

The Effect of Body-Weight-Supported Training Exercises on Functional Ambulation Profile in Patients with Paraplegic Spinal Cord Injury

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ABSTRACT

Purpose: This study aimed to examine the effect of Body-Weight-Supported Treadmill Training (BWSTT) exercises on functional ambulation profile in patients with paraplegic spinal cord injury.

Methods: This was a quasi experimental study with pre test and post test. The statistical population consisted of paraplegia spinal cord injured persons in Shahrekord City. Seventeen voluntary patients with paraplegic spinal cord injury (American Spinal Injury Association [ASIA] B, C classification, with the demographic data [mean±SD] of age 32.53±1.793 y, height 175.71±1.658 cm, weight 71.59±2.442 kg, and Body Mass Index [BMI] 23.18±0.828 kg/m²) selected with convenience sampling. The subjects were randomly assigned to BWSTT group (n=10) and traditional exercise group (n=7). Both groups were trained 60 min per session, 4 sessions per week for 12 weeks. BWSTT included 15 min warm up on fixed gear bike, 45 min BWSTT with 50% body weight and finally 10 min cold down. About 10% load was added each week. Traditional exercises included 15 min warm up plus 45 min stretch exercise and resistance training. SPSS 19.0 software was used to examine between groups. An independent t test was used to compare the changes between pretest and post test between BWSTT and traditional training groups.

Results: The data showed that there were significant differences between BWSTT and traditional groups with regard to changes in lower extremity motor score (P<0.001), walking index spinal cord injury (P=0.002), 6 min walking test (P=0.001), and 10 meter walking test (P=0.001).

Conclusion: BWSTT in comparison with traditional exercise can improve more motor function and quality and quantity of walking in people with paraplegic spinal cord injury (ASIA B, C classification).

Keywords:

Spinal cord injury,
Paraplegic, Exercise,
Motor function, Body-
weight-supported training

1. Introduction

Spinal Cord Injury (SCI) is a destructive condition (1), which more than 130000 new injuries are reported in the U.S. every year [2]. SCI is associated with loss of sensory and motor functions below the level of the damage to the spinal cord, which can affect quality and quantity

of movements [3]. There are several therapeutic interventions for spinal cord injury such as resistance exercise training [4], hydrotherapy, body-weight-supported treadmill training (BWSTT) [5], and Functional Electrical Stimulation (FES) [2]. Recently, recovery of motor function has become more widely acknowledged. One way for recovery of neuromuscular dysfunction is task-specific gait training [5].

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It is now more than a decade that BWSTT studies in animals has shown enhancement locomotor function after spinal cord transaction [6]. BWSTT is a safe and practical intervention that allows gait training [7] and can be applied in rehabilitation of neuromuscular disorders such as spinal cord injury, aging and lower-extremity disorders [8]. BWSTT allows spinal cord injured individuals to walk on a treadmill with some of their body-weight supported [9]. BWSTT has originated from the Central Pattern Generator (CPG) theory of gait control [10].

The clinical application of BWSTT was confirmed by studies in spinalized cats in which improvement in the sensory-motor function was reported [11]. The results of a systematic review regarding efficacy of different rehabilitation programs indicated that recovery programs that facilitate gait have the greatest benefits to motor function in SCI [12]. Based on these studies, it was found that the quality of motor function improves by walking on a treadmill that involves Central Pattern Generators (CPGs) [13]. It has been shown that CPGs could produce most of the rhythmic motor functions, such as walking and running [14].

CPGs stimulate appropriate afferents according to the external requirements, as there is a deficiency in utilization of afferent inputs after SCI [15]. Studies have shown beneficial effects of BWSTT on the function of incomplete SCI, and even complete SCI may recover mobility function with locomotor training [16, 17]. Recent findings have shown that FES is a painful technique in rehabilitation of individuals with incomplete spinal cord injury [18]. Some studies reported that recovery treatments such as over-ground walking, and FES are equally effective on improving motor function [19, 20]. Frood (2011) illustrated that rehabilitation of SCI should not be limited to one method [21].

