The Scientific Temper
Vol. 13, No. 2, July-December, 2022:pp 309-316
ISSN 0976-8653, E-ISSN 2231-6396
A Web of Science Journal
DOI: https://doi.org/10.58414/SCIENTIFICTEMPER.13.2.2022.309-316
Doc ID: https://connectjournals.com/03960.2022.13.2.309

Enhancing Trunk Control Balance in Children with Spastic Diplegic Cerebral Palsy: Comparative Effectiveness of the Vestibular Stimulation Technique and Standard Treatment

Vinay Viratia, Sandeep Kumar*, Shama Praveen, Tarang Shrivastava and Priyanka
Department of Physiotherapy, School of Paramedical Sciences, SMI Hospital, Shri Guru Ram Rai University, Patel Nagar, Dehradun-248001, Uttarakhand, India.
**Corresponding author: drskumarmalik@gmail.com*

ABSTRACT

In a developing fetus or kid, non-progressive brain injury or a brain anomaly can cause the most common kind of cerebral palsy, called spastic diplegic cerebral palsy. Some of the usual symptoms include muscular weakness, poor muscle coordination, poor balance, loss of postural control, and postural misalignment. The issue is not confined to physical restrictions when a person has poor postural instability that makes walking challenging; instead, the person has increasing psychological challenges and problems. For this study, 30 children with SDCP from the pediatrics physiotherapy OPD and IPD departments at the Shri Guru Ram Rai Institute of Medical Science and Shri Mahant Indresh Hospital in Patel Nagar, Dehradun, were chosen. For testing, children were randomly split into two groups: one group of 15 kids received standard care alone, while the other group of 15 kids received standard care with the Vestibular Stimulation Technique. When the data from both groups are evaluated, there was a significant difference between them, however group A shows more development. The findings of the analysis of the data from the PBS and MAS outcome measures are the same for both outcome measures. From the data collected it was suggested that the patients will probably have benefited more after four weeks of treatment with VST plus conventional therapy than if conventional therapy were administered alone. Although vestibular stimulation paired with conventional therapy demonstrated a more obvious improvement in clinical results for trunk control, both therapies were proven to significantly improve trunk control of balance.

Keywords: Spastic Diplegic Cerebral Palsy, Vestibular Stimulation Technique, PBS (Pediatric Balance Scale), MAS (Modified Ashworth Scale)

INTRODUCTION

A lifelong disorder, cerebral palsy is brought on by non-progressive brain damage or a brain abnormality in a growing fetus or child (Rosenbaum, et al., 2007). The most prevalent form of CP is spastic diplegic CP (SDCP) **(Yeargin-Allsopp, et al., 2008)**. Muscular weakening, poor muscle coordination, poor balance, loss of postural control, and postural misalignment are some of the typical symptoms **(Donker, et al., 2008; Prosser, et al., 2010; de Medeiros, et al., 2015; Reid, et al., 2015)**. People with CP experience challenges with regular tasks, leisure and sports exercise involvement, and life quality including interpersonal relationships because of reduced postural control, which impacts gross motor abilities including walking, sprinting, and leaping **(Rose, et al., 2002; Boulet, et al., 2009; Surana, et al., 2019; Tracy, et al., 2019)**. When a person has defective postural instability that makes walking difficult, the problem is not limited to physical limitations; instead, the psychological difficulties and hardships mount for the individual **(Morgan, et al., 2013; Morgan, et al., 2014; Boyer, et al., 2018)**. Since the vestibular system sends sensory data to the brain through the vestibular nerve to keep postural stability, stimulating this mechanism should help both children and adults having CP who have balancing problems **(Topley, et al., 2021)**.

