

Comparing Trunk Stabilization Exercises with and without BOSU Ball for Balance and Gross Motor Functions in Children with Spastic Diplegia: Randomized Control Trial

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ABSTRACT

Background and Purpose: Spastic diplegic cerebral palsy (SDCP) mainly affects the lower limbs and is associated with trunk weakness, reduced balance and difficulties in carrying out activities of daily living. Trunk stabilization exercises enhance muscle strength and postural control. Performing these exercises on unstable surfaces like BOSU ball may develop neuromuscular demands and trunk control. This study aimed to compare the effects of trunk stabilization exercises with and without a BOSU ball on balance and gross motor functions in children with SDCP.

Methods: 20 subjects with SDCP were recruited based on the inclusion and the exclusion criteria and were randomly assigned into two groups. Group A (n=10) received trunk stabilization exercises on BOSU ball, while Group B (n=10) received the same exercises on a mat. Both groups underwent intervention 4 times a week for 4 weeks. Pre and post intervention assessments were done using Pediatric Balance Scale (PBS), Gross Motor Functions Measure-88 (GMFM-88), and Wee FIM as outcome measures.

Results: Group A showed a statistically significant improvement in PBS scores ($p < 0.004^*$) and in GMFM-88 domains C, E, and total scores ($p < 0.030^*$) compared to Group B. No significant difference was observed in GMFM domain D ($p > 0.09$) or in WeeFIM scores between the groups.

Conclusion: Trunk stabilization exercises on a BOSU ball were better in improving balance and specific gross motor functions, like sitting and walking, when compared with exercises done without it. However, both methods were equally effective for standing and performing daily functional tasks.

Keywords: Spastic Diplegic Cerebral Palsy, Trunk Stabilization Exercises, BOSU ball, Gross motor functions, Balance, Activity of Daily Living.

INTRODUCTION

Cerebral palsy is a non- progressive developmental disorder caused by the injury to the developing brain resulting in

abnormality in muscle tone, movement and motor functions.^[1] It can lead to hyper reflexes, flaccidity or spasticity of the limbs and trunk, abnormal posture and lack of

postural control, involuntary movements, lack of selective movements, and impaired agonist-antagonist coordination. Abnormal tone and movement result in poor postural control and limitations in daily functions such as sitting, reaching out and walking. [2,3,4] The prevalence of CP for all live births is approximately 3 per 1000 livebirths. [5] Spastic diplegia is amongst the most widely recognized clinical subtypes of Cerebral Palsy (CP). It accounts for about 44% of the total incidence of Cerebral Palsy. In SDCP, the motor impairment in the upper limbs is milder than the lower limbs. Most children exhibit trunk weakness and hypertonicity in the extremities [6] The Children with CP who struggle controlling their trunk often face difficulty in carrying out their ADLs causing hindrance in balance and mobility. [2]

Postural abnormality, loss of selective motor control, impaired trunk control, and poor balance, all are observed in children with cerebral palsy, all of which contribute to poor postural control and limitations in their daily activities. [7]

Trunk stabilization exercises aim to train the spine to maintain its position, promoting the development of muscular strength, flexibility and coordination. [8] A study showed that children with SDCP improved their balance and walking abilities after receiving core strengthening exercises. [9]

Unstable surfaces like BOSU ball, balance pad, foam pad poses a higher neuromuscular demand on patients when exercises and balancing is being done on them. Trunk exercises on unstable surfaces could further improve trunk control, upper extremity control in sitting and walking. [10]

Both Sides Up Ball is an unstable hemispherical device for balance core strengthening and proprioceptive training. It has an inflated surface and a flat solid surface, resembling a halved physio ball. [11] In previous study on stroke showed that trunk exercises performed on unstable surfaces improve core muscle and limb control. [10]

This study aims to compare and find the effect of trunk stabilization exercise done

with and without BOSU ball on the balance and gross motor functions of children with SDCP.

MATERIALS AND METHODS

Study design: This study was a randomized controlled trial (RCT).

Study location: Rehabilitation centers in Delhi

Sample size: 20 (10 in each group). Sample size was calculated based on a previous study using an estimated effect size of 0.80, yielding a total of 20 participants (10 per group) at a 0.05 significance level.