Traditional rehabilitation is designed to recover ambulation through improvement of strength and endurance of the muscles and compensate for the absence of volitional lower-limb muscle contractions or their weaknesses [22]. Mehrholz et al. (2008) showed that effect of BWSTT on ambulation is similar to the conventional traditional physical therapy training [23]. But some studies concluded that gait training is more effective and contributes to better balance and motor function compared to traditional training in Incomplete Spinal Cord Injuries (iSCI) [24-28]. Alexeeva et al. (2011) reported that gait training is superior to conventional rehabilitation program for ambulation in persons with SCI [29]. A single-blinded, randomized study with subjects clas-

sified as ASIA grades B, C, and D injuries illustrated that 12 weeks BWSTT improved walking speed in a few ASIA B and most ASIA C and D patients with SCIs (30). High-intensity locomotor training on a treadmill with assistance had positive effects on over-ground walking [26]. Musselman et al. (2009) illustrated that skill training was more effective than BWSTT [31]. Postans et al. (2004) concluded that the group that received BWSTT obtained better outcomes on walking speed compared to conventional training group [32]. Furthermore, Gupta et al. (2009) stated that BWSTT is more effective than over-ground training in improving gait performance of patients with iSCI [28].

On the other hand, Field-Fote and Roach (2011) showed that over-ground training is superior to gait training [33]. Brown et al. (2005) reported that over-ground gait training is more effective than BWSTT for improving walking [34]. It is believed that increase in weight bearing on lower extremities through BWSTT facilitates weight shifting while controlling posture. To our knowledge, there is insufficient evidence to conclude which therapeutic interventions (BWSTT vs. traditional training) is more effective for improving walking and sensory-motor functions in people with SCI (ASIA B and C). So, this study is an attempt to compare traditional exercises and new rehabilitation approach, BWSTT, that include the mechanical reduction of gravity with weight bearing on functional ambulation profile in paraplegic SCIs.

2. Materials & Methods

Subjects

This was a quasi experimental study with pre test and post test. The statistical population consisted of paraplegia spinal cord injured persons in Shahrekord City. This study focused on individuals with incomplete SCI. Participants were recruited via contact with Spinal Cord Injury Association at Shahrekord City. A total of 20 male paraplegic spinal cord injured patients (demographic data as mean±SD; age, 32.30±1.50 y; height, 175.40±1.40 cm; weight, 71.50±2.2 kg; BMI, 23.15±0.70 kg/m²) with motor incomplete SCI with the primary neurologic insult due to trauma (diagnosed by surgical neurologist) participated in a quasi-experimental study by using the two-group pretest, posttest design knowingly and voluntarily. Subjects were classified based on the ASIA classification [35]. All subjects had paraplegia. The time passed since injury was more than six months. Most participants have been injured in motor vehicle accidents or fallen from height.

All subjects signed an informed consent. Inclusion criteria included having classified as ASIA grades B and C. Exclusion criteria were having cardiovascular disease, undergone dialysis, abusing alcohol and substance, having diabetes, osteoporosis, bedsores, high blood pressure, lung disease, being older than years, and having fractures. The subjects filled medical history questionnaire. They were assured that all answers would be kept confidential. After baseline assessments, participants were randomly assigned to BWSTT group (n=10) and traditional group (n=10). In the traditional group, 3 subjects left the study because of bedsores (2 subjects) and operation (1 subject).

Anthropometric measures

Body fat percentage was calculated from the value of 4-site skin fold test (abdominal, triceps, thigh, and suprailiac) [36], measured with a Lafayette Skinfold Caliper II. Weight was measured by a suspended counterweight system. Height was measured in the supine position. BMI was calculated for each subject using the formula: $BMI = \text{weight (kg)} / \text{height}^2 (\text{m}^2)$.