The motor controls are the result of some innate reflexes that are developed as the brain matures. These motor behaviors can also be inhibited due to brain maturation. Individuals affected by CP show delayed reflex response but if the reflexes are not deterred, voluntary movements can be developed in a delayed fashion **(Perret, et al., 1992)**. To maintain proper posture as well as stability, balancing requires several systems to function in concert. People who have cerebral palsy frequently struggle to maintain stability because of issues with muscle strength, muscle tone, or sensory processing. The development of children's motor skills is fundamentally dependent on balance control, particularly postural stability **(Overstall, 2003)**. Regarding posture regulation to function, there must be a careful balance between directives from the central nervous system, visual, vestibular, and proprioceptive signals, and neuromuscular reflexes, notably muscular strength and response time **(Nashner, et al., 1982)**. A significant barrier to the motor growth of kids with CP is poor postural control. These kids exhibit a variety of instability-related restrictions in their competence to do both stationary and dynamic tasks including sitting, standing, and moving **(Kyvelidou, et al., 2010)**.

Affected individuals have shown gains in postural stability, notably in static and dynamic balance, as well as in seated harmony, after receiving vestibular stimulation through specialized tasks like spinning and swinging **(An, 2015; Tramontano, et al., 2017)**. The vestibulocochlear reflex may mature, permitting a steady retinal picture through head motion, and effects on the lateral vestibulospinal tract may occur, assisting in maintaining an erect, stable position **(Clark, et al., 1977; Hosseini, et al., 2015)**. Electric signal applied through self-adhesive pads on the mastoid processes can activate the vestibular system; this procedure is usually referred to as galvanic nerve stimulation or vestibular nerve stimulation (VeNS) **(Pal, et al., 2009; Iwasaki, et al., 2014; Samoudi, et al., 2015; Fujimoto, et al., 2016; Kataoka, et al., 2016; Inukai, et al., 2018; McKeown, et al., 2020)**. To enhance trunk control balance in children with spastic diplegic CP, this study aims for an approach to study the efficiency of the vestibular stimulation approach compared to that of traditional therapy. The effectiveness of the two methods is measured with the help of collected statistical data obtained from the two groups of patients divided among the two methods of treatment.

MATERIAL AND METHODS

Sample collection

30 children with SDCP were selected for this study. Children were randomly divided into two groups for testing one group of 15 children with standard treatment alone and another group of 15 children with standard treatment along with the Vestibular Stimulation Technique. Subjects for this test were collected from the OPD and IPD department of pediatric physiotherapy, Shri Guru Ram Rai Institute of Medical Science, and Shri Mahant Indresh Hospital, Patel Nagar, Dehradun.

Inclusion Criteria

Children having an SDCP diagnosis ranged in age from 3 to 9 years and belonged to both sexes, boys and girls. The GMFCS (Gross Motor Function Classification System) levels values were 2 to 4.

Exclusion Criteria

Children having symptoms including a fractured spine or lower extremity, a seizure, epilepsy, or a bone abnormality were solely excluded from this study.

Materials used

Material and equipment used for this study include Tilt boards, Scooter boards, Physio balls, Therapeutic mats, Swings, Straps, Toys, etc.

Study Design

Two groups naming, A and B were defined. Group A included the children with SDCP and treated with Vestibular Stimulation Technique along with the conventional method of treatment. Group B included the children with SDCP and treated them with the only conventional method of treatment.

Standard Treatment

The conventional exercise and treatment steps include pelvic bridging, assisted kneeling side-to-side walking, trunk rotation, trunk rotation with trunk flexion and extension, transfer of weight on the bolster, and Walking on a soft surface with a little foundation. Traditional therapy included functional grasping, quadruped, kneeling, bilateral and unilateral take a seat, bridging, and ball-throwing-and-keeping movements in distinct angles.

- bridges with a 10-second hold between each.
- Four-legged - five minutes
- Kneeling for five minutes
- Bilateral Sit to Stand: Perform one set of 10 repetitions.
- Pitching and retaining a ball—one set of 10 repetitions.

- During advancement, the duration of time and frequency was extended.

Vestibular Stimulation Technique

The vestibular Stimulation technique that was used in the treatment of children includes the use of a Scooter Board and T-swing, etc.

Scooter Board

With the help of the therapist, the children sat on the scooter board. Sat next to the kid on the rollator stool, hold their thighs with straps to avoid falls, and gradually advance and receded the board to help the youngster gain more stability.

T-swing

To enhance trunk balance, children sat on the T-swing and holds it with both hands and legs. The therapist kneeled in front of the child and slowly rotate the swing in all directions, including clockwise and counterclockwise.

