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Effect of treadmill training combined with ankle weight on balance in spastic cerebral palsied children: A randomized controlled trial

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ABSTRACT

The aim of this study was to examine the impact of treadmill training combined with ankle weights on balance and dorsiflexor muscle strength in children with spastic hemiparetic cerebral palsy (CP). This clinical, randomized trial included forty boys and girls suffering from spastic hemiparetic cerebral palsy, ranging in age from 6 to 9 years old. They were split into two equal groups (control group = 20, study group = 20). Both groups received a program of physiotherapy in addition to treadmill exercise, while the study group also received ankle weights for eight weeks. The Biodex stability system was employed to evaluate stability indices, including the overall stability index (OASI), anteroposterior stability index (APSI), and mediolateral stability index (MLSI). Functional balance was measured using the Pediatric Balance Scale (PBS). A Lafayette manual muscle tester (MMT) was used to record the peak force of ankle dorsiflexor muscle strength for both groups, pre- and post-therapy. Post-therapy results showed a significant decrease in all stability indices at stability levels 8 and 4, and a significant increase was observed in functional balance and ankle dorsiflexor muscle strength in both groups ($p<0.05$). The study group showed a more significant improvement in all outcome measures after therapy than the control group (p<0.05). The program of physiotherapy, treadmill training, and ankle weights was effective in improving balance and dorsiflexor muscle strength among children with spastic hemiparetic cerebral palsy, with ankle weights contributing to greater progress.

KEYWORDS

Cerebral Palsy; Treadmill Training; Ankle Weight; Balance; Muscle Strength

1. INTRODUCTION

Spastic hemiplegia affects about 33% of children with cerebral palsy (CP). These children can exhibit a variety of asymmetrical symptoms between both sides of the body, including spasticity, weakness, sensation loss, a reduction in the volume of muscles in the paretic side, and a significant difference in leg length (Heneidy et al., 2020).

Children with spastic hemiplegia have diminished balance and a faulty gait pattern due to decreased weight-bearing in the paretic limb, delayed development of their neural control mechanisms, and secondary musculoskeletal disturbances including sluggish proprioception, muscle weakness, and spasticity. These factors lessen their ability to symmetrically shift body weight from repose to motion to maintain balance (Heneidy et al., 2020; Park et al., 2016).

In children with hemiparetic cerebral palsy, spasticity and tightness of the plantar flexor muscles inhibit and weaken the anterior tibial muscles, resulting in equinus foot (64% of hemiplegic CP children have equinus deformities) and toe walking (Bahar-Özdemir et al., 2021; Ahmed et al., 2019), which leads to ankle instability, dysfunction, increased risk of falling, and subsequent joint deformities (Ahmed et al., 2019).

The ankle joint is essential for balance and gait as it acts as a shock absorber (Yoon et al., 2011). Thus, a decrease in ankle muscle strength and/or range of motion (ROM) may result in a loss of balance (Sung & Kim, 2018; Fujimoto et al., 2013). Diminished motor ability and muscle weakness are more restrictive in children with hemiparetic cerebral palsy than spasticity, and they are accompanied by difficulties in performing functional activities. Therefore, the focus has shifted from spasticity control to strength training (Park et al., 2016; Ahmed et al., 2019).

Resistance training is now well-proven as a secure and well-tolerated exercise program that improves muscle architecture, increases muscle activation, reduces irregular co-contraction, and thus improves gait and gross motor function in children with cerebral palsy who exhibit muscular weakness and functional limitations (Elnaggar, 2022). Furthermore, literature describes that adding weight to the lower limb (LL) during walking causes compensatory motor responses in the walking of both healthy babies and adults as well as those with neurological disorders (Ahmed et al., 2019; Simão et al., 2014).

