CP and also describes specific protocol parameters, so that generalizing its use across different groups of persons with CP is possible.[13–16] In contrast to an earlier study which suggested that self-selected over-ground walking tended to be the most functional for safety of an individual, our study observed that both over-ground and treadmill walking was functional and safe.[29,30] The effectiveness seen for the group which used the BWST device in both over-ground and treadmill walking can be explained by earlier studies which reported that stretching the hip flexors in terminal stance activated the muscles and initiated the leg to come forward. In addition, the increased tension placed on the triceps surae muscle by loading the limb in mid-stance during BWST was also found in the cited studies to facilitate muscle activation.[30,31] BWST has been reported to be beneficial as a treatment method because the movement of the lower extremities into extension facilitated by the treadmill assisted in stimulating a stepping response not elicited in an over-ground walking training. In addition, the upright and safe position of the participant achieved by the BWST device through the vest was not only functional, but it also allowed the physiotherapist to handle and guide the participants more effectively.[6,9,21,32] Also, no accidental falls were observed during the training program for participants in the experimental group when compared with the control group, which highlighted the safety aspect of the BWST device, similar to previous studies.[31,32] Safety is an important concern, especially in the rehabilitation phase of post SEMLARASS, because falls often lead to fractures due to low bone mineral density, and lead to a fear of walking.

The limitations of the present study are as follows. Firstly, as the adjustments (overhead system, handrails and counterweights) were done manually, and the manual effort of a therapist plus more than one further therapist or caregiver was needed for handling each participant. Secondly, other outcome measures of gait, balance, quality of life, functional outcomes and more detailed evaluation were not taken for the study. The limitations would be rectified in a future research study with a larger sample size and a longer follow-up. Further improvements in the present design of the BWST device can be developed with this study as a baseline, such as provisions for reducing manual effort for suspending the patient in the device, and shifting the vertical frame to the sides or to the back, which can help in cueing the patient to get the visual feedback from a mirror for better reinforcement and also would be useful in additional therapies, for example use of a visual display unit (incorporating BWST with a virtual reality-based therapy) or vibration plate (for whole body vibration therapy).

Conclusion

BWST was found to be effective in improving the gait and mobility parameters in persons with CP when

compared with the group which did not use the BWST device. The low-cost BWST device helped improve both the over-ground and treadmill walking in the studied group of a population with ambulatory deficits.

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Declaration of conflicting interests