Result and Discussion

30 patient subjects were selected for this study from the OPD and IPD department of pediatric physiotherapy, Shri Guru Ram Rai Institute of Medical Science, and Shri Mahant Indresh Hospital, Patel Nagar, Dehradun. Children belonged to both genders, boy and girl, aged 3 to 9 years with SDCP diagnosis **(Table 1)**. GMFCS levels ranged from 2 to 4. A similar study was performed in which children with GMFCS 2 to 3 were considered and the study included 40 children **(Shailendra, et al., 2022)**. It shall be noted that a study contained 6 weeks of intervention whereas our study continues for 12 weeks for every patient **(Shailendra, et al., 2022)**. Children are exclusively excluded from the symptoms like fractures in the spine or lower extremity, seizure, epilepsy, or bone deformity. Using the Pediatric Balance Scale (PBS), a balance was evaluated. A and B were two distinct groupings that were named. Children with SDCP who received both conventional therapy and the Vestibular Stimulation Technique were included in Group A. The sole traditional way of therapy was used on the children in Group B who had SDCP. According to the post-12-week treatment results, all groups greatly improved. However, group A outperformed group B by a large margin. To determine the significance of the data between group A and group B, a paired t-test was conducted. In all, 15 kids receive both conventional treatment and vestibular stimulation, while 15 kids just get conventional therapy **(Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, Figure 6)**. A random selection of these patients was made using the inclusion and exclusion criteria. Within group A and group B as well as between group A and group B, the results of the data analysis of the two outcome measures, PBS (Pediatric Balance Scale) and MAS (Modified Ashworth Scale), are the focus of this study. The results were examined and analyzed to assess whether or not VST (Visual Scanning Therapy) and conventional treatment are effective in treating spastic diplegic CP. The results of groups A and B were analyzed and contrasted using a paired t-test. Data analysis was conducted at a significance level of 0.0001. When group A after treatment means and standard error of mean were compared to group A before treatment mean and standard error of the mean (0.667 ± 0.210), the PBS analysis clearly showed a significant difference. When group B after treatment means and standard error of the mean (1.333 ± 0.1260) were compared to group B's mean and standard error of the mean (0.6000 ± 0.1902), analysis of PBS showed a marginally significant difference. Both groups A and group B showed a substantial difference when PBS was analyzed, however group A's result is marginally more significant. There was a significant difference between group A and group B after the analysis of the post-PBS data, with group A showing better improvement after receiving VST and conventional treatment (group A Mean and SEM: 2.133 ± 0.1919, group B Mean and SEM: 1.333 ± 0.1260) (Table 2, Table 3, Figure 7). When comparing group, A after treatment means and standard error of the mean (0.6000 ± 0.1309) to group A before treatment means and standard error of the mean (2.600 ± 0.1309), analysis of MAS showed a significant difference. When comparing group B after treatment means and standard error of the mean (1.867 ± 0.1652) to group B before treatment means and standard error of the mean (2.467 ± 0.1333), analysis of MAS showed a significant change. When group A's and group B's MAS were analyzed, there were substantial differences between the two groups, with group A showing somewhat more significance in the outcome **(Table 2, Table 3, Figure 8)**. There was a substantial improvement in group A, i.e., group A exhibited higher improvement when treated with VST & conventional therapy, according to an analysis of post data of MAS of both group A & B, group A Mean & SEM (0.6000 ± 0.1309), and group B Mean & SEM (1.867 ± 0.1652) **(Table 4, Figure 9)**.

Table 1: List of children treated with conventional and vestibular stimulation techniques.