Different studies have recommended that activating lower limb muscle strength among stroke patients and children with cerebral palsy through weight-loaded exercise is beneficial for walking (Ahmed et al., 2019; Simão et al., 2014; Hwang et al., 2017; Lee, 2018; Simão et al., 2019). The use of weight load to improve balance among adults of different ages has only been studied in a small number of studies (Shin & Lee, 2014; Jung & Kim, 2015; Park et al., 2014). In addition, the activity of flexor muscles during the swing phase of gait has received relatively little attention compared to the extensor muscle group, which is an essential part of the stance phase (Simão et al., 2019). As a result, we were the first to perform a randomized controlled trial to examine the impact of treadmill training combined with ankle weights on balance and dorsiflexor muscle strength in children with spastic hemiparetic CP.

2. METHODS

2.1. Study Design

A clinical, randomized trial was conducted from November 2021 to August 2022. The ethical committee at the Faculty of Physical Therapy, Cairo University, Egypt, approved the study before it began. The research followed the Guidelines for the Conduct of Human Research established by the Declaration of Helsinki. The study protocol was registered on ClinicalTrials.gov (No: NCT05106829). Before the study procedures started, parents signed a consent form allowing their children to participate.

2.2. Participants

This study included forty children aged 6 to 9 with spastic hemiparetic cerebral palsy, chosen from various private pediatric physiotherapy clinics and outpatient clinics of El-Sahel Teaching Hospital and the National Institute of Neuromotor System (General Organization of Hospitals and Institutes, Egypt). Children of both sexes diagnosed with spastic hemiparetic cerebral palsy by a pediatric neurologist were eligible for this research if they met the following criteria: they were between the ages of 6 and 9; their affected ankle plantarflexor spasticity grades varied between 1 and 1+ using the Modified Ashworth Scale (Bohannon & Smith, 1987); their degree of gross motor function fell between levels I and II according to the Gross Motor Function Classification System (GMFCS)

(Palisano et al., 1997); they had balance disturbances proven by the Biodex Stability System; they were capable of standing and walking freely despite having abnormal gait patterns; and they could follow simple verbal directions and instructions. We excluded children whose height was less than 100 cm, those with seizures, auditory or visual defects, cardiovascular disease, fixed deformities in both upper and/or lower extremities, those who had received botox injections within the last 6 months, and those with previous surgery at the ankle joint.

The overall stability index (OASI) data from the pilot study on 5 children for each group were used to calculate the sample size before the research employing G*Power statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany). This calculation indicated that the appropriate sample size for this research was 20 in each group. Calculations have been performed with α=0.05, β=0.2, and effect size= 0.91, and allocation ratio N2/N1=1.

The children were assigned equally into two groups using a computer-generated random table to minimize selection bias (Saghaei, 2004). The allocation of children was illustrated in a CONSORT flow chart (Figure 1).

