



Original Article

Investigating the Effects of Vestibular Stimulation on Balance Performance in Children with Cerebral Palsy: A Randomized Clinical Trial Study

Seyed Ali Hosseini¹, Bahareh Zeynalzadeh Ghoochani^{1*}, Saeed Talebian², Ebrahim Pishyare¹, Hojjat Allah Haghgoo¹, Roya Mahmoodi Meymand¹, Afsaneh Zeinalzadeh²

¹University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

²Department of Physiotherapy Faculty of Rehabilitation Sciences Tehran University of Medical Sciences and Health Services, Tehran, Iran

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ABSTRACT

Background: Centre of pressure displacement is an indicator of postural control. Children with cerebral palsy have poor postural control. One common intervention to enhance their balance is vestibular stimulation. The aim of this research was to investigate the effect of vestibular stimulation on COP parameters in children with cerebral palsy (3-10 years old).

Methods: This study was a randomized double-blind controlled clinical trial. Twenty children with cerebral palsy received vestibular stimulation, two sessions per week with a course of twelve sessions, based on vestibular stimulation protocol including anteroposterior, lateral, ascending–descending movements and spinning. One cerebral palsy group experienced current and conventional occupational therapy while the other received a period of vestibular stimulation during treatment. Force plate outcome measures were center of pressure displacement parameters as well as velocity, area, displacement in X and Y axes.

Results: According to Mann-Whitney U test, means in post-tests in two groups with both conditions of eyes open and closed were significant in velocity parameter (eyes open $P=0.036$; eyes closed $P=0.021$) while Area parameter, COP displacement in X axis (Rang fore after), COP displacement in Y axis (Rang side way) were not significant ($P>0.05$). Wilcoxon Test showed significant difference in the velocity parameter; eyes open ($P=0.012$) and eyes closed ($P=0.018$).

Conclusion: Children who received vestibular stimulation are able to change and control COP displacement faster (according to changes in velocity parameters). So we suggest rehabilitation team members especially occupational therapist to apply vestibular stimulation during their treatment.

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Introduction

Anatomical structures related to postural control show three [3] main tracts which originate from vestibular nuclei; lateral vestibulospinal, medial vestibulospinal and reticulospinal tracts. Medial vestibulospinal tracts originate from the vestibular nuclei and most of its

fibers terminate at the cervical spinal tract. Therefore, it is reasonable to assume that stimulating the vestibular system would have an effect on the cervical postural control. The most important impact is related to the lateral vestibulospinal tracts because it passes through all parts of spinal cord. Results obtained from experimental trials have shown the facilitator efficacy of lateral vestibular nuclei, on the activity of spinal mechanisms controlling muscle tone [1, 2].

These neural pathways has an important role in balance,

*Corresponding author: Bahareh Zeynalzadeh Ghoochani, PhD student of Occupational Therapy, University of Social Welfare and Rehabilitation Sciences, Zip code: 9188637185, Tehran, Iran.
E-mail: b_zeynalzade@yahoo.com

both stability and movements [1, 3, 4]; thus, vestibular stimulation has a strong effect on postural control and balance in children with cerebral palsy, especially through the medial and lateral vestibulospinal tracts. It is clear that the vestibular labyrinth has a critical role to play in the balance system. The balance system is not limited to just the vestibular system. A more accurate picture of the balance system consists of various sensory inputs (visual, proprioceptive, and vestibular) integrated by automatic and coordinated postural control of muscles. Visual and proprioceptive information are changing all the time but the vestibular reference (that is gravitation) remains the same. Alum and Faltz [5] suggested that vestibular stimulation is effective on the dynamic balance of human beings at 65%, consequently visual and proprioceptive would have fewer portions. Static balance does not primarily rely on the vestibular stimulation. Hobeika reported proprioceptive input as the major contributor part in static balance [6]. However, when proprioception is not effective (as on a movable surface), vision would have a dominant role. In light of the above, the balance system is dynamic, rapidly relying on visual, vestibular and proprioceptive feedbacks [1, 7]. The trunk and cervical muscles create motions and their development is the basis of postural control. If proximal muscle structures are not well developed, it results in inability of maintaining balance [1, 8]. Numerous studies in this field have shown that ankle proprioceptive is necessary for repositioning action [1, 5, 9, 10]. Nashner and Greem showed that when proprioceptive information from the lower extremity is not available, the vestibular system will be responsible for balance control and answers result in responds to perturbations with some delays [11]. One goal of postural control system function is management of a sudden deviation of center of mass, during standing walking and so on.