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References

1. Rosenbaum P, Paneth N, Leviton A, et al. A report: The definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl* 2007; 109: 8–14.
2. LePage C, Noreau L and Bernard PM. Association between characteristics of locomotion and accomplishment of life habits in children with cerebral palsy. *Phys Ther* 1989; 78: 458–469.
3. Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol* 1997; 39: 214–223.
4. Lovely RG, Gregor RJ, Roy RR, et al. Effects of training on the recovery of full weight-bearing stepping in the adult spinal cat. *Exp Neurol* 1986; 92: 421–435.
5. Visintin M, Barbeau H, Korner-Bitensky N, et al. A new approach to retraining gait in stroke patients through body weight support and treadmill stimulation. *Stroke* 1998; 29: 1122–1128.
6. Mutlu A, Krosschell K and Gaebler Spira D. Treadmill training with partial body-weight support in children with cerebral palsy: A systematic review. *Dev Med Child Neurol* 2009; 51: 268–275.
7. Kleim JA and Jones TA. Principles of experience-dependent neural plasticity: Implications for rehabilitation after brain damage. *J Speech Lang Hear Res* 2008; 51: S225–S239.
8. Damiano DL and DeJong SL. A systematic review of the effectiveness of treadmill training and body weight support in pediatric rehabilitation. *J Neurol Phys Ther* 2009; 33: 27–44.
9. Mattern-Baxter K. Effects of intensive locomotor treadmill training on young children with cerebral palsy. *Pediatr Phys Ther* 2009; 21: 308–319.
10. Angulo-Barroso RM, Wu J and Ulrich DA. Long-term effect of different treadmill interventions on gait development in new walkers with Down syndrome. *Gait Posture* 2008; 27: 231–238.
11. Ulrich DA, Ulrich BD, Angulo-Kinzler RM, et al. Treadmill training of infants with Down syndrome: Evidence-based developmental outcomes. *Pediatrics* 2001; 108(5): E84.
12. Ulrich DA, Lloyd MC, Tiernan CW, et al. Effects of intensity of treadmill training on developmental outcomes and stepping in infants with Down syndrome: A randomized trial. *Phys Ther* 2008; 88(1): 114–122.
13. Dodd KJ and Foley S. Partial body-weight-supported treadmill training can improve walking in children with cerebral palsy: A clinical controlled trial. *Dev Med Child Neurol* 2007; 49: 101–105.
14. Provost B, Dieruf K, Burtner PA, et al. Endurance and gait in children with cerebral palsy after intensive body weight-supported treadmill training. *Pediatr Phys Ther* 2007; 19: 2–10.
15. Schindl MR, Forstner C, Kern H, et al. Treadmill training with partial body weight support in nonambulatory patients with cerebral palsy. *Arch Phys Med Rehab* 2000; 81: 301–306.
16. Begnoche D and Pitetti K. Effects of traditional treatment and partial body weight treadmill training on the motor skills of children with spastic cerebral palsy: A pilot study. *Pediatr Phys Ther* 2007; 19: 11–19.
17. Mehrholz J, Pohl M and Elsner B. Treadmill training and body weight support for walking after stroke. *Cochrane Database Syst Rev* 2014; 1: CD002840.
18. Graham HK and Selber P. Musculoskeletal aspects of cerebral palsy. *J Bone Joint Surg* 2003; 85-B(2): 157–166.
19. Renshaw TS and Deluca P. Cerebral Palsy. In: Morrissy RT, Weinstein SL (eds) *Lovell and Winter's Pediatric Orthopedics*. Philadelphia: Lippincott, Williams and Wilkins, 2005, pp.551–603.
20. Sharan D. Neuromusculoskeletal Rehabilitation of Cerebral Palsy using SEMLARASS. In: Emira Svraka (ed.) *Cerebral Palsy – Challenges for the Future*. Rijeka, Croatia: Intech, 2014, pp.193–215.
21. Hesse S, Konrad M and Uhlenbrock D. Treadmill walking with partial body weight support versus floor walking in hemiparetic subjects. *Arch Phys Med Rehabil* 1999; 80(4): 421–427.
22. Ada L, Dean CM and Morris ME. Supported treadmill training to establish walking in non-ambulatory patients early after stroke. *BMC Neurology* 2007; 7: 29–34.
23. Hesse S. Treadmill training with partial body weight support after stroke: A review. *NeuroRehab* 2008; 23: 55–65.
24. Lubetzky-Vilnai A, Jirikowic TL and McCoy SW. Investigation of the Dynamic Gait Index in children: A pilot study. *Pediatr Phys Ther* 2011; 23(3): 268–273.
25. Koman LA, Mooney JF 3rd, Smith B, et al. Management of cerebral palsy with botulinum-A toxin: Preliminary investigation. *J Pediatr Orthop* 1993; 4: 489–495.
26. Maathuis KGB, Van der Schans CP, Van Iperen AV, et al. Gait in children with cerebral palsy: Observer reliability of Physician Rating Scale and Edinburgh Visual Gait Analysis Interval Testing scale. *J Pediatr Orthop* 2005; 25: 268–272.
27. Graham HK, Harvey A, Rodda J, et al. The Functional Mobility Scale (FMS). *J Pediatr Orthop* 2004; 24(5): 514–520.

28. Chen G and Patten C. Treadmill training with harness support: Selection of parameters for individuals with post-stroke hemiparesis. *J Rehabil Res Dev* 2006; 43(4): 485–498.

29. McNevin NH, Coraci L and Schafer J. Gait in adolescent CP: The effect of partial unweighting. *Arch Phys Med Rehabil* 2000; 81: 525–528.

30. Mattern-Baxter K. Effects of partial body weight supported treadmill training on children with cerebral palsy. *Pediatr Phys Ther* 2009; 21: 12–22.

31. Schindl MR, Forstner C, Kern H, et al. Treadmill training with partial body weight support in nonambulatory patients with CP. *Arch Phys Med Rehabil* 2000; 81: 301–306.

32. Finch L, Barbeau H and Arsenault B. Influence of body weight support on normal human gait: Development of a gait retraining strategy. *Phys Ther* 1991; 71: 842–856.