Outcome measures: Pediatric Balance Scale was used for measuring balance, components of GMFM-88 (Gross Motor Function Measure-88) GMFM C, GMFM D, GMFM E and GMFM Total were used for measuring gross motor functions, and Wee FIM was used for measuring ADLs. The PBS was found to be a valid tool for assessing balance in children with CP. [12] The ICC scoring of PBS for inter and intra-rater and test-retest reliability of the total score were found to be 0.901, 0.9086 and 0.978 respectively. [13]. GMFM-88 was found to be a valid tool with reliability of ICC scoring above 0.99. [14] Wee FIM was also found to be a valid tool and reliability with Cronbach's alpha value of 0.93. [15]

Inclusion Criteria: Children with GMFCS level 1 and 2, age between 5 to 12, with Modified Ashworth scale for lower limbs muscle less than or equals to 3, modified MMSE score with more than or equals to 24 and sitting balance for at-least 10 seconds were included in the study. [16,17,18,19]

Exclusion Criteria: Children having any neurological, orthopedic, cardiopulmonary, vestibular deficit or having any infectious disease, children having any orthopedic intervention or botulinum toxin injection since last year were excluded from the study [16,20,21,22].

PROCEDURE

A randomised sample of 20 children with SDCP were enrolled in the study, with 10 in each group. Sample size was calculated using the median of Gross motor functions measure. After the clearance from institutional ethical committee with the reference number of ISIC/ RP/2023/049 and CTRI with registration number CTRI/ 2023/12/060888 a sample of 20 participants who met the inclusion and exclusion criteria were recruited from Indian spinal injuries center, Akshya Prathishtan and other rehabilitation centers. The procedure was explained to parents/legal guardian of all children and written informed from all parents/legal guardian was obtained. Demographics details were obtained from all subjects detailed neurological assessment was done. GMFCS level, spasticity with MAS, sitting time and MMSE score of the child were assessed. Pre intervention tests were recorded at baseline and post interventional tests were recorded with outcome measures after the completion of 4 weeks. Group A was given Trunk stabilization exercises using a BOSU ball along with conventional therapy. Group B was given Trunk stabilization exercises on mat along with conventional therapy. The intervention was carried out for 4 weeks and 4 sessions a week. Each exercise in both the groups was performed in 3 sets with 10 repetitions each.

Procedure for Group A- Trunk stabilization with BOSU ball (Fig -1)

1. The subject performed Abdominal Drawing in Manoeuvre by lying supine with knee flexed and back on the solid surface of the BOSU ball, pulling in abdominals toward the back and holding it for 10 seconds. (Fig.1.a)
2. The subject performed pelvic bridging by keeping knees flexed and the feet placed on the dome of the BOSU ball and then lifted the pelvis off the floor while holding the position for 10 seconds. (Fig.1.b)

3. The subject performed Quadruped by keeping 4-point weight on hands and knees on the dome while holding the position for 10 seconds. (Fig.1.c)
4. The subject performed Bird -dog exercise by keeping the hands on the floor and the knee on the dome and lifting opposite arm and leg alternatively holding each position for 10 seconds. (Fig.1.d)
5. The subject was asked to get in semi-plank and keeping the elbows extended and shoulder, trunk hips and knees aligned and hands on the solid bottom part of the BOSU ball and hold it for 10 seconds. (Fig.1.e)
6. The subject's trunk was flexed to one side in semi-plank position on the solid bottom part and the position was held for 5 to 10 seconds. (Fig.1.f)

Procedure for Group B- Trunk Stabilization without BOSU ball (Fig- 2)

1. The subject performed abdominal drawing in Manoeuvre by lying in supine with knee flexion, pulling in abdominals toward the back while holding the position for 10 seconds. (Fig 2.a)
2. The subject performed Pelvic Bridging by lifting his pelvis performing the bridging exercise on mat and maintained that position for 10 seconds. (Fig 2.b)
3. The subject performed Quadruped by 4-point weight on hands and knees on mat while holding that position for 10 seconds. (Fig 2.c)
4. The subject performed bird-dog exercise by getting in quadruped and lifting his alternate arms and legs at the shoulder level holding this position for 10 seconds. (Fig 2.d)
5. The subject was made to get in semi plank position by keeping the elbows extended and shoulder, trunk hips and knees aligned and hands on the solid and knees on mat and elbows extended for 10 seconds. (Fig 2.e)
6. The trunk of the subject was flexed to one side in semi- plank position. (Fig 2.f)



Fig 1.a – ADIM on BOSU Ball



Fig 1.b Bridging on BOSU ball



Fig 1.c- Quadruped On BOSU ball



Fig 1.d- Bird-Dog On BOSU ball



Fig 1.e- Semi Planks On BOSU Ball



Fig 1.f- Semi Planks with trunk Flexed to one side On BOSU ball

Figure 1: Trunk Stabilization Exercise on BOSU Ball



Fig 2.a- ADIM on Mat



Fig 2.b- Bridging on Mat



Fig 2.c- Quadruped On Mat



Fig 2.d- Bird-Dog exercise on Mat



Fig 2.e- Semi Planks on Mat



Fig 2.f- Semi Planks with spine flexed to one side On Mat

Figure 2: Trunk Stabilization Exercise on Mat without BOSU ball

STATISTICAL ANALYSIS

Data was analyzed using SPSS version 27.0 for Windows (SPSS Inc., Chicago Illinois). Demographic data of the subjects including age, gender, GMFCS level, modified mini mental status examination. After checking the normality of the data with Shapiro Wilk test, mean change scores were calculated as the difference between post and pre-test, and an independent t-test was used to test the difference in the changed scores between the two groups. Paired t-test was used to analyze within-group differences. The level of significance was set at 0.05.

