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Effectiveness of Vestibular Versus Dual-Task Training on Balance in Children with Diplegic Cerebral Palsy

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Abstract

Background: Cerebral palsyis a neurodevelopmental disorder that caused by non-progressive lesion to the immature brain, this lesion causes permanent motor disability that presents with or without other associated disorders. Diplegia is a CP'S subtype where the four limbs of the body affected with more affection in both lower limbs. Balance problems are major problems faced by these children.

Aim of Study: The purpose of the current study was to investigate which is more effective and has a better impact on balance in diplegic CP.

Subjects and Methods: Thirty-four children with diplegic Cerebral Palsy of both genders, aged from 5 to 11 years with spasticity ranged from grade 1 or 1+ 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 2 equal groups; All the included children received traditional physical therapy program while group (A) received additional vestibular training program, and group (B) received additional dual-task training program. Balance was assessed before and after the study using HUMAC balance system and pediatric balance scale.

Results: There was significant increase in all variables that represent balance (p>0.001), center of pressure, eye open firm surface, eye closed firm surfaceand pediatric balance scale in both group post treatment compared with pretreatment results, but there was no significant difference betweenall these variablesin the between groups comparison pre or post treatment (p>0.05).

Conclusion: Both vestibular training and dual task training improve balance of diplegic children mostly to the same extent, therefore, we can recommend them as basic protocols that should be included in the treatment plan for diplegic children.

Key Words: *Cerebral palsy – Diplegia – Balance – Vestibular training – Dual task training – HUMAC – Pediatric balance scale.*

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Introduction

DIPLEGIA is the most prevalent anatomical type of cerebral palsy (CP), which affects the lower limbs more severely than the upper limbs, it's linked to prematurity and a low birth weight **[1]**. Children with spastic diplegic CP face significant challenges related to balance issues, which make it difficult for them to achieve and maintain stability. Poor performance in balance control has reportedly been attributed to a lack of neuromotor control **[2,3]**.

For the majority of practical skills, balance control is crucial. Children with CP have impaired postural balance control compared to children who are typically developing, which is most likely caused by the secondary musculoskeletal abnormalities and the slower and impaired neural motor control systems. Children with spastic diplegic cerebral palsy experience significant motor impairment, which is heavily reliant on balance control **[4,5]**.

Vestibular stimulation has shown improvements in postural stability, specifically, static and dynamic balance and in seated balance in kids with cerebral palsy. Possible mechanisms of action include influences on the lateral vestibulospinal tract, which helps maintain an upright and balanced posture, and development of the vestibuloocular reflex, which enables steady retinal image during head movements **[6,7,8]**.

Children with spastic diplegic CP can benefit from dual task training as an effective intervention to enhance balance and walking **[9]**. Dual-task training has higher significance if the childrenhave cognitive disorders and motor disturbance, because it can generate behavioral modalities by promoting two motor tasks to be completed simultaneously [10].

Subjects and Methods

The current study was conducted from June 2022 to December 2022, after approval by the Ethical Committee at the Faculty of Physical Therapy, Cairo University (P.T.REC/012/003716). Also the study was registered on Protocol Registration and Results System (NCT05692336).Consent form was obtained from each child's parent regarding the participation of their children in the study.

Subjects:

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

Children who met the following criteria were chosen to participate in the study: Their ages were ranged from 5 to 11 years old, they had grade 1 or 1+ 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 command and instructions.

Patients were excluded if they had one of the following criteria: Epileptic fits, severe visual and auditory problems, structural or fixed soft tissue deformities of lower extremities, severe mental retardation or Botox injection in the lower extremities in the past 6 months.

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, 40 diplegic children with CP were assessed for eligibility. Six of them were excluded since they didn't meet theinclusion criteria. The remaining 34 kids were divided into two groups, vestibular training group (A) and dual task group (B) as described in the participants flow chart Fig. (1).