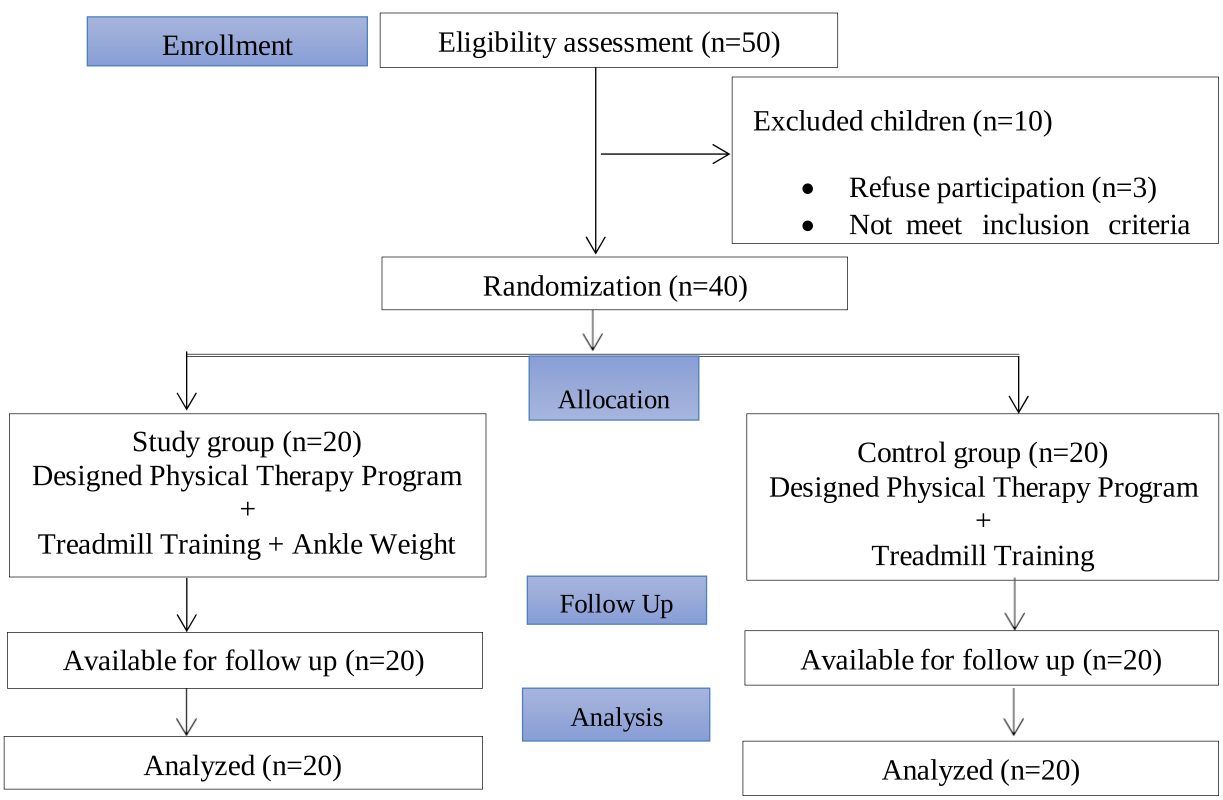

Figure 1. Flow chart

2.3. Study Procedures

2.3.1. Measurement Procedures

2.3.1.1. Dynamic balance

The Biodex stability system provides a dynamic balance evaluation and training system that is both valid and reliable (Cachupe et al., 2001). Balance was evaluated using the Biodex Stability System (Model 945-300 Biodex Medical System, Shirley, New York). For the same set of testing before and following therapy, each child in the study and control groups performed a dynamic balance test at two conditions: stability level 8 (the most stable level) and stability level 4 (a level that is less stable). This was done to assess how well each child could control the platform's tilt angle.

At first, all children received an explanation session prior to the measurement procedure so they would be aware of and familiar with the device and test. Every child has been asked to stand with two legs and bare feet on the center of the device's closed platform while holding the handrails. The display screen has then been modified so that the child can gaze straight at it. The following parameters have been taken and entered into the device: the child's weight, height, and age, as well as level of stability (platform firmness). The child was asked to keep a center position in a slightly unsteady platform through alternating his position of feet until keeping the cursor became effortless in the middle of the display while standing in a comfortable straight position. Once achieving centering and adjusting the cursor to the target's center on the display, the child has been requested to keep his feet in place until the platform is stabilized. Following the entry of heel coordinates and foot angle data into the device system, the test began. The child has been requested to look at the display and maintain the cursor in the center while keeping both arms at his or her sides and avoiding grabbing the handrails when the platform moved. The test was performed in 3 trails of 30 seconds each, with at least 10 seconds between each trial and a 2-minute rest time in between conditions. A printout report including the values of the overall, anteroposterior, and mediolateral stability indices has been obtained at the end of every test trial, and the average of the 3 trials was calculated to avoid excessive balance deviations. A high stability index value indicates poor neuromuscular control, balance problems, and thus less stability, and vice versa (Heneidy et al., 2020; Zaky et al., 2019; El-Basatiny & Abdel-Aziem, 2015).

