Med. J. Cairo Univ., Vol. 92, No. 1, Accepted 7/2/2024
DOI: 10.22608/MJCU. 177-184, March 2024
www.medicaljournalofcairouniversity.com

Combined Effect of Quad Springboard Walkway with Platform Swing on Gait Pattern of Children with Spastic Diplegia

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Abstract

Background: Cerebral palsy (CP) is a childhood condition in which there is a motor disability (palsy) caused by a static, non-progressive lesion in the brain (cerebral). Spastic diplegia is a common subtype of CP where the four limbs of the body are affected with more affection in both lower limbs. So, gait problems are oftenpresentat thiscondition.

Aim of Study: The purpose of the current study was to investigate the combined effect of quad spring board walkway integrated into platform swing on gait pattern in children with spastic diplegia.

Material and Methods: Thirty children with diplegic Cerebral Palsy of both genders, aged from 4 to 7 years with spasticity ranged from mild up to moderate (1 or 2) according to Modified Ashworth Scale and they were at level I or II on Gross Motor Function Classification System participated in the study. They were randomly assigned into two equal groups; group (A) received traditional physical therapy program, and group (B) receive the same traditional program in addition to gait training onquad spring board walkway integrated into dynamic platform swing walkway. All subjects were assessed before and after the study using GMFM-88 (standing and walking, running, and jumping dimensions).

Results: There was significant increase in all mean variables of GMFM-88 and in favor for the study group (p>0.05).

Conclusion: Quad spring board walkway combined with platform swing have a significant effect on gait pattern in children with spastic diplegia due to implementation of vestibular stimulation and unstable surface training and further research is recommended to investigate study effect on other types of cerebral palsy.

Key Words: Cerebral Palsy – Diplegia – Unstable surface training – Vestibular training – Quad spring board – Rebound therapy – GMFM-88.

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Introduction

CEREBRAL palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitations 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 as well as seizures and secondary musculoskeletal problems. Historically, children were diagnosed with CP if the insult occurred at prenatal, perinatal, and postnatal period. On the basis of the current definition, no upper age limit has been determined for postnatal onset. For this reason, children are being diagnosed with CP throughout infancy and early childhood **[1].**

Spastic diplegia is the common term applied to variation of spastic quadriparesis in which the lower limbs are more affected than upper limbs. It accounts for approximately 50% of total CP population **[2].**

In spastic diplegic children muscle stiffness is in the legs and less severely affects the arms and face, although the hands may be clumsy. Tightness in leg muscles makes the legs move like the arms of scissors. Children with this type of cerebral palsy may require a walker or leg braces. Intelligence and language skills are usually normal **[3].**

Usually, child with spastic diaplegia can achieve independent walking with or without assistive device, according to severity by age of approximately 4 years, with one of these common gait patterns (true equinus gait / Jumping gait / apparent equinus gait / crouch gait / asymmetric gait). In each of these three walking patterns the child will have to adopt a different posture of the spine, in order to remain upright and compensate for these abnormal positions **[4,5].**

Quad spring board it is a wooden panel that is covered with durable skin guard and supported at bottom by 4 steel springs providing unstable rebounding surface (Rebound therapy) **[6]**.

Rebound therapy which provide unstable surface could be used to improve balance, movement, sensory integration and therefore posture control **[7]**.

Platform swing walkway is a large metal platform that is used as a source of vestibular stimulation during gait process by providing two types of motion sensors, the semicircular canals and the otoliths. It swings forward, backward and side to side directions **[8]**.

The vestibular system is a complex sensory organization which involves the communication between the peripheral vestibular apparatus, the ocular system, postural muscles, the brainstem, cerebellum and the cortex. Small structures in the inner ear make up the vestibular apparatus and detect head motion and gravitational forces on the body. This information is processed by vestibular centers in the brain to allow the body to maintain balance and proper spatial orientation during movement, as well as the correct processing of visual images during motion **[9]**.

The vestibular system, within the inner ear, is made up of 3 semicircular canals, an utricle, and a saccule. The semicircular canals detect angular, fast, short bursts of movement. The utricle and saccule (otolith organs) detect gravity and linear acceleration. The vestibular system as a whole is important for maintenance of balance and sensation of the body's movement through space. It works with the visual and proprioceptive systems to achieve balance, postural adjustments, optimal muscle tone, equilibrium reactions, and movement in general **[10]**.