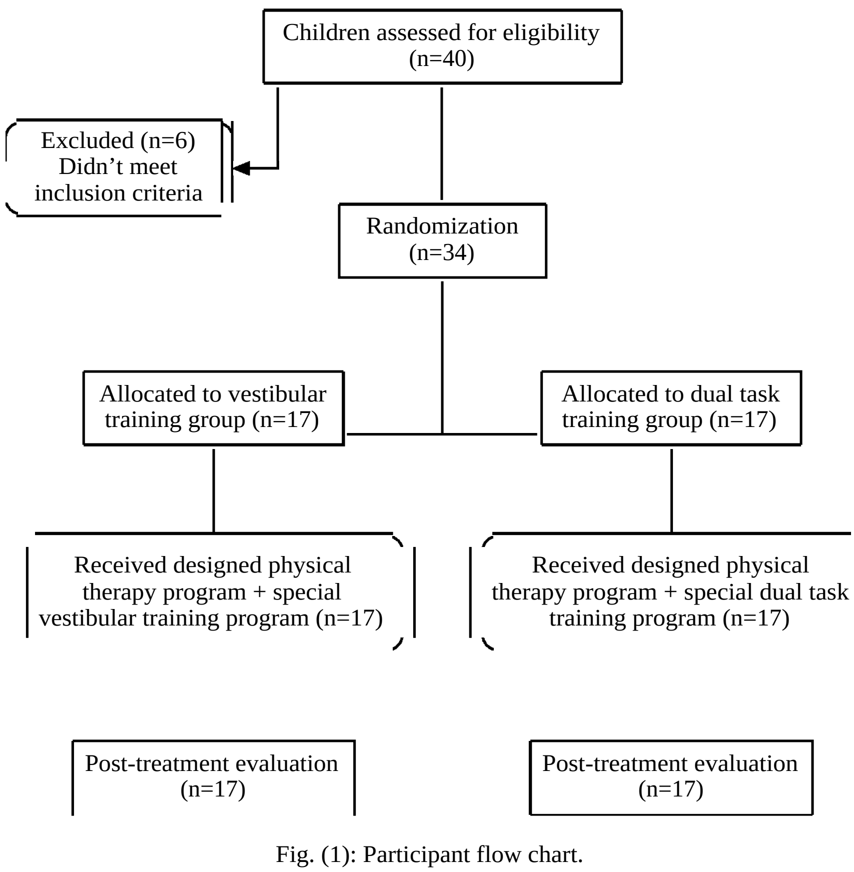

Fig. (1): Participant flow chart.

Procedures:

The participants were randomly assigned into 2 equal groups:

Group (A) (Vestibular training group): 17 children received 30 minutes of vestibular training in the form of: Walking on the platform swing walkway, walking on balance board while blinding eyes, walking on balance beam blind folded and blind folded standing on balance board. The vestibular training program was added to the traditional physical therapy program that included: Strengthening exercises for lower limbs muscles, pelvic control exercises in the form of kneeling, half kneeling and kneel walking, trunk control exercises like bridging, abdominal and back exercises and facilitation of postural reactions.

Group B (dual-task training group): 17 children received 30 minutes of dual-task training in the form of: Walking on balance board while throwing ball towards a target, standing on balance board while reaching to different directions, walking on balance beam while catching and throwing ball with the therapist and single limb support throwing and catching ball. All these exercises were added to the traditional physical therapy program.

Intervention was given for both groups 3 sessions/week, for 2 successive months. The evaluation was carried out using HUMAC Balance System and Pediatric Balance Scale (PBS) before and immediately after two months of treatment. The following tests were measured by HUMAC, center of pressure (COP), eye open firm surface (EOFS) and eye closed firm surface (ECFS).

Statistical analysis:

Unpaired *t*-test was conducted for comparison of subject characteristics between groups. Chi squared test was conducted for comparison of sex distribution. 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. Unpaired *t*-test was conducted for comparison of COP, EOFS, ECFS and PBS between groups. Paired t test was conducted for comparison between pre and post treatment within groups. The level of significance for all statistical tests was set at $p<0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

Results

I- Subject characteristics:

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

II- Within group comparison:

There was a significant increase in COP, EOFS, ECFS and PBS post treatment in both groups compared with that pre treatment ($p>0.001$). The percent of increase in COP, EOFS, ECFS and PBS of group A was 15.22, 12.24, 24.39 and 24.51% respectively and that in group B was 18, 12.42, 14.05 and 16.18% respectively, as presented in Table (2).

III- Between group comparison:

There was no significant difference between groups pre treatment ($p>0.05$). Comparison between groups post treatment revealed a non significant difference in COP, EOFS, ECFS and PBS ($p>0.05$), as illustrated in Table (2).

Table (1): Comparison of subject characteristics between group A and B.

	Group A Mean ± SD	Group B Mean ± SD	MD	*t*-value	*p*-value
Age (years)	7.56±1.77	7.66±2.17	–0.1	–0.15	0.88
Weight (kg)	20.71±4.79	21.88±5.93	–1.17	–0.63	0.52
Height (cm)	119.00±10.68	121.11±9.49	–2.11	–0.61	0.54
Age (years)	7.56±1.77	7.66±2.17	–0.1	–0.15	0.88
Sex, n (%):					
Girls	7 (41%)	7 (41%)		(χ^2=0)	1
Boys	10 (59%)	10 (59%)			

SD, Standard deviation. MD: Mean difference. $\chi 2$: Chi squared value. *p*-value: Probability value.