S.No.	Patient Identity	Conventional Treatment	Vestibular Stimulation Technique
1	Patient 1	+	+
2	Patient 2	+	−
3	Patient 3	+	−
4	Patient 4	+	−
5	Patient 5	+	+

6	Patient 6	+	−
7	Patient 7	+	+
8	Patient 8	+	+
9	Patient 9	+	+
10	Patient 10	+	−
11	Patient 11	+	−
12	Patient 12	+	+
13	Patient 13	+	−
14	Patient 14	+	−
15	Patient 15	+	+
16	Patient 16	+	−
17	Patient 17	+	−
18	Patient 18	+	+
19	Patient 19	+	+
20	Patient 20	+	+
21	Patient 21	+	+
22	Patient 22	+	−
23	Patient 23	+	+
24	Patient 24	+	−
25	Patient 25	+	+
26	Patient 26	+	−
27	Patient 27	+	+
28	Patient 28	+	−
29	Patient 29	+	−
30	Patient 30	+	+

+ = Patient was treated with respective method of treatment; −= Patient was not treated with respective method of treatment

Table 2: Comparison of the outcome measure between groups within group A

S.No.	Outcome Measure	Pre (Mean ± Sem)	Post (Mean ± Sem)	P value
1	PBS	0.667 ± 0.210	2.133 ± 0.1919	P < 0.0001
2	MAS	2.600 ± 0.1309	0.6000 ± 0.1309	P < 0.001

Table 3: Comparison of the outcome measure between groups within group B

S.NO.	Outcome Measure	Pre (Mean ± Sem)	Post (Mean ± Sem)	P value
1	PBS	0.6000 ± 0.1902	1.333 ± 0.1260	P < 0.0012
2	MAS	2.467 ± 0.1333	1.867 ± 0.1652	P < 0.0025

Table 4: Post-data outcome measure comparison between groups A and B within each group

S.No.	Outcome Measure	Group A Post Data (Mean ± Sem)	Group B Post Data (Mean ± Sem)	P value
1	PBS	2.133 ± 0.1919	1.333 ± 0.1260	P < 0.0016
2	MAS	0.6000 ± 0.1309	1.867 ± 0.1652	P < 0.0001

Group A = Patients treated with conventional therapy along with Vestibular Stimulation Technique.

Group B = Patients treated with conventional therapy alone.

Although there is a substantial difference between the two groups when the data from both groups are analyzed, group A exhibits more progress. When the data from the PBS and MAS outcome measures are analyzed, the results are identical for both outcome measures. In light of these findings, it is likely that after four weeks of treatment with VST and conventional therapy, the patient will have improved more than if conventional therapy were used alone. Both therapies were shown to considerably enhance trunk control of balance, although vestibular stimulation combined with traditional therapy showed a more pronounced improvement in clinical outcomes for trunk control.

Figure 1: Facilitation of Trunk Balance.

Figure 2: Side-to-side weight shift on bolster exercise for improving trunk control balance.

Figure 3: Clock-wise rotation exercise for improving trunk control balance.

Figure 4: Anti-Clockwise rotation exercise for improving trunk control balance.

Figure 5: Kneeling position exercise for improving trunk control balance.

Figure 6: Pelvic Bridging exercise for improving trunk control balance.

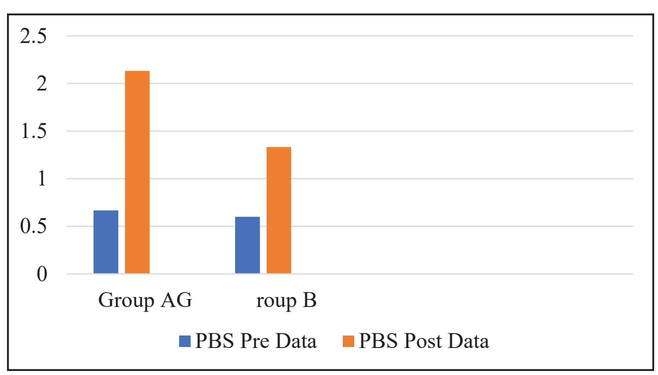

Figure 7: Group A and Group B pre- and Post-PBS comparison

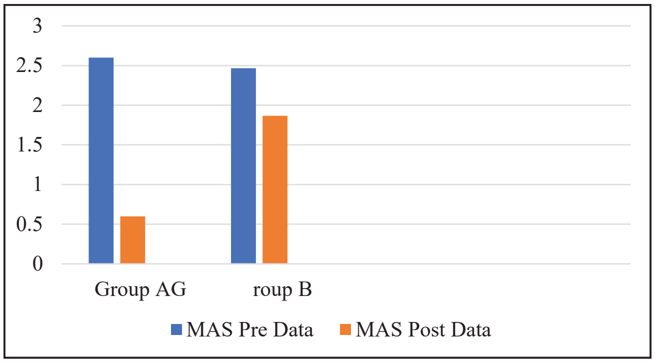

Figure 8: Group A and Group B pre- and post-MAS comparison.