For a better understanding about balance in children with cerebral palsy, major parts should be discussed based on neuroscience and treatment approaches. Gravitational or positional insecurity plays an important role in stable emotional development, balance and positional mechanism as well as spatial orientation [5]. Children, who are oversensitive to motion, are afraid of being lifted from the ground (no foot contact with ground or increasing the level of their position from earth) [6]. Their neck and body will be locked, as they avoid motor activities [12]. Fisher et al. reported that gravitational insecurity is due to weak adjustment of otolith inputs [13]. They have difficulties in dynamic balance. Primary role of balance system is providing security and an efficacy in relation with environment.

During our intervention, the objectives were stimulating and integrating both the vestibular and proprioceptive systems in a manner that all vestibular receptors be stimulated. Since system integration is helpful in combining the current therapy and vestibular stimulation, those groups that received both would have significant difference in their postural control.

Methods

Twenty CP children participated in this randomized

double-blind controlled clinical trial after filling out consent form. Subjects were selected from a population of children with cerebral palsy 3 to 10 year old in Tehran. They were selected by convenient sampling, assigned and allocated by online randomizer software into two groups. During this process, at first four [4] children were excluded from participating because of problems and limitations which are mentioned in discussion. Subjects were matched chronologically, with their weight and height and also level of function, every two or more children with alike conditions were put in the same randomization round so that in each group we would have parallel characteristic. All subjects were diagnosed by a neurologist. Inclusion criteria included being able to stand and walk independently (they should be at first, second and third level of the gross motor classification system [14]), Modified Ashworth scale of less than 3 in lower extremity. The exclusion criteria included: history of fracture in spine or lower extremity and seizure or any kind of epilepsy diagnosed by a neurologist.

In our study one group experienced current and conventional occupational therapy while the other received a period of vestibular stimulation during their usual treatment sessions (half vestibular stimulation plus half current occupational therapy).

The independent variable was the type of vestibular stimulation provided and included 1) anteroposterior tilt, stimulation 2) lateral tilts 3) ascending – descending orientation with gravity 4) spinning, turning around the axial axis of each case. Researcher move children in special axis depending on the kind of stimulation with clinical vestibular stimulation instruments such as tilt boards, scooter boards, CP balls and spinners. Dependent variables were Rang for after (RFA): Range of anterior posterior displacement in Y axis, a quantitative dependent variable which is calculated by Matlab software. Range side way (RSW): displacement in the X axis, a quantitative dependable variable calculable with software. Mean Velocity (MV): The division of displacement on numbers, a quantitative variable calculated by software. The area of center of pressure is the mean rate of COP displacement in both X and Y axes. Tehran university force plate was a 9090 series (Sampling Rate 400 Hz-Sensitivity 10 –Height 15.2- Size 90x90 - Duration 20 Sec). In case of high local standard deviation for anterior-posterior and mediolateral center of pressure, postural stability is assumed to be less [15]. At first goals and project demands were explained to parents and also to the children, in the case of their acceptance they read and filled consent form and finally, assessment was started. Children in the control group received the current standard occupational therapy which includes 45 min twice a week. Children in the trial group received vestibular stimulation in the last 20 min of the session as half of usual rehabilitation sessions. Organized vestibular treatment starts with prone and supine position because the height of the center of gravity in these positions would be the least possible and balance postural control would be easier to handle and would gradually be integrated. Hosseini's vestibular stimulation protocol was used in this project [1]. This

protocol consists of all kind of mechanical vestibular stimulation stimulating all receptors, starting from prone to finally standing position. In the prone position, the extensory pattern is facilitated and co-contraction in the trunk, especially shoulders lead to stability of the head and shoulder [4]. Different types of stimulations were used during intervention (all vestibular receptors were activated and stimulated). Treatment continued in the sitting position. All kinds of vestibular stimulation were performed in every position. Stimulation continued in quadruped position (height of center of gravity would be increased rather than sitting position), stimulation consists of tilts (lateral and front to posterior), spinning and linear motions plus ascending –descending. The procedure was continued in kneeling position; center of gravity was placed higher and the supporting surface was decreased in comparison with previous positions. In the initial point of treatment, children were supported completely. After, the child’s adaptation to the stimuli, support was decreased and finally omitted. Finally, stimulation was given in a standing position, center of gravity height was then at its highest level and supporting surface would be the least. The support decreased gradually until the child was able to organize his independent standing, all types of stimulation were also given in this position [1]. The pretest-posttest assessments were done by force plate. The groups were similar at the start of the trial and apart from experimental intervention, the groups were treated equally. Patients were analyzed in the groups to which they were randomized.