Table (2): Mean COP, EOFS, ECFS and PBS pre and post treatment of group A and B.

	Group A Mean ± SD	Group B Mean ± SD	MD	*t*-value	*p*-value
COP:					
Pre treatment	65.29±13.41	63.41±13.98	1.88	0.4	0.69
Post treatment	75.23±13.39	74.82±11.72	0.41	0.09	0.92
MD	–9.94	–11.41			
% of change	15.22	18			
t-value	–14.66	–7.39			
	p=0.001	*p*=0.001			
EOFS:					
Pre treatment	70.17±8.61	67.23±15.50	2.94	0.68	0.49
Post treatment	78.76±7.94	75.58±11.80	3.18	0.92	0.36
MD	–8.59	–8.35			
% of change	12.24	12.42			
t-value	–7.99	–5.03			
	p=0.001	*p*=0.001			
ECFS:					
Pre treatment	61.00±16.06	60.29±13.98	0.71	0.13	0.89
Post treatment	75.88±9.70	68.76±13.45	7.12	1.76	0.08
MD	–14.88	–8.47			
% of change	24.39	14.05			
t-value	–6.06	-6.36			
	p=0.002	*p*=0.001			
PBS:					
Pre treatment	35.00±8.70	35.29±7.98	–0.29	-0.10	0.91
Post treatment	43.58±7.36	41.00±8.00	2.58	0.98	0.33
MD	–8.58	–5.71			
% of change	24.51	16.18			
t-value	–16.23	–9.62			
	p=0.001	*p*=0.001			

SD: Standard deviation. MD: Mean difference. *p*-value: Probability value.

Discussion

'Balance problems' is a serious statement when we deal with cerebral palsied children and it must have a special concern. Sah et al., [11] stated that the diplegic children have significant barrier to follow the sequence of motor development due to trunk control abnormalities and the increased center of pressure oscillations in the anteroposterior and mediolateral directions, which also cause balance abnormalities and truncal instability. Therefore, the direction of our study is to improve the balance abilities in the children with spastic diplegic CP.

Comparing the pre-treatment values of all variables representing balance between both groups (A) and (B) revealed no significant difference, also comparing the age and sex distribution in both groups revealed no significant difference, which means that both groups were homogenous.

No significant difference was revealed when both groups were compared post treatment, which means that both protocols can improve balance mostly to the same extent.

The results of the current study showed that there were significant improvements in center of pressure (COP), eye open firm surface (EOFS), eye closed firm surface (ECFS) and pediatric balance scale (PBS) in both groups (A) and (B), which means that both treatment program were effective in improving both static and dynamic balance in such children.

The improvement that occurred in balance in Group (A) that was treated by vestibular training came in accordance with Viratia et al., [12] whostated that four weeks of training with vestibular stimulation in conjunction with traditional physical therapy showed a great improvement in the trunk control and balance in children with diplegic CP. They relayed this improvement to the fact that vestibular exercises train the sensory systems to deliver accurate spatial cues for head and body movements. Also Tramontano et al., [8] reported thatthe vestibular training improves gross motor abilities and facilitate both static and dynamic balance control in CP children.

That improvement also may be due to that vestibular stimulation boosts the acceleration forces acting on the muscles, improving the exercise load and enhancing neuromuscular activation also muscle strength is enhanced by this type of training, which also improves balance abilities [13].

Another justification for balance improvement in group (A) is that this type of training causes improvement in the abdominal and back strength and the improvement in the coordination between them, also the hip extensors, knee extensors and ankle dorsi flexors are strengthened [14].

The results of the study conducted by Gharib, [15] came in agreement with our results. The study documented that the use of suspension therapy, which is a way of vestibular training, is effective in improving balance in the children with spastic diplegia.

Finally changes that occurred in group (A) may be due to that vestibular stimulation elicits inputs from vestibular receptors, optical cues, impulses from proprioceptors in joint capsules and from cutaneous extra receptors, which are integrated through the nervous system at different levels to maintain posture [16].

Balance changes that occurred in group (B) following the treatment with dual task training in combination with traditional physical therapy may be due to the robust activation of different routes including the cerebellum, sensorimotor cortex, and lateral premotor cortex that occurred when performing dual tasks, and that activation can be used to explain the improvements in postural stability measures [17,18].

Another possible explanation the improvement that occurred in static and dynamic balance in group (B) may be that dual task training increases conscious control mechanisms and attention techniques while diminishing automatic control throughout activities. Dual-task training may have a significant influence on how the attention increases cortical plasticity in the somatosensory and motor cortex and improves functional activity so dual task triggers plastic changes in the brain [19].