Exercise training protocols

Two exercise interventions were used. They comprised 12 weeks of BWSTT and traditional training. After the initial assessment, both groups underwent 36 sessions of training.

Body-weight-supported treadmill training

A standard BWSTT equipped with an overhead suspended counterweight system was used to suspend subjects by wire harness, so that the body weight of SCI was supported continuously by counter weight. Individuals participated in BWSTT 4 times per week, 60 minutes each session over a 3 months period. Supported weight began initially with 50% body weight and decreased to ensure full weight bearing at the end of the study. They started at a speed of 0.3 km/h. BWSTT session included a 10-minute warm up with passive stretch training, 3 bouts of gait training on BWSTT, and 10 minutes cool down. Bouts were separated by a 5-minute rest interval. However, BWSTT would stop if the participant requested a rest.

Traditional training

Traditional training consisted of a 10-minute warm up with passive stretch exercises, 45 minutes mobilization exercises of the hip, knee, and ankle joints and over-

ground walking assisted by devices and/or manual assistance; functional exercises; and finally strengthening and stretching activities. Therapeutic exercises aimed to activate the paralyzed muscles and strengthen the weak musculature. It followed by a 10-minute cool down.

Lower extremity motor score

To check the ability of patients with iSCI to move their lower extremity joints (for ASIA UEMS assessment), their key muscles, including hip flexors (iliopsoas – L2), knee extensors (quadriceps – L3), ankle dorsiflexors (tibialis anterior – L4), long toe extensors (extensor hallucis longus – L5), ankle plantar flexors (gastrocnemius, soleus – S1) [37], were assessed with 6-point score (0–5; 0: no contraction or movement, 1: minimal movement, 2: active movement, but not against gravity, 3: active movement against gravity, 4: active movement against resistance, 5: active movement against full resistance) [38] conventional manual muscle tests as established by the ASIA Impairment Scale.

The spinal cord injury ambulation function

To assess the functional ambulation profile of patients with iSCI, Walking Index for Spinal Cord Injury II (WISCI II), 10-Meter Walk Test (10-MWT), and 6-Minute walk test (6-MWT) were used [39]. Walking speed was examined using 10-MWT [40]. Subjects used an assistive brace device in pretest and posttest of the 10-MWT and 6-MWT.

Statistical analyses

All values are presented as mean±SD. For testing the normality of distribution, Kolmogorov-Smirnov test was used. An independent t test was used to compare the changes between pretest and post test between BWSTT and traditional training groups. SPSS 19.0 software was used to examine between groups.

3. Results

The results were based on the observations of 10 people with iSCI in the BWSTT group and 7 people with iSCI in the traditional training group who completed the study. Table 1 presents the results after 12 weeks exercise training according to the two different protocols.

The data showed that there were significant differences between BWSTT and traditional training groups with respect to changes of body mass (4.8% vs. 1.27%, respectively, $P=0.003$) after 12 weeks of intervention. BMI de-

Table 1. The comparison of changes pretest and posttest in the measured variables before and after 12 weeks of intervention.

Variable	Group	Mean±SD		t	P value
		Pretest	Posttest		
Body Mass (kg)	BWSTT	74.30±2.71	70.7±2.63	-3.63	0.003**
	Traditional	67.71±4.31	68.57±4.34		
BMI (kg/m ²)	BWSTT	23.90±0.93	22.50±0.78	-4.05	0.001**
	Traditional	22.14±1.50	22.57±1.59		
% Body Fat	BWSTT	23.92±1.09	21.52±0.81	-4.32	0.001**
	Traditional	23.73±1.87	24.18±1.63		
LEMS	BWSTT	0.00±0.00	11.00±0.95	5.72	0.000**
	Traditional	0.00±0.00	2.86±1.06		
WISC II	BWSTT	5.70±1.04	8.20±0.70	4.17	0.002**
	Traditional	8.14±1.80	8.14±1.80		
10-MWT	BWSTT	65.30±13.40	57.10±6.86	-4.27	0.001**
	Traditional	46.29±8.54	42.86±6.93		
6-MWT	BWSTT	340.00±89.70	640.00±97.99	4.191	0.001**
	Traditional	685.71±176.51	814.29±180.51		
Walking speed	BWSTT	0.94±0.25	1.78±0.24	4.191	0.001**
	Traditional	1.51±0.25	1.87±0.26		