Results

In this study, sixteen [16] children (reduced through

attrition because of problems and limitations) were divided into two: (1) control and (2) trial groups. The trial group consists of eight children (3 male and 5 female) while the control group had eight children (2 female and 6 male) mean age was 61.5 months in trial and 68 months in the control group. Since the sample size was eight (8) people in each group; in the case of few sample size the distribution is not assumed to be normal. Results show no significant difference between sex (P=0.614), age (P=0.833), weight (P=0.875), and height (P=0.958) in the trial and control groups (Statistical significance: P<0.05) (Table 1). Kolmogorov-Smirnov test P values were 0.03-0.04-0.001-0.002 for RSW (eyes open), Area (eyes closed), RFA (eyes closed), RSW (eyes closed).

Statistical results according to Wilcoxon Test showed that there was no significant difference between mean of pretest and post test in the intervention and control groups with eyes open and closed, except in velocity parameter in the intervention group (P>0.05) (Tables 2-7).

Discussion

Statistical results according to Wilcoxon Test showed that there was no significant difference between mean of pretest and post test in the intervention and control groups with eyes open and closed, except in velocity parameter in the intervention group. The change of mean velocity parameter is a dynamic parameter and is indicative of change in the center of pressure pattern. Children have shown increase in velocity parameter after vestibular stimulation, as a result of the attempt to gain environmental information. These changes seem to be the result of vestibular stimulation added to intervention.

Table 1: Demographic characteristics

Variable	Control group		Trial group		Z	P
	Mean	Standard Deviation	Mean	Standard Deviation		
Age	68	36.58	61/5	27.39	0.211	0.833
Weight	19.6	8.88	17.0	4.47	0.58	0.875
Height	108.75	26.655	104.25	13.895	0.53	0.958

Table 2: Pretest according to Mann-Whitney U test in control and intervention groups*

Variable	Trial group			Control group			Z	P value	
	Number	Mean	Standard Deviation	Number	Mean	Standard Deviation			
Pretest									
Eyes Open	Area	8	173.43	18.017	7	192.34	61.731	0.116	0.908
	RFA	8	2.57	1.398	8	1.77	0.972	1.155	0.248
	RSW	8	11.07	0.643	7	10.70	0.374	1.171	0.241
	Velocity	8	45.47	23.748	8	50.42	53.592	0.735	0.462

*Comparison of mean Velocity, Area, RFA, RSW in pretest according to Mann-Whitney U test in control and intervention groups (Statistical significance: P<0.05).

Table 3: Post test according to Mann-Whitney U test*

Variable	Trial group			Control group			Z	P value	
	Number	Mean	Sd.	Number	Mean	Sd.			
Post-test	Area	8	192.44	67.398	8	23.110	54.844	0.210	0.834
Eyes Open	RFA	8	2.47	1.756	8	2.19	1.628	0.158	0.875
	RSW	8	10.64	0.619	8	10.68	0.257	0.383	0.702
	Velocity	8	66.37	29.680	8	36.06	28.615	2.100	0.036

*Comparison of posttest mean velocity, RFA, RSW, Area in control and intervention groups with eyes open according to Mann-Whitney U test

Table 4: Pretest according to Mann-Whitney U test *

	Variable	Trial group			Control group			Z	P value
		Number	Mean	Sd.	Number	Mean	Sd.		
Pre-test	Area	8	159.17	8.078	7	195.07	54.844	1.042	0.298
Eyes closed	RFA	8	4.42	6.383	8	2.60	1.964	0.263	0.793
	RSW	8	10.86	0.240	7	9.65	2.646	2.079	0.138
	Velocity	8	21.68	10.128	8	55.14	58.899	0.315	0.753

*Comparison of mean velocity, RFA, RSW, Area in pretest of participants with eyes closed according to Mann-Whitney U test in control and intervention groups

Table 5: Posttest according to Mann-Whitney U test.*

	Variable	Trial group			Control group			Z	P value
		Number	Mean	Sd.	Number	Mean	Sd.		
Post-test	Area	7	193.89	54.626	8	160.54	58.135	0.810	0.418
Eyes closed	RFA	7	2.15	1.029	8	3.88	4.404	0.694	0.487
	RSW	7	11.16	0.953	6	10.82	0.148	0.621	0.534
	Velocity	7	47.16	31.157	8	23.84	23.289	2.315	0.021

*Comparison of mean velocity, area, RFA, RSW in post test of control and intervention groups with eyes closed according to Mann-Whitney U test.