Concerning improvement in group (B), Lee et al., [20] found that the use of dual-task training is an efficient clinical intervention technique for improving static & dynamic balance, as well as their gross motor function in children with spastic diplegia CP.

Balance improvement that occurred in group (B) was supported by the results of Fritz et al., [21] who stated that dual task training improves the ability to perform 2 tasks spontaneously and improves spatiotemporal measures of the gait, it also improves the independence level, decreases the risk of fall, enhances gait and improves cognition.

There is only one previous study that conducted by Saleem et al., [22] who compared the effectiveness of both dual task (DT) and vestibular rehabilitation training (VRT) on gait and balance in posterior cerebral artery stroke patients. They preferred the use of VRT rather than using DT to improve balance. Our study revealed that the diplegic children benefit mostly to the same extent from both vestibular training and dual task training.

The inconsistent finding in the previous literaturemay be due to different choice of the population, our work was directed to the diplegic children, while other study was directed to adult with stroke, the duration of the whole treatment also was different, our study continued 2 successive months while the other one continued for only one month, which is a period that may be not sufficient to maximize the effect of dual task training, also this difference may be due to the change in capacity of neural plasticity, which is more working in children than the adult, this neural plasticity normally works when we train for new task like performing and training a dual task training.

The current study faced some limitations, some parents refused the participation of their children to the study, which in turn prolonged the period to collect the study. Another limitation was the relative wide age range of our sample which may affect the generalizability of results.

Conclusion:

Both vestibular training and dual task training have positive impact on balance of the diplegic children mostly to the same extent, both could improve balance and so our study recommended to engage both types of treatment when we deal with a diplegic child.

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فعالية تدريب الجهاز الدهليزى مقابل التدريب ثنائى المهام على التوازن لدى الأطفال المصابين بالشلل الدماغى المزدوج

خلفية الدراسة : يوصف الشلل الدماغى (CP) على أنه اضطرابات النمو العصبى التى تسببها الإصابة غير التقدمية للدماغ غير الناضج، وتسبب هذه الإصابة إعاقة حركية دائمة تظهر مع أو بدون اضطرابات أخرى مرتبطة بها. شلل مزدوج هو نوع فرعى من CP حيث تتأثر الأطراف الأربعة من الجسم مع مزيد من الشدفى الطرفين السفليين، مشاكل التوازن من المشكلات الرئيسية التى يواجهها هؤلاء الأطفال.

الهدف من هذه الدراسة : هو معرفة أى نوعى التدريب أكثر فعالية وله تأثير أفضل على التوازن فى الشلل الدماغى تدريب الجهاز الدهليزى أم التدريب ثنائى المهام.

المرضى وطرق الدراسة : تم اختيار أربعة وثلاثين طفلاً مصابين بالشلل الد ماغى المزدوج من كلا الجنسين أعمارهم تتراوح بين ٥ إلى ١١ عام مع تشنج يتراوح من ١ أو ١+ وفقاً لمقياس أشوورث المعدل و كانوا فى المستوى الأول أو الثانى فى نظام تصنيف الوظيفة الحركية. تم تقسيم المرضى بشكل عشوائى إلى مجمو عتين متساويتين تماماً، جميع الأطفال المشاركين فى الدراسة تلقو برنا مج العلاج الطبيعى التقليدى، بينما تم إضافة برنامج تدريب الجهاز الدهليزى إلى الخطة العلاجية للمجموعة (أ) ، وتم إضافة أيضاً برنامج التدريب ثنائى المهام إلى الخطة العلاجية للمجموعة (ب).

النتائج : هناك زيادة معنوية فى جميع المتغيرات التى تمثل التوازن وهى (COP) و (EOFS) و (ECFS) و (PBC) و ، فى كلتا المجموعتين بعد العلاج مقارنة مع نتائج ما قبل العلاج (p>0.001)، لكن المقارنة بين المجموعتين كشفت عن عدم وجود فرق كبير بين (COP) و(EOFSECFS) و (PBS) فى كلا المجموعتين قبل العلاج وبعده (p>0.05).

الاستنتاج : يحسن كل من تدريب الجهاز الدهليزى والتدريب على المهام المزدوجة على توازن الأطفال المصابين بشلل مزدوج فى الغالب بنفس القدر، ويمكن لكليهما تحسين التوازن ؤذا يمكننا التوصية بهما كبروتوكولات أساسية يجب تضمينها فى خطة العلاج للأطفال المصابين بشلل مزدوج.