The labyrinth of the inner ear senses head rotation and linear acceleration and sends that information to secondary vestibular neurons in the brainstem vestibular nuclei. Secondary vestibular neuron signals diverge to other areas of the central nervous system to drive vestibular reflexes. Specifically, neurons encoding head movement form synapses within the ocular motor nuclei to elicit the patterns of extra-ocular muscle contraction and relaxation needed for the vestibulo-ocular reflex (VOR), which stabilizes gaze (eye position in space). Other secondary vestibular neurons synapse on cervical spinal motor neurons to generate the vestibulo-colic reflex (VCR) or to lower spinal motor neurons to generate the vestibulo-spinal reflexes (VSR). These reflexes stabilize posture and facilitate gait **[11]**.

The purpose of the study is to determine the different effect of quad spring board walkway integrated into platform swing on gait pattern in children with spastic diplegia.

We hypothesized that there will be no influence of using quad spring board walkway with platform swing in on gait pattern of children with spastic diplegia.

Subjects and Methods

The current study was conducted from June 2023 to December 2023, after approval by the Ethical Committee at the Faculty of Physical Therapy, Cairo University (P.T.REC/012/004086). Consent form was obtained from each child's parent regarding the participation of their children in the study.

Subjects:

Thirty children of both genders were selected from outpatient clinic of faculty of physical therapy and private clinic, diagnosed with spastic diplegic cerebral palsy.

Children who met the following criteria were chosen to participate in the study: Their ages were ranged from 4 to 7 years old; they had grade 1 or 2 according to Modified Ashworth Scale, and they were at level I or II on Gross Motor Function Classification System. All the children were able to follow verbal commands and instructions. Patients were excluded if they had one of the following criteria:visual or auditory problems. had made any surgical interference in the lower limb for at least 2 years. They had special medications affecting muscle and/or mental functions. They had any contracture or fixed deformity at four limbs.

Design, randomization, and blinding:

The randomization allocation software version 1.0.0 method was used to assign numbers randomly to group (A) or group (B), for the children who met the study's inclusion criteria. Each member of the chosen children was given a number as part of this process. For the current study, 38 diplegic children with CP were assessed for eligibility. Eight of them were excluded since they didn't meet theinclusion criteria. The remaining 30 kids were divided into two groups, control group (A) and study group (B) as described in the participants flow chart Fig. (1).

Procedures:

The participants were randomly assigned into 2 equal groups:

• Group (A) (control group): 15 children Flexibility exercises: For hamstring, iliopsoas and calf muscles can increase range of motion in patients with limited ROM and poor balance. Strength Training: For all antigravity muscles. Gait Training: Walking in all directions (forward, backward, and sideways); Obstacles were used on the walkway inside and outside the parallel bar such as: Wedges with