Table 6: Pretest-posttest according to Wilcoxon Test*

	Variable	Trial group		Control group	
		Z	P value	Z	P value
Pre-test Eyes open	Area	0.140	0.889	1.014	0.310
	RFA	0.420	0.674	0.700	0.484
	RSW	0.730	0.465	0.000	1
	Velocity	2.521	0.012	0.560	0.575

*Comparison of mean Velocity, Area, RFA, RSW in pretest-posttest of control and intervention groups with open eyes according to Wilcoxon Test

Table 7: Pretest posttest according to Wilcoxon Test.*

	Variables	Trial group		Control group	
		Z	P value	Z	P value
Pretest-post test with eyes closed	Area	1.183	0.237	1.014	0.310
	RFA	1.014	0.31	1.4	0.161
	RSW	0.730	0.465	1.461	0.144
	Velocity	2.366	0.018	1.820	0.069

*Results of comparing mean velocity, area, RFA, RSW pretest post test in control and intervention groups with eyes closed according to Wilcoxon Test.

Whenever sensory inputs necessary for maintaining balance are reduced, due to pathology or aging, the range of center of pressure displacement increases. Although this has exceptions, for example the reduction noted in persons with Parkinson’s disease or the increase in ballet-dancers who have great balance skills. Hosseini found vestibular stimulation effective and his findings are in strong agreement with ours. Changes in joints such as ankle, knee and hip are key inputs for correction of center of mass after any perturbation. Making the center of mass lower would lead to increasing stability, so cerebral palsied children will automatically try to stand with knees flexed, in this way they will control the center of mass, in order to maintain their balance and stability. In Seyed Ali Hosseini’s research, joint’s angle such as ankle, knee and hip were increased after intervention. Any way when proprioceptive inputs are not enough, visual and vestibular inputs compensate [11]. Hosseini’s results show that a combination of the two treatments had significant effect on postural control and CP’s balance. Hosseini’s groups were three

and among all, the one with combined treatment had significant differences in all aspects, namely center of gravity, joints angle, muscle tone and EMG. Palmer [12] reported that larger clinical trials must be conducted to investigate the effect of neurodevelopmental treatment. A combination of the two treatments causes stimulation of three systems. The vestibular, proprioceptive and visual systems are responsible for postural control and balance, so according to system integration approach, a combination of the two treatments would have a stronger effect on the development of cerebral palsied children. Vestibulopostural deficits are one of the most common problems in CP children, based on vestibular. By means of antigavity postures with vestibular stimulation and functional activities, muscle tone can be modified [6]. Our method for intervention was the same as Hosseini’s method. So it can confirm their results and support our findings. But the study of Sellick and Over [16], gave a negative result to these evidences whether the motor skills of children would be changed by physical therapy. The results of Sellick and Over were in complete contrast

with Chee et al.'s reports [17], Hosseini and the findings of this study, in terms of whether vestibular stimulation is effective on motor function or not. Establishing a foundation for solving these contradictory results, the stimulation condition seems to be comparable and sample sizes are close to each other, cases were in the same range of age and ability; objective tests were used to assess motor performance. They were blind and comparison was made between control and trial groups. One possible answer is the differences in matching. Although children were randomly assigned into the control and trial groups, it was not possible to be completely balanced in primary function, age or classification. These are all because of the limited existing sample of cerebral palsied children and also, another factor is the variety of their deficit characteristics. Another point of debate is the contrast of objective assessment tools for motor performance. In Chee's research, a test of modified motor performance explained by Kantner was used (for assessment of gross motor function and seven reflexes with four scales criteria). Selick and Over used Bayle's infant scale for gross and fine motor as well as eye hand coordination. The objective tests used in this project were sensitive enough to show maturation results for both groups in all calculations. Another important point is that some cases have previous history of treatments, this is the only parameter which was not considered in any research.

The contradiction between the findings of Sellick and Over, as well as Chee et al. left a question open whether vestibular stimulation is effective in motor development of CP children. Other researches should be done with consideration of vestibular performance, age, classification and therapy history. Vestibular stimulation has caused so many debates among therapists and researchers. These debates are because the results gained from vestibular stimulation researches are not in agreement. Some authors found significant functional difference and some kind of efficiency [1, 16]. Sellick and Over found that more researches related to vestibular stimulation must be done to prove its efficacy, generalizability, and longtime effects. Debates are about protocols, patient position while receiving stimulation, time of receiving stimulation and duration of receiving stimulation. There are few researches that show knowledge and ideas of therapists about this issue, although it is critical and one part of treatment. Additionally, current research methods are not able to completely separate vestibular stimulation from proprioceptive sense while receiving treatment [18] and little studies have been conducted on this. It seems that in Sellick and Over results, the lack is because of treatment plan or the treatment itself, whether time of treatment was short or the sample size was not suitable.