BWSTT group: subjects who participated in a body weight supported treadmill training program; Traditional group: subjects who participated in a program of rehabilitation traditional training; BMI: body mass index; LEMS: Lower Extremity Motor Score; WISCI: walking index spinal cord injury; 6-MWT: Six-Minute Walk Test; 10-MWT: 10 meter walking test.

** Significant difference between two interventions ($P < 0.01$).
Data are presented as mean±SD.

creased in the BWSTT group after training. In traditional training group, however, the BMI increased during the experimental period (5.85% vs. 1.94%, $P = 0.001$). The changes in body fat percentage of the two groups were significantly different; in BWSTT group body fat decreased, while the traditional training group showed increase in this variable during these 12 weeks (10.03% vs. 1.89%, $P = 0.001$). LEMS tended to increase to a greater extent following BWSTT compared to other intervention training ($P = 0.000$). The results illustrated that there were significant differences between two groups with respect to changes of WISCI II (43.85% vs. 0%, $P = 0.002$). A comparison of the changes in scores suggested that there were greater improvement in 10-MWT (40.12% vs. 7.40%, $P = 0.001$) and 6-MWT (88.23% vs. 18.74%, $P = 0.001$) after BWSTT compared to conventional training. Twelve weeks of BWSTT appeared to improve walking speed more efficiently compared to the traditional training (88.29% vs. 23.84%, $P = 0.001$).

4. Discussion

We examined two different types of exercise training (BWSTT vs. traditional training) on ambulation function of people with paraplegic spinal cord injury. This study is the first one comparing the effect of 12 weeks BWSTT and traditional training on ambulation functions of patients with iSCI. There is a large volume of published studies and reviews in the literature describing the effect of BWSTT on patients with acute and chronic spinal cord injury. Using regular BWSTT has been shown to recover the ability to walk after SCI [41]. Some studies also showed that BWSTT is an intervention that can not only improve quality and quantity of walking but also increase musculoskeletal adaptations such as bone and muscle mass and reverse osteoporosis [42, 43]. It seems that BWSTT can activate and train CPGs found in spinal cord (44) and are responsible to generate a rhythmic, alternating hindlimb stepping pattern [45].

PHYSICAL TREATMENTS

Comparing rates of improvement in the body composition, BWSTT was more effective than conventional training. In our study, regular BWSTT reduced the body mass, body fat percentage, and BMI compared to conventional training. It seems that through its involvement of a larger muscle mass and the postural challenge of being upright, BWSTT provided a greater stimulus and reduced body fat percentage and body mass in iSCI compared to conventional training [46]. Similar results despite the differences in subject populations were also cited by Hicks and Ginis (2008) who found that BWSTT (2-3 sessions/week) decreases total body fat [46]. Recently, in accordance with our research, Koury et al. (2012) illustrated that regardless of differences in age, type of training, exercise duration and spinal cord injury level, 3 months physical training decreased total body mass (-13%), body mass index (-16%), and fat mass (-39%) [47].

Our study is inconsistent with some research reported that BWSTT had no effect on body fat percentage in patients with iSCI [48, 49]. This difference may be related to the level of spinal cord injury (ASIA C vs. ASIA B, C), history of injury (6 months vs. 12 months), age of the subjects, and number of training sessions per week (3 times/week vs. 4 times/week). This study showed that the present training of BWSTT was of sufficient intensity and duration to induce a decrease in the body mass, body fat percentage, and BMI.