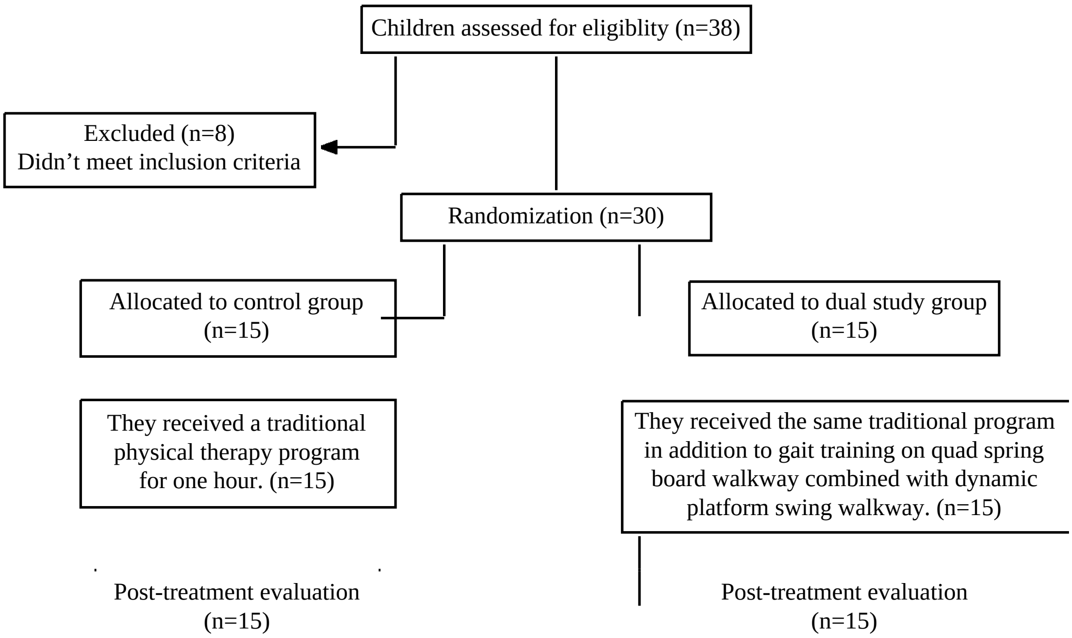

Fig. (1): Participant flow chart.

different height, rolls with different widths, Steeper andclimbing stairs up and down. Balance training program by: Kneeling on the balance board; Standing on the balance board; One leg stance; Walking on balance board; Walking on balance beam; Walking on balance board with obstacles on it; walking on rollators.

• Group B (study group): 15 children received Each child in this group performed the same training program given to children in the control group in addition to gait training on quad spring board applied on platform swing walkway at the same time. The therapist encouraged the child to stand on the walkway in a relaxed state and to hold cords of walkway. The therapist asked the child to start walking on quad spring boards without platform swinging back and forth. Then with platform swing static to be familiar with task at initial attempt. Then, the child was asked to walk in forward, backward and a sideward direction on board with platform swing is moving. The therapist swung the walkway in forward and backward directions slowly and fast. The therapist swung the walkway side to side direction slowly and fast. Linear vestibular stimulation was applied at tolerable speeds and durations and in unthreatening positions with period of rest if needed. The treatment stopped if there was any sign of (vertigo, dizziness or emotional stress).

Intervention was given for both groups daily, for 3 successive months. The evaluation was carried out using GMFM-88 (standing, walking, running and jumping dimensions) before and immediately after three months of treatment.

Statistical analysis:

The unpaired *t*-test was conducted for comparison of subject characteristics between groups. Chi squared test was conducted for comparison of sex distribution between groups. Normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. The unpaired *t*-test was conducted for comparison of GMFM 88, hip, knee and ankle angles in midstance between groups and paired *t*-test was conducted for comparison between pre and post treatment in each group. The level of significance was set at $p<0.05$. All statistical analysis was conducted through the statistical package for social sciences (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics:

Table (1) shows the subject characteristics of study and control groups. There was no significant difference between groups in age, weight, height and sex distribution ($p>0.05$).

Table (1): Basic characteristics of participants.

	Control group Mean ± SD	Study group Mean ± SD	*t*-value	*p*-value
Age (years)	5.07±1.07	5.63±1.07	–1.45	0.15
Weight (kg)	17.73±2.84	18.92±	–1.01	0.32
Height (cm)	111.80±6.25	112.70±8.96	–0.32	0.75
Sex, n (%):				
Girls	8 (53%)	5 (33%)	($\chi 2$=1.22)	0.27
Boys	7 (47%)	10 (67%)		

SD: Standard deviation. *p*-value probability value.
$\chi 2$: Chi squared value.

Effect of treatment on GMFM 88, hip, knee and ankle angles in midstance:

Within group comparison:

There was a significant increase in GMFM 88 standing and walking post treatment compared with that pretreatment in both groups (p>0.001). (Table 2).

Between groups comparison:

There was no significant difference between groups pretreatment (p>0.05). There was a significant increase in GMFM 88 standing and walking of study group compared with that of control group post treatment (p<0.01). (Table 2).

Table (2): Mean GMFM 88 standing and walking pre and post treatment of study and control groups.

GMFM 88	Pre-treatment Mean ± SD	Post-treatment Mean ± SD	MD	% of change	*t*-value	*p*-value
Standing:						
Control group	0.55±0.10	0.67±0.08	–0.12	21.82	–6.93	0.001
Study group	0.59±0.09	0.79±0.11	–0.20	33.90	–12.68	0.001
MD	–0.04	–0.12				
t-value	–1.32	–3.53				
	p=0.19	*p*=0.001				
Walking:						
Control group	0.32±0.11	0.38±0.12	–0.06	18.75	–9.51	0.001
Study group	0.33±0.07	0.54±0.17	–0.21	63.64	–6.25	0.001
MD	–0.01	–0.16				
t-value	–0.41	–2.81				
	p=0.68	*p*=0.009				

SD: Standard deviation. $\chi 2$: Chi squared value. *p*-value probability value.