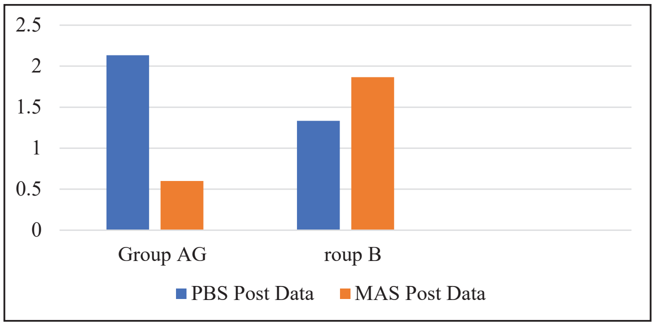

Figure 9: Group A and Group B post-PBS and MAS comparison.

For children to be more motivated and eager to engage in the treatment, treatment activities should be engaging, interesting, and rewarding. If treatment is too difficult, it's fulfilling because it inspires kids. When engaging in the exercises within the trampoline frame, the kids had fun **(Dunn, 2000; Nielsen, et al., 2015)**. Individuals suffering from spastic diplegic cerebral palsy who performed balance exercises while employing trunk-supported floor leaping (suspension treatment) had greater improvements in their balance and gross motor function **(El-Bamma, et al., 2016)**. Another study stated attempted to discover how vestibular stimulation affected balance in cerebral palsy quadriplegic patients. 44 quadriplegic patients were taken for the study and 6 weeks intervention period was allowed **(Bashir, et al., 2022)**. There is a new method of approaches that may not be fully conventional and therapeutic related but the involvement of certain activities that are not originally considered as exercises by all has shown profound positive results to the children. An adolescent with cerebral palsy was given highly engaging virtual reality game-based therapy, and its benefits on gross motor function, balance, including gait were examined. As a consequence, it was shown that fully interactive virtual reality game-based training can improve gait, balance, and gross motor function in teenagers with cerebral palsy **(Lee, et al., 2022)**. Such activities are truly engaging, and interesting and open up a wide regime yet to be explored within children. This study includes only one adolescent child and if a such strategy of approach to treating patients can be applied belonging to younger minds and children, it is possible to receive a unique set of data and understanding that can be much more beneficial to such patients in the future. This study also lacks the involvement of varied games that are available and such a study to explore more to this area more can be designed for future studies. The study was done over a brief period and revealed a moderate effect. Due to the COVID-19 epidemic, proper follow-up with the children was not done. The sample size for the current investigation was minimal. The genders of youngsters are not separated. Because the trial lasted just 12 weeks, no long-term effects could be seen.

Declaration: *We also declare that all ethical guidelines have been followed during this work and there is no conflict of interest among authors.*

CONCLUSION

Spastic Diplegic Cerebral Palsy is a serious threat to children and the need for better treatment options is essential for improving the quality of life of affected children. However, there are certain limitations with the existing and known methods of treatment, it is sufficient to say that the treatment options discussed in this study depict that the combination therapy of the conventional method with the use of the Vestibular Stimulation Technique provides promising results than using the single technique alone. The results that can be seen with the supported data suggest the use of the Vestibular Stimulation Technique along with the standard method of treatment that is conventionally known is far more beneficial to us in improving the trunk control balance.

REFERENCES

An, S.J.L. (2015). The effects of vestibular stimulation on a child with hypotonic cerebral palsy. *J. Phys. Ther. Sci*. **27(4)**: 1279-1282.

Bashir, A., Arshad, H., Shabbir, A., Abid, F., Khalid, M.U. and Khan, R.R. (2022). Effects of Vestibular Stimulation on Balance in Children with Quadriplegic Cerebral Palsy. *Pak. J. Med. Health Sci*. **16(06)**: 800-800.