2.3.1.2. Functional balance

A modified version of the Berg balance scale, the Pediatric Balance Scale (PBS) (El-Gohary et al., 2017), was developed to evaluate functional balance in children who have neuromotor dysfunction (Bahar-Özdemir et al., 2021). It is quickly and easily administered, taking no more than 15 minutes. It has been proven to be valid, and trustworthy evaluation tool. There are 14 tasks in it that are comparable to daily living activities in three aspects including sitting, standing, and postural change (Park et al., 2016; Chen et al., 2013; Duarte et al., 2014).

Children have been given one or/two practice trials based on their ability to understand the instructions of each item before testing. Verbal and visual directions may be clarified through the use of physical prompts. The activities are assessed on a 5-point scale (0, 1, 2, 3, or 4), with a score of zero indicating failure to do the activity without help and a score of four indicating full independence in performing the activity. The maximum score is 56 points. The better the balance, the higher the score. The scores are determined by the length of time that a position could be held, the distance that the upper extremity could extend in front of the body, and the time needed to accomplish the activity ((Park et al., 2016; Duarte et al., 2014). The scale was applied before and after therapy for both groups.

2.3.1.3. Muscle strength

The Lafayette Manual Muscle Test (MMT) (Model 01165 Lafayette, IN 47904 USA) was used to record the peak force of ankle dorsiflexors in pounds (Ib) pre and post treatment, as it is considered valid and reliable. The test procedure was explained to every child aiming to practice one trial before testing (Daubney & Culham, 1999). The test was performed with the researcher maintaining the dynamometer steady while the child applied maximum force to it. Standardized and comfortable positions were used to perform MMT for ankle dorsiflexors: sitting with the hips, the knees flexed 90◦, and neutral foot position. On the foot's dorsal surface, the dynamometer was placed quite proximal to the metatarsophalangeal joints (van den Beld et al., 2006). The child was instructed to contract his ankle dorsiflexors 5-6 sec. against the dynamometer. During the test, the child received verbal encouragement. Three trials were done for each child, with resting for 15–60 seconds in between trials to prevent trial fatigue (Sisto & Dyson-Hudson, 2007), and the average values were recorded (Bakırhan et al., 2021).

2.3.2. Intervention Procedures

Children with spastic hemiparesis in both groups had a physiotherapy program specifically created for them that lasted 60 minutes per session as well as 30 minutes of treadmill gait training per session to improve balance, based on Sherief et al. (2015). Selected exercises of the designed physiotherapy program included:

- *Manual standing on the mat:* the child was gently tilted forward, backward, and sideways by the therapist as he sat behind him and manually locked his knees.
- *Manual standing on the mat with step forward and step backward:* the child was instructed by the therapist to alternately transfer his weight forward and backward while the therapist sat behind him
- *Half kneeling and kneeling on the mat:* the child stood on both knees facing the stand bar in front of the therapist, the therapist grasping the child around the pelvis.
- *Position-changing exercises from prone to standing, as well as supine to standing*: the therapist, grasping the child's pelvis or/hands, then encouraged him to rise from lying "prone and supine" to standing.
- *Righting, equilibrium, and protective reactions using balance board and medical ball:* the therapist stood or/sat behind the child then postural reactions training (righting, tilting equilibrium, and protective reactions) were carried through tilting from different positions (forward, backward, and sideways) to improve postural mechanisms via variety of exercises applied on balance board and medical ball.
- *Balance exercise performed from standing on the mat:* to increase standing balance, the therapist stood behind the child and gently pushed him forward, backward, and laterally.
- *Dorsiflexors strengthening exercises:* The therapist applied manual resistive exercises to strengthen the dorsiflexors.
- *Stooping and recovery exercising from a standing position:* The child actively tried to stoop and recover as the therapist manually locked his knees while sitting behind him.
- *Squatting to standing exercise:* the child actively tried to squat as the therapist manually locked his knees while sitting behind him.
- *Gait training in different environments and directions:* walking in a closed environment using a parallel bar and stepper; walking across obstacles in an open environment using varying sizes of blocks, wedges, and rolls in three directions: backward, forward, and sideways; walking on various floor surfaces using hard and spongy surfaces on mats and on the floor.
- *Tight muscle stretching exercises:* elbow flexors, wrist flexors, pronators, hamstrings, calf muscles, and hip flexors.