Discussion

This present study was conducted to investigate the therapeutic benefits of vestibular stimulation during gait induced by platform swing combined with quad spring board at same time on gait pattern of spastic diplegic child.

We included spastic diplegic type of cerebral palsy, which constitutes a major classification among spastic type. This finding was reported by Huntsman et al., [12] who stated that spastic diplegic account for about nearly one-third of all spastic cerebral palsied cases.

Child with classical diplegia has slightly flexed and internally rotated hips, semi-flexed knees and planter flexed ankle. There is also some associated posturing in the upper limbs with internally rotated shoulders, flexed elbows, wrists and fingers, and adducted/opposed thumbs. This pattern is often not seen until after two years of age and may not be completely apparent until three years [13].

Parents of children with cerebral palsy (CP) often ask about and focus on their child's ability to walk. Population-based studies show that about 69% of children with CP are classified as walking with or without aids [14].

The age of children had participated in this study ranged from 4 to 7 years, this comes in agreement with Rosenbaum et aland Miller, [15,16] who stated that gross motor function measure (GMFM) scale of cerebral palsied children plateau by six or seven years of age. Also, children are reaching a plateau in neurologic development, and the rate of learning motor and balance skills is plateauing as well.

Regarding the post treatment results of both study groups, the improvements in walking pattern may be attributed to the combined effect of swing platform walkway and quad spring board through vestibular stimulation on improving the postural control. A peripheral sensory apparatus consists of a set of motion sensors (visual, vestibular and proprioceptive) that send information about head angular velocity and linear acceleration to the CNS, especially, the vestibular nucleus complex and the cerebellum. Then the CNS processes these signals and combines them with other sensory information to estimate head and body orientation. In addition, these improvements may be attributed to the activation of cerebral cortex of the brain which organizes the sensory information through its connections with the brain stem, motor region and spinal cord also selects and initiates the proper voluntary motor pattern and postural strategy that may improve motor control process.

This comes in agreement with Tsang, [17] who reports that Postural control is dependent on integration of proprioceptive, vision and vestibular systems of which vestibular input is particularly important. Adequate motor performance and postural control is needed for an infant of young child to independently perform and participate in play activates of daily living and social interactions.

In addition, Tramontano et al., [18] stated that the patients who received vestibular stimulation had greater improvement in their ability to ambulate than did the patients who did not receive this stimulation.

The dynamic platform swing walkway and quad spring board were used as a source of vestibular stimulation which was designed to provide two types of motion sensors, the semicircular canals (SCCs) and otoliths by linear acceleration with up and down movement. When the child was presented on device and intense vestibular inputs, he focused on gait pattern and responded by holding his head and trunk more erect and eventually improved his postural control enough for him to walk.

This comes in agreement with Hosseini et al., [19] Vestibular system maintains postural balance and equilibrium and is essential for the development of motor development and coordination and helps to improve accuracy of the voluntary movements. Vestibular stimulation mainly causes excitation of extensor or antigravity muscles and reciprocally inhibits flexor muscles.

in addition, vestibular stimulation through quad spring board walkway may help in balancing the body over the small base of support provided by the feet. As a sensor of gravity, the vestibular system is one of the nervous system's most important tools to control posture. The vestibular system is both a sensory system and a motor system. As a sensory system, the vestibular system provides the central nervous system (CNS) with information about the position and motion of the head and the direction of gravity. The CNS uses this information, together with information from other sensory systems, to construct a picture (sometimes called a "model" or "schema" or an "internal representation" or "map") of the position and movement of the entire body and the surrounding environment. In addition to providing sensory information, the vestibular system also contributes directly to motor control. The CNS uses descending motor pathways, which receive vestibular and other types of information, to control static head and body positions and to coordinate postural movements.

This comes in agreement with Shumway-Cook and Woollacott, [20] they reported that, balance information provided by the peripheral sensory organs (eyes, muscles, joints and the two sides of the vestibular system) is sent to the sorted out and integrated with learned information contributed by the cerebellum (the coordination center of the brain) and the cerebral cortex (the thinking and memory center). The cerebellum provides information about automatic movements that have been learned through repeated exposure to certain motions.