Boulet, S.L., Boyle, C.A. and Schieve, L.A. (2009). Health care use and health and functional impact of developmental disabilities among US children, 1997-2005. *Arch. PediatrAdolesc. Med*. **163(1)**: 19-26.

Boyer, E.R. and Patterson, A. (2018). Gait pathology subtypes are not associated with self-reported fall frequency in children with cerebral palsy. *Gait Posture*.**63**: 189-194.

Clark, D.L., Kreutzberg, J.R. and Chee, F.K. (1977). Vestibular stimulation influence on motor development in infants. *Science*. **196(4295)**: 1228-1229.

de Medeiros, D.L., Conceição, J.S., Graciosa, M.D., Koch, D.B., Dos Santos, M.J. and Ries, L.G.K. (2015). The influence of seat heights and foot placement positions on postural control in children with cerebral palsy during a sit-to-stand task. *Res. Dev. Disabil*. **43**: 1-10.

Donker, S.F., Ledebt, A., Roerdink, M., Savelsbergh, G.J. and Beek, P.J. (2008). Children with cerebral palsy exhibit greater and more regular postural sway than typically developing children. *Exp. Brain Res*. **184(3)**: 363-370.

Dunn, J.C. (2000). Goal orientations, perceptions of the motivational climate, and perceived competence of children with movement difficulties. *Adapt. Phys. Activ. Q*. **17(1):** 1-19.

Fujimoto, C., Yamamoto, Y., Kamogashira, T., Kinoshita, M., Egami, N., Uemura, Y., Togo, F., Yamasoba, T. and Iwasaki, S. (2016). Noisy galvanic vestibular stimulation induces a sustained improvement in body balance in elderly adults. *Sci. Rep*. **6(1)**: 1-8.

Hosseini, S.A., ZeynalzadehGhoochani, B., Talebian, S., Pishyare, E., Haghgoo, H.A., Mahmoodi Meymand, R. and Zeinalzadeh, A. (2015). Investigating the effects of vestibular stimulation on balance performance in children with cerebral palsy: a randomized clinical trial study. *J. Rehabil. Sci. Res*. **2(2)**: 41-46.

Inukai, Y., Otsuru, N., Masaki, M., Saito, K., Miyaguchi, S., Kojima, S. and Onishi, H. (2018). Effect of noisy galvanic vestibular stimulation on center of pressure sway of static standing posture. *Brain Stimul*. **11(1)**: 85-93.

Iwasaki, S., Yamamoto, Y., Togo, F., Kinoshita, M., Yoshifuji, Y., Fujimoto, C. and Yamasoba, T. (2014). Noisy vestibular stimulation improves body balance in bilateral vestibulopathy. *Neurology*. **82(11)**: 969-975.

KKataoka, H., Okada, Y., Kiriyama, T., Kita, Y., Nakamura, J., Morioka, S., Shomoto, K. and Ueno, S. (2016). Can postural instability respond to galvanic vestibular stimulation in patients with Parkinson's disease? *J Mov Disord*. **9(1)**: 40.

Kyvelidou, A., Harbourne, R.T., Shostrom, V. K. and Stergiou, N. (2010). Reliability of center of pressure measures for assessing the development of sitting postural control in infants with or at risk of cerebral palsy. *Arch. Phys. Med Rehabil*. **91(10)**: 1593-1601.

Lee, K., Oh, H. and Lee, G. (2022). Fully Immersive Virtual Reality Game-Based Training for an Adolescent with Spastic Diplegic Cerebral Palsy: A Case Report. *Children*. **9(10)**: 1512.

McKeown, J., McGeoch, P.D. and Grieve, D.J. (2020). The influence of vestibular stimulation on metabolism and body composition. *Diabet. Med*. **37(1)**: 20-28.

Morgan, P. and McGinley, J. (2013). Performance of adults with cerebral palsy related to falls, balance and function: a preliminary report. *Dev. Neurorehabilit*. **16(2)**: 113-120.

Morgan, P. and McGinley, J. (2014). Gait function and decline in adults with cerebral palsy: a systematic review. *Disabil. Rehabil*. **36(1)**: 1-9.