Children in the two groups were trained on the treadmill (a motorized treadmill, VEGAMAX 8000IC), with speeds accommodated according to the child's comfort and a zero- degree inclination. The height of the parallel bar has been modified for each child individually.

Each child received an explanation of the procedure before starting the treadmill training, and underwent five minutes of warm-up activities that included gentle stretching and walking back and forth within the room (Sherief et al., 2015). Familiarization period of 2 min. of the treadmill speed which was kept constant during the session should be considered (Simão et al., 2019). Each child assumed an upright posture and was told to hold the treadmill's parallel bars tightly with both hands, which were adjusted according to everyone's needs by the therapist. The therapist then asked the child to look forward while walking to promote independent walking (Alsakhawi & Elshafey, 2019; Thabet et al., 2017). In 1-minute training cycles, the child performed treadmill training under three conditions. The child may hold onto the handrails with both hands for 15 seconds of every minute, then with one hand for the following 15 seconds, and finally without holding onto the handrails for 30 seconds. This procedure was carried out 20 times by each child. The child has been told to cease walking right away if he experiences pain, fainting, or feeling short of breath. There was a 5-minute cooldown period at the end of the procedure (Sherief et al., 2015; Alsakhawi & Elshafey, 2019).

Additional ankle weight was added to the study group during the treadmill training procedure to provide resistance for the muscles' strength. Ankle weight comparable to 60% of LL mass has been put around the anterior aspect of the ankle on the paretic side and secured by Velcro straps based on Simão et al. (2019). For eight successive weeks, both groups received treatment three times each week.

2.4. Data Analysis

The children's characteristics were compared between groups using unpaired t-tests. The chi-squared test was used to compare the sex, affected side, spasticity grades, and GMFCS distribution among groups. The Shapiro-Wilk test was employed to determine whether the data had a normal distribution. The homogeneity between groups was examined using Levene's test for variance homogeneity. Mixed MANOVA was used to compare between-group and within-group impacts on stability indices, including the Overall Stability Index (OASI), Anterior-Posterior Stability Index (APSI), and Medial-Lateral Stability Index (MLSI) at levels 8 and 4, the Pediatric Balance Scale (PBS), and ankle dorsiflexor muscle strength (DF). For subsequent multiple comparisons, post-hoc tests with Bonferroni correction were conducted. The significance level for each statistical test was set at $p < 0.05$. All statistical analyses were carried out using SPSS version 25 for Windows (IBM SPSS, Chicago, IL, USA).

3. RESULTS

3.1. Children characteristics

The characteristics of the study participants (both the study and control groups) are displayed in Table 1. Age, weight, height, distribution of sex, affected side, spasticity grades, and the Gross Motor Function Classification System (GMFCS) were not statistically different between groups ($p > 0.05$).

Table 1. Characteristics of children in the study and control groups

	Study group	Control group	p-value
	Mean ±SD	Mean ±SD	
Age (years)	7.6 ± 0.36	7.8 ± 0.49	0.15
Weight (kg)	27.25 ± 2.14	28.25 ± 2.56	0.19
Height (cm)	127.32 ± 2.31	128.47 ± 3.34	0.21
Sex, n (%)			
Girls	11 (55%)	12 (60%)	0.74
Boys	9 (45%)	8 (40%)	
Affected side, n (%)			
Right	13 (65%)	10 (50%)	0.33
Left	7 (35%)	10 (50%)	
Spasticity grade, n (%)			
Grade I	12 (60%)	13 (65%)	0.74
Grade I+	8 (40%)	7 (35%)	
GMFCS, n (%)			
Level I	11 (55%)	12 (60%)	0.74
Level II	9 (45%)	8 (40%)	

Note: SD, Standard deviation; p values, probability values

3.2. Treatment's effect on stability indices at levels 8 and 4, PBS, and ankle DF

Treatment and time had a significant interaction ($F = 589.77$, $p = 0.001$, $\eta^2 = 0.99$). The main effect of time was significant ($F = 7564.93$, $p = 0.001$, $\eta^2 = 0.99$). The main effect of the treatment was significant ($F = 21.89$, $p = 0.001$, $\eta^2 = 0.85$).