In addition, Era et al., [21] they described balance as "sensing the position of the body's center of mass and moving the body to adjust the position of the center of mass over the base of support provided by the feet. In order to maintain balance, vision, the somatosensory system and the vestibular organ interact and register inputs from the surroundings, which are integrated and processed in the central nervous system. The vestibulo-ocular reflex (VOR) coordinates eye and head movements, making it possible, for example, to walk and read signs at the same time. The cervico-ocular reflex interacts with the VOR, providing information about head movements in relation to the trunk. Sensory receptors in the skin as well as mechanoreceptors in the muscles provide input as to how gravity affects the body. For the preservation of balance, input from the various parts of the balance system is constantly reconsidered and response from the motor cortex is sent back.

Improvement in posture and movement in the study group may be attributed to the activation of cerebral cortex, basal ganglia and cerebellum through vestibule stimulation, which may improve voluntary motor capabilities, muscle tone and movement pattern all over the body.

This comes in agreement with Appiah-Kubi & Wright, [22] they suggested that vestibular stimulation via stimulation of vestibular system, improve the whole-body postural control though improving the accuracy of voluntary movements all over the body.

Madrona, [23] reported that Rehabilitation of Children Diagnosed with Cerebral Palsy Using "Adeli" Suit is based on Dynamic Proprioceptive Correction. Development of the brain and the spinal cord is significantly influenced by the interceptive impulses from the ligamentous-muscular apparatus and vestibular system. Structures of the vestibular system are one of the major zones processing impulses from proprioceptors. Factors injuring/damaging the central nervous system (CNS) significantly compromise functions at all levels of the vestibular system. This results in (motor) dysfunction in all CNS levels responsible for the formation and control of movement. This study indicated that using the "Adeli" method in the rehabilitation of children diagnosed with Cerebral Palsy stimulates the restarting of the developmental process of the vestibular system and helps in muscle tone. Gradually, particularly after the 2nd and 3rd session, the function within the semicircular canals and otolithic organs normalized and manifested in decreased spasticity.

In addition, vestibular inputs through swing platform walkway may decrease contracture of the hamstring, increase knee and hip ROM, and flexibility which improve the pattern of movement (co-contraction of agonist, antagonist and synergists) that are responsible for proper postural control and stability.as presented in our study, there was reduction in hips and knee flexion in the study group than did in control group and more improvement of GMFM-88 scoring at standing and walking, running and jumping dimensions of study group. These improvements were statistically significant at mid stance phase of gait cycle of right and left hip and knee joints. Also, the result of increasing percentage scores of standing and walking, running and jumping dimensions in study group than did in control group.

Regarding the present study, vestibular stimulation through combination of swing platform walkway and quad spring board has a positive effect on motor skills in children with spastic diplegia.

This comes in agreement with Kelly, *[24]* who described the effects of rotational vestibular stimulation to increase gross motor co-ordination in children and adults. Kelly showed that rotational vestibular stimulation was effective in increasing reflex integration, balance, intellectual functions, Perception motor skills, hearing language and socio-emotional development.

The improvement in motor performance in the study group may be attributed to the effect of vestibular stimulation through walking on platform swing walkway and quad spring board on psychological state of participated children as a source of funny and play and become more motivated to participate in the treatment program.

This comes in agreement with other studies that reported that Sensory integration of the vesicular system provides a 'gravitational security' which helps with the emotional well-being. However, due to the subject's poor integration of the vestibular system, he may have been fearful of being moved during all of his therapies which made him resistant and cry. When the subject was presented with intense vestibular inputs on different swings, he stopped crying very quickly and responded by holding his head and trunk more erect and eventually improved his postural control enough for him to walk. In addition, the vestibular system is thought to be a primary organizer of sensory information and contributes to physical and emotional security *[25,26]*.

The quad spring board as an unstable surface used for vertical vestibular input (bouncing) work like mini trampoline but with metal springs instead with low up and down swing during walking. Exercise with bouncing is the most effective form of exercise to correct posture and it can improve muscle strength (especially of the trunk muscle), endurance, coordination, and flexibility. This leads to an enhanced physical functional capacity resulting from improvements in balance sense and ability by stimulating proprioception.