Schler is among the first professionals, who investigated the importance of the vestibular system in human development [19]. He assessed the vestibular system integrator function in the central nervous system, and its role in the development of body image. Various studies agree with his findings. Most of them accepted the importance of the vestibular system in the development of movements, reflex integration, creation of eye movement,

visual attention and development of exploratory behaviors with integration of arousal level. However, there is little research information accessible, for explaining this participation in the control and integration of upper level functions. Although some researches accepted its positive effectiveness, there are few academic researches in some aspects of that. For example, many researchers suggested the assumption about its facilitatory effect on human development. Krutsberg [20] used vestibular stimulation as a sensory saturator to increase the rate of synaptic maturation related to inhibitory tracts, as this would help infant synapses to mature faster. This would result in inhibition of inappropriate reflexes and enhancement of his motor responses, finally creating a more stable environment for a faster revolution [15]. Ayres suggested that vestibular system stimulation is effective in all sensory experiments and those treatments with this part would activate inactive synapses [21]. Dequires and Escherager [22] stated that the vestibular system is necessary for the development of body potentials because this system exchanges information about body position, movement and equilibrium with higher centers, thereby facilitating the learning process in humans. They believed that any disturbance in the vestibular system could lead to impairment in brain higher level functions such as laterality and language development. Studies in the field of anatomy and physiology have shown the importance of anatomical, functional and vestibular characters [23]. At first, the concern of researches about postural control was on investigating approaches to control anterior posterior deviation but recently lateral mechanisms are the focus of attention. Nowadays, major emphasis is on early interventions for CP children. The participants in Chee et al.'s study had not previously experienced vestibular stimulation, thus they recorded better response to treatment. Although vestibular stimulation was used in some researches, the question of whether it is effective on infants has not been answered. This is a pilot study since no similar research has been found in the literature in Iran or any other countries. Recent researches work on different sensory stimulations to help better neural development and one major complement is the vestibular stimulation. Those researches have been investigated and some show that controlled vestibular stimulation, have fruitful and positive effect on arousal level, visual exploratory behavior, motor development and reflex integration. Also, there is still a need for more applicable clinical researches and specifying the best kind of vestibular stimulation and the population that are the best receivers. Vestibular stimulation is a sensory supplementary stimulation in order to increase arousal level, increase visual exploratory behavior, motor development and reflex integration in high risk infants and delayed children. Most recent researches accepted the importance of vestibular stimulation on other CNS structures [24, 25]. Researchers should use this kind of stimulation more and therapists should record and report their findings. More organized researches would help therapists to choose the best vestibular stimulation protocol. There are many questions to be answered with

extra focused and clinical researches. For example, which of the linear or circular vestibular stimulation is more effective? What is the best speed of circular motions per minute? Should head position be defined or not? Is vestibular stimulation proper for a special age or diagnosis? Answers to these questions opens a new area of revolution in our knowledge about vestibular stimulation and its role in rehabilitation and also help practitioners to choose the best method and gain the best result and insight. Since this method is going to be used more than ever, academic researches should be conducted to shed light on this important field, parallel to the demands of clients. One problem in this study was the families' problems. Assessment was performed at Tehran University and transfer was so hard for the families because of their time schedule, the cost, children condition and even distance from the university location. Another problem was our access to cerebral palsied children. Children should be selected from those who receive usual treatments and clinic manager's refusal and family agreement was the limitation. One other problem was special and restricted inclusion criteria, most of children available are not able to stand independently but during our study they should stand on force plate independently and this made us so limited to a few sample size.

Conclusion

In this research, parameters related to stability of posture were analyzed. Additionally, control of posture in quiet stance was investigated by means of changes of velocity according to time. The change of mean velocity parameter is a dynamic parameter and is indicative of change in the center of pressure pattern. Change in velocity show that children are now able to control COP displacement faster. They would become able to move more while maintaining their stability. As a consequence they are now able to move in the environment and explore it contrary to those children who suffer from motion deprivation and are isolated in their real life context. Children have shown increase in velocity parameter after vestibular stimulation, as a result of having better balance performance it is possible to have more attempt to gain environmental information and enhancement in exploratory behavior although not necessarily. However, increase in velocity lead to increase reactions and being able to manage purterbances. So it seems reasonable to assume that vestibular stimulation was effective to improve balance function in children with cerebral palsy. We suggest occupational therapist to apply vestibular stimulation in their treatment schedule to amend their therapeutic process.

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