3.2.1. Within group comparison

The study group and control group both exhibited a statistically significant decrease in all stability indices, including the Overall Stability Index (OASI), Anterior-Posterior Stability Index (APSI), and Medial-Lateral Stability Index (MLSI), at stability levels 8 and 4 post-treatment compared to pre-treatment ($p < 0.05$) (see Tables 2 and 3).

In both the study group and control group, there was a statistically significant increase in the Pediatric Balance Scale (PBS) and ankle dorsiflexors (DF) post-treatment compared to pre-treatment ($p < 0.05$) (refer to Table 4).

3.2.2. Between groups comparison

All parameters across groups before treatment did not differ statistically significantly ($p > 0.05$). A comparison of the study group and control group following therapy demonstrated a statistically significant decrease in OASI, APSI, and MLSI at stability levels 8 and 4 in the study group in comparison to the control group ($p < 0.05$). (Table 2, 3). Also, the pediatric balance scale (PBS) and ankle dorsiflexors (DF) of the study group were statistically significantly higher after therapy in comparison to those of the control group ($p < 0.05$). (Table 4).

Table 2. Mean OASI, APSI, and MLSI at stability levels 8 before and after therapy in the study group and control group

Stability level 8	Study group	Control group	MD	95% CI	p-value
	mean ± SD	mean ± SD			
OASI					
Pre treatment	3.09 ± 0.31	3.21 ± 0.39	-0.12	-0.35: 0.09	0.26
Post treatment	1.59 ± 0.26	2.05 ± 0.35	-0.46	-0.65: -0.26	0.001
MD (% of change)	1.5 (48.54)	1.16 (36.14)			
p-value	***p = 0.001***	***p = 0.001***			
APSI					
Pre treatment	2.57 ± 0.17	2.58 ± 0.18	-0.01	-0.12: 0.09	0.83
Post treatment	1.35 ± 0.22	1.62 ± 0.23	-0.27	-0.41: -0.12	0.001
MD (% of change)	1.22 (47.47)	0.96 (37.21)			
p-value	***p = 0.001***	***p = 0.001***			
MLSI					
Pre treatment	2.28 ± 0.2	2.32 ± 0.18	-0.04	-0.16: 0.08	0.51
Post treatment	1.28 ± 0.16	1.56 ± 0.21	-0.28	-0.40: -0.16	0.001
MD (% of change)	1 (43.86)	0.76 (32.76)			
p-value	***p = 0.001***	***p = 0.001***			

Note: SD, standard deviation; MD, mean difference; CI, confidence interval; p-value, level of significance

Table 3. Mean OASI, APSI, and MLSI at stability level 4 before and after therapy in the study group and control group

Stability level 4	Study group	Control group	MD	95% CI	p value
	mean ± SD	mean ± SD			
OASI					
Pre treatment	3.35 ± 0.30	3.44 ± 0.27	-0.09	-0.27: 0.09	0.34
Post treatment	2.07 ± 0.28	2.73 ± 0.31	-0.66	-0.85: -0.46	0.001
MD (% of change)	1.28 (38.21)	0.71 (20.64)			
p-value	***p = 0.001***	***p = 0.001***			
APSI					
Pre treatment	2.61 ± 0.16	2.63 ± 0.15	-0.02	-0.12: 0.07	0.63
Post treatment	1.43 ± 0.24	2.09 ± 0.22	-0.66	-0.81: -0.51	0.001
MD (% of change)	1.18 (45.21)	0.54 (20.53)			
p-value	***p = 0.001***	***p = 0.001***			
MLSI					
Pre treatment	2.37 ± 0.21	2.47 ± 0.28	-0.1	-0.25: 0.05	0.21
Post treatment	1.38 ± 0.19	1.92 ± 0.23	-0.54	-0.68 -0.41	0.001
MD (% of change)	0.99 (41.77)	0.55 (22.27)			
p-value	***p = 0.001***	***p = 0.001***			