This comes in agreement with Patel et al., *[27]* who said Postural adjustment requires an active sensorimotor control system, with information being fed back from the somatosensory, visual and vestibular systems. Integration between these three systems and the cognitive system generates motor responses that maintain stability.

Walking with bouncing exercises stimulates skin, joint and muscle receptors as well as the vestibular system, resulting in improved joint stability, modulation of muscle tone, muscle co-contraction and improved core stability.

This finding agrees with Abd-Elmonem and Elhady, *[28]* who stated that the use of unstable surfaces has been found to disrupt balance, increase the sensory stimulation required between the skin and joints, and increase equilibrium reactions caused by stimulation of the body-positioning mechanism.

Some limitations of this study are the relatively small sample size and lack of follow-up. Therefore, larger experimental studies are necessary to define the subcategories of children with CP most likely to benefit from gait training on the platform swing walkway with quad spring board. The strengths of the study are the integration of safety precautions and accommodation during gait training instudy settings.

Conclusion:

Based on our study results, it can be concluded that platform swing walkway combined with quad spring board could improve gross motor function and gait patterns in children with spastic diplegia. The platform swing walkway and quad spring board were tolerable at the protocol settings applied and provided the basis for stimulation of safety and efficacy. Future studies should examine the long-term effect of using them on different types and variables of CP.

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دراسة تأثير الممشى الزنبركى الرباعى داخل المنصة المتأرجحة على أنموذج المشى عند الاطفال المصابين بالشلل التشنجى المزدوج

الخلفيـة: الشـلل الدماغـى (CP) هـو حالـة فـي مرحلـة الطفولـة حيث توجـد إعاقـة حركيـة (شـلل) ناتجـة عـن آفـة ثابتـة غيـر تقدميـة فـي الدمـا غ (دماغيـة). الشـلل التشـنجى هـو نـوع فرعـى شـائع مـن CP حيـث تتأثـر الأطـراف الأربعـة للجسـم بمزيـد مـن الاصابـه فـى كلا الطرفيـن السـفليين. لذلـك، غالبـاً مـا تكـون مشـاكل المشـى موجـودة فـى هـذه الحالـة.

الهـدف مـن الدراسـة: كان الغـرض مـن الدراسـة الحاليـة هـو التحقيـق دراسـة تأثيـر الممشـى الزنبركـى الرباعـى داخـل المنصـة المتأرجحـة علـى أنمـوذج المشـى لـدى الأطفـال المصابـين بالشـلل التشـنجى.

الطريقـة: اشـترك فـي الدراسـة ثلاثـون طفـلا مصابـا بالشـلل الدماغـى مـن كلا الجنسـين تتـراوح أعمارهـم بـين ٤ و٧ سـنوات مـع التشـنج مـن خفيـف إلـى معتـدل (١ أو ٢) وفقـا لمقيـاس أشـوورث المعـدل وكانـوا فـى المسـتوى الأول أو الثانـى علـى نظـام تصنيـف الوظائـف الحركيـة الإجماليـة (GMFM–٨٨). تم تعيينهـم عشـوائيا فـى مجموعتـين متسـاويتين. تلقـت المجموعـة (أ) برنامـج العـلاج الطبيعـى التقليـدى، وتلقـت المجموعـة (ب) نفـس البرنامـج التقليـدى بالإضافـة إلـى التدريـب علـى المشـى علـى تأثيـر الممشـى الزنبركـى الرباعـى داخـل المنصـة المتأرجحـة. تم تقييـم جميـع الأشـخاص قبـل وبعـد الدراسـة باسـتخدام GMFM–٨٨ (الوقـوف والمشـي والجـري والقفـز).

النتائج: كانت هناك زيادة معنوية فى جميع المتغيرات المتوسطة ل GMFM–٨٨ ولصالح مجموعة الدراسة (p < ٠,٠٥).

الخلاصـة: الممشـى الزنبركـى الرباعـى جنبـاً إلـى جنـب مـع تأرجـح المنصـة لـه تأثيـر كبيـر علـى نمـط المشـى لـدى الأطفـال المصابـين بالشـلل التشـنجى بسـبب تنفيـذ التحفيـز الدهليـزى والتدريـب السـطحى غيـر المسـتقر ويوصـى بإجـراء مزيـد مـن الأبحـاث للتحقيـق فـى مـدى تأثيـره علـى الأنـواع الأخـرى مـن الشـلل الدماغـى.