The main finding of the present study was that 12 weeks of supervised BWSTT produced significant therapeutic effects on LEMS as well as speed and quality of walking. The results supported the hypothesis of our study that BWSTT would result in a better recovery. There are no studies that compare these results with them. The present findings seem to be consistent with other research, which found BWSTT is better than other exercise therapies. In accordance with our research, Hornby et al. illustrated that ambulation ability of patients with SCI improved during the course of robotic- and manual-assisted BWSTT in comparison to conventional rehabilitation training [50].

Gait training allows patients with SCI and independent walking ability to undergo ambulation training. Furthermore, Wernig et al. (2005) confirmed that Laufband therapy is superior to conventional therapy in walking without help from others [51]. In addition, Hicks et al. (2005) showed that BWSTT is an effective intervention to recover walking ability and most of these improvements maintained for up to 8 months following training [52]. Other studies also indicated that BWSTT is an ef-

fective intervention to recover walking ability in patients with SCI [8, 30, 53, 54]. Besides, Behrman and Harkema (2000) found that BWSTT on SCI (ASIA C, D) has led to improvement in walking speed [22]. In another study, Protas et al. (2001) indicated that supported treadmill ambulation training improved gait in patients with iSCI. About 40% of body weight was supported in this study [55].

Field-Fote et al. (2005) illustrated that recovery of walking function is dependent on training approach. They showed that patients with SCI benefitted the most from locomotor training [56]. Comparing BWSTT with physiotherapy, Lucareli et al. (2011) showed that body weight supported training was more effective than conventional physiotherapy on improving the quality and quantity of walking among patients with iSCI [24]. Although the results were similar, the participants had different levels of damage (ASIA B, C). In another study, Behrman et al. (2008) showed that despite improvement in gait independence, improvement in LEMS score was not observed following 16 months of BWSTT in patients with iSCI [57]. These differences could be due to age differences, damage level of subjects, and duration of training.

Unlike our results, walking speed did not increase through BWSTT more than land-based rehabilitation therapy following 12 weeks training. Some of these differences are due to age and damage level of subjects [19]. Also, in another study, Dobkin et al. (2007) showed that following 12 weeks of BWSTT compared to land-based training, there was no different outcomes with regard to walking speed and LEMS scores [30]. Furthermore, Field-Fote and Roach (2011) showed that there was no difference between BWSTT and land-based rehabilitation training following 3 months training in patients with SCI (level damage ASIA C, D) [33]. The discrepancy in results may be due to differences in intervention mode, number of sessions per week, age of subjects, and damage level.

BWSTT has been shown to result in greater improvements in walking speed, endurance, and motor function compared to conventional rehabilitation interventions, because repetition of the normal stepping pattern of gait activates the CPGs and improves functional ambulation profile. Unlike BWSTT, other forms of rehabilitation treatments such as over-ground walking; physiotherapy and strength training fail to take full benefit of motor learning.

In summary, despite of the fact that some studies showed no difference between BWSTT and other types of rehabilitation interventions, we showed that BWSTT is more effective than other treatments. Twelve weeks of BWSTT (4 sessions per week) effectively improved walking ability in patients with iSCI (ASIA B, C classification). However, this study confirms that gait training has benefits for recovery of incomplete spinal cord injury.

Clinical implication

It seems that BWSTT is effective in improving walking and movement of patients with spinal cord injury dependent on walking assistance, and most outcome measures showed a trend toward improvement in gait training. BWSTT modality was goal-directed and intensive. The therapists could choose BWSTT based on the patients' preferences and availability of equipment and resources.

Limitations of the study

This study has some limitations that need to be acknowledged. A major limitation is the relatively small sample size. Another limitation of the present study may have resulted from inability of the researchers to be blinded to the study modalities in two groups.

Conflict of interest

The authors declare that they have no competing interests.

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