Note: SD, standard deviation; MD, mean difference; CI, confidence interval; p-value, level of significance

Table 4. Mean pediatric balance scale (PBS) and ankle dorsiflexors (DF) before and after therapy in the study group and control group

Variable	Study group	Control group	MD	95% CI	p value
	mean ± SD	mean ± SD			
PBS					
Pre treatment	37.5 ± 2.94	37.1 ± 2.88	0.4	-1.46: 2.26	0.66
Post treatment	52.45 ± 2.62	46.5 ± 2.94	5.95	4.16: 7.73	0.001
MD (% of change)	-14.95 (39.87)	9.4 (25.34)			
p-value	***p = 0.001***	***p = 0.001***			
Ankle DF					
Pre treatment	2.21 ± 0.37	2.12 ± 0.23	0.09	-0.11: 0.28	0.41
Post treatment	2.84 ± 0.35	2.22 ± 0.28	0.62	0.41: 0.81	0.001
MD (% of change)	-0.63 (28.51)	0.1 (4.72)			
p-value	***p = 0.001***	***p = 0.01***			

Note: SD, standard deviation; MD, mean difference; CI, confidence interval; p-value, level of significance

4. DISCUSSION

Children with hemiparetic cerebral palsy lack dissociated movement due to weakened muscles, poor motor control, and spasticity (Heneidy et al., 2020). Equinus foot and toe walking are common clinical issues in these children, resulting from diminished motor control of the ankle dorsiflexors (Supriya & Mandar, 2020). Ankle dorsiflexors contract concentrically during the swing phase to dorsiflex the foot and eccentrically at the beginning of the stance phase to control plantar flexion, crucial for activities like walking and maintaining balance during stance perturbations. Consequently, a decline in dorsiflexor function could impair functional performance (Holmbäck et al., 2003). Thus, it is crucial to educate children with hemiparetic cerebral palsy on optimizing ankle joint motor control, enhancing balance, and initiating or improving gait by facilitating and strengthening dorsiflexor muscle activity. This approach mitigates the effects of musculoskeletal and neuromuscular impairments, promoting functional adaptation (Heneidy et al., 2020; Supriya & Mandar, 2020).

The study results indicated that all stability indices at levels 8 and 4 were significantly lower in both the study and control groups post-treatment, while the Pediatric Balance Scale (PBS) and ankle dorsiflexors (DF) were significantly higher compared to pre-treatment levels ($p<0.05$). Furthermore, before treatment, there were no statistically significant differences between the two groups in any of the parameters ($p>0.05$). However, following therapy, all stability indices at levels 8 and 4 showed significant decreases, and both the Pediatric Balance Scale (PBS) and ankle dorsiflexors (DF) demonstrated significant increases compared to the control group ($p<0.05$).

The combined impact of the selected exercises from the designed physical therapy program in addition to treadmill training may be responsible for the improvement obtained in both groups. This is consistent with different studies that stated that physical activity and rehabilitation programs improved functional independence and overall physical capacity in children suffering from cerebral palsy. These studies also emphasized the necessity of promoting and maintaining sports or training programs for children suffering from cerebral palsy to enhance their daily living activities (Heneidy et al., 2020; El- Basatiny & Abdel-Aziem, 2015).

The enhanced results of the designed physiotherapy program could be explained by its neurodevelopmental basis, which aimed to inhibit abnormal muscle tone as well as abnormal postural reflexes, facilitate normal postural control patterns (righting and equilibrium reactions), provide postural adaptations and alignment to enhance balance in all positions, and develop a wider range of normal movement patterns, especially in the trunk and lower limbs.