Nashner, L.M., Black, F.O. and Wall, C.I.I.I. (1982). Adaptation to altered support and visual conditions during stance: patients with vestibular deficits. *J. Neurosci*. **2(5)**: 536-544.

Nielsen, J.B., Willerslev-Olsen, M., Christiansen, L., Lundbye-Jensen, J. and Lorentzen, J. (2015). Science-based neurorehabilitation: recommendations for neurorehabilitation from basic science. *J. Mot. Behav*. **47(1)**: 7-17.

Overstall, P.W. (2003). The use of balance training in elderly people with falls. *Rev. Clin. Gerontol*. **13(2)**: 153-161.

Pal, S., Rosengren, S.M. and Colebatch, J.G. (2009). Stochastic galvanic vestibular stimulation produces a small reduction in sway in Parkinson's disease. *J. Vestib. Res*. **19(3-4)**: 137-142.

Perret, Y.M. and Batshaw, M.L. (1992). Children with Disabilities: A Medical Primer.

Prosser, L.A., Lee, S.C., VanSant, A.F., Barbe, M.F. and Lauer, R.T. (2010). Trunk and hip muscle activation patterns are different during walking in young children with and without cerebral palsy. *Phys. Ther*. **90(7)**: 986-997.

Reid, S.L., Pitcher, C.A., Williams, S.A., Licari, M.K., Valentine, J.P., Shipman, P.J. and Elliott, C.M. (2015). Does muscle size matter? The relationship between muscle size and strength in children with cerebral palsy. *Disabil. Rehabil*. **37(7)**: 579-584.

Rose, J., Wolff, D.R., Jones, V.K., Bloch, D.A., Oehlert, J.W. and Gamble, J.G. (2002). Postural balance in children with cerebral palsy. *Dev. Med. Child Neurol*. **44(1)**: 58-63.

Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., Bax, M., Damiano, D., Dan, B. and Jacobsson, B. (2007). A report: the definition and classification of cerebral palsy April 2006. *Dev. Med. Child Neurol. Suppl*. **109(suppl 109)**: 8-14.

Samoudi, G., Jivegård, M., Mulavara, A.P. and Bergquist, F. (2015). Effects of stochastic vestibular galvanic stimulation and LDOPA on balance and motor symptoms in patients with Parkinson's disease. *Brain Stimul*. **8(3)**: 474-480.

Shailendra Kurmi, M.P.T., Mohanty, P., Pattnaik, M.M. and Kurmi, S. (2022) Effect of Balance Training Using Bungee Cords And Trampoline For Functional Balance In Spastic Diplegic Cerebral Palsy Children. Swami Vivekanand National Institute of Rehabilitation *Train. Res*. 6.

Surana, B.K., Ferre, C.L., Dew, A.P., Brandao, M., Gordon, A.M. and Moreau, N.G. (2019). Effectiveness of lower-extremity functional training (LIFT) in young children with unilateral spastic cerebral palsy: A randomized controlled trial. *Neurorehabilit. Neural Repair*. **33(10)**: 862-872.

Topley, D., McConnell, K. and Kerr, C. (2021). A systematic review of vestibular stimulation in cerebral palsy. *Disabil. Rehabil*. **43(23)**: 3291-3297.

Tracy, J.B., Petersen, D.A., Pigman, J., Conner, B.C., Wright, H.G., Modlesky, C. M. and Crenshaw, J. R. (2019). Dynamic stability during walking in children with and without cerebral palsy. *Gait posture*. **72**: 182-187.

Tramontano, M., Medici, A., Iosa, M., Chiariotti, A., Fusillo, G., Manzari, L. and Morelli, D. (2017). The effect of vestibular stimulation on motor functions of children with cerebral palsy. *Mot. Control*. **21(3)**: 299-311.

Yeargin-Allsopp, M., Van Naarden Braun, K., Doernberg, N.S., Benedict, R. E., Kirby, R. S. and Durkin, M.S. (2008). Prevalence of cerebral palsy in 8-year-old children in three areas of the United States in 2002: a multisite collaboration. *Pediatrics*. **121(3)**: 547-554.