Such exercises included weight bearing on the involved side, symmetrical weight shift over both legs, antigravity mechanisms, postural reaction components, and, lastly, postural correction exercises and balancing exercises lead to reestablish symmetry by stretching shortened muscles and strengthening weak muscles (Thabet et al., 2017). Also, it was assured that proprioceptive data is crucial for the motor control system to choose the proper motor strategy of reciprocal activation between the agonists and antagonists to gain effective balance (Olama & Thabit, 2012).

Abd El-Nabie & Attia (2019) postulated that treadmill walking allows multiple repeats of gait cycle's strides in a regular pattern, enhancing coordination between agonists and antagonists muscles and strengthening the muscles of the lower limb by boosting neural adaptation, which in turn boosts neuromuscular ability in children who have disabilities. In addition, it offers longer weight bearing on the lower limb and activates the spinal cord's central pattern generators that lead to rhythmical steps, which in turn improves training for gait cycle, standing balance, and stability. Using a treadmill for gait training for hemiplegic people frequently concentrates on teaching them to weight bear, weight shift, and balance as separate tasks prior to incorporating such tasks into locomotion. Also, stepping on a treadmill improves balance and builds the strength of muscles in the lower extremities, which are crucial in the development of independent walking. This gain in the strength of muscles allows the child suffering from hemiparetic CP to elevate the swing extremity into more flexion, leading to improvements in feedback and neuromuscular functioning (Thabet et al., 2017; Olama, 2011).

Our study showed that adding ankle weight produced a more beneficial effect, which concurs with findings from Joshua et al. (2014) that confirmed that resistance training using sandbags is becoming an increasingly popular intervention for improving function, balance, and promoting independent mobility by increasing muscular strength. Also, Duclos et al. (2014) supported the idea that gait training while adding a load at the ankle is an easy technique to cause functional muscle strengthening.

Normal sensory inputs and central integration are required in normal subjects to sustain balance, which necessitates appropriate musculoskeletal support. Therefore, adding a load to the ankle raised the weight burden on the body, resulting in optimal musculoskeletal support through improved muscle strength, which enhanced balancing capability (Jung & Kim, 2015). Similarly, Simão et al. (2014) suggested that adding load to the ankle during treatment of hemiparetic cerebral palsy children will impose resistance in the swing phase, resulting in a higher activation of the lower limb's flexor muscles.

This response could be regarded as a neuromotor adaptation strategy, mediated through feedback mechanisms that happen as a result of variations in proprioceptive input throughout walking with load. Furthermore, Shin & Lee (2014) found that gait training with added weight significantly enhanced balance abilities; as a result, an increase in balance is influenced by higher degrees of muscular activation with added weight. Moreover, Park et al. (2014) reported that the lower extremity's involved side’s muscular strength increased by using weight loading with a stroke patient due to repetitive weight loading gait training. Hence, the capability to shift weight improved, which in turn enhanced ankle stability and balance ability. Also, improved muscle strength on the involved side's lower limb, like ankle dorsiflexors and hip flexors, decreased the phenomenon of foot dragging throughout the swing phase. As a consequence, the involved side's lower limb spent less time in the air, allowing for weight shift and improved balance, resulting in a faster gait.

5. LIMITATIONS

Limitations of this study include: first, it focused exclusively on children with one type of cerebral palsy (CP) aged between 6 and 9 years. Second, neither intervention had a control group for comparison. Third, additional outcome measures such as ankle range of motion, strength of other ankle muscles, gait parameters, and energy expenditure were not evaluated. Future research should address these limitations by including diverse types of cerebral palsy and incorporating control groups. Long-term follow-up studies are also needed to assess the sustained impact of training interventions in children with hemiplegic cerebral palsy.

6. CONCLUSIONS

Adding ankle load weights equivalent to 60% of the lower limb mass to the physical therapy regimen of children with hemiparetic cerebral palsy results in a significant improvement in both ankle dorsiflexor strength and overall balance. This approach provides an additional challenge to the muscles, encouraging greater neuromuscular activation and adaptive responses. Consequently, children undergoing this enhanced therapy program can experience better functional outcomes, contributing to increased mobility and stability in daily activities.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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