RESULT

Data were analyzed using SPSS version 27.0 for Windows (SPSS Inc., Chicago, IL, USA). After confirming data normality, mean change scores (post-test minus pre-test) were computed. Independent t-tests were used to compare change scores between groups, while paired t-tests assessed within-group differences. Statistical significance was set at $p < 0.05$.

There was no significant difference in the age, GMFCS level and MMSE scores between the two groups as shown in Table 1.

Demographic	Group A (N=10)		Group B (N=10)		T-value	P-value
	Mean	SD	Mean	SD		
Age (in years)	8.90	2.73	8.40	2.07	1.681	0.109
Gender	M=8 F= 2		M=7 F=3			
GMFCS Participants	Level 1 = 8 Level 2 = 2		Level 1= 5 Level 2=5			
GMFCS mean	1.26	0.42	1.50	0.53	1.405	0.176
Modified MMSE	34.50	3.92	31.30	4.74	1.644	0.117

Table 1-Demographics of group A and B

- a) Group A: Trunk Stabilisation Exercises with BOSU Ball
- b) Group B- Trunk Stabilisation Exercises without BOSU Ball
- c) Modified MMSE- Modified Mini Mental Status Examination
- d) GMFCS- Gross Motor Function Classification System
- e) M- Male
- f) F- Female
- g) SD- Standard Deviation

The pre intervention scores for GMFM, PBS and Wee FIM showed no significant difference between the two groups as shown in Table 2.

Variables	Group A mean	Group A SD	Group B Mean	Group B SD	T value	P value
PBS	49.20	2.03	48.20	2.04	1.080	0.295 ^{NS}
GMFMC	91.70	3.56	89.31	3.03	1.616	0.124 ^{NS}
GMFMD	81.83	7.75	78.56	6.48	1.023	0.320 ^{NS}
GMFME	80.67	7.58	72.20	12.95	1.784	0.091 ^{NS}
GMFM total	90.64	3.11	87.92	3.93	1.716	0.103 ^{NS}
Wee FIM	107.9	15.02	99.60	10.96	1.411	0.175 ^{NS}

Table 2 -Group A and Group B pre intervention scores

- a) NS= non-significant
- b) Group A: Trunk Stabilisation Exercises with BOSU Ball
- c) Group B- Trunk Stabilisation Exercises Without BOSU Ball
- d) PBS- Pediatric Balance Scale
- e) GMFM C, D, E and Total- Sub scales of Gross Motor Functions Measure-88
- f) Wee FIM- Functional Independence Measure for Children

The comparison of Pre-intervention and post-intervention scores of PBS between group A

showed a statistically significant difference in Table 3. The comparison of Pre-

intervention and post-intervention. scores of GMFM -88 (domains C, D, E and Total) between group A showed a statistically significant difference Table 3. The

comparison of Pre-intervention and post-intervention scores of Wee FIM between group A showed a statistically significant difference as shown in Table 3.

Variables	Pre-Mean	S. D	post	S. D	T value	P
PBS	49.20	2.03	51.40	2.06	6.73	0.004*
GMFM C	91.70	3.56	95.38	2.33	5.03	0.017*
GMFM D	81.83	7.75	85.99	7.59	3.39	0.008*
GMFM E	80.67	7.58	83.76	7.45	3.70	0.005*
GMFM Total	90.64	3.11	92.70	2.73	5.400	0.032*
Wee-FIM	107.90	15.02	109.1	14.98	3.087	0.013*

Table 3- Difference of pre and post intervention scores in Group A

- a) *p<0.05, considered statistically significant
- b) NS= non-significant
- c) Group A: Trunk Stabilisation Exercises with BOSU Ball
- d) Group B- Trunk Stabilisation Exercises Without BOSU Ball
- e) PBS- Pediatric Balance Scale
- f) GMFM-88
- g) Wee FIM- Functional Independence for children

The comparison of Pre-intervention and post-intervention scores of outcome measures in group B showed a statistically significant difference in Table 4.

Variables	Pre-Mean	S. D	Post Mean	S. D	T value	P value
PBS	48.20	2.04	49.30	2.05	4.714	0.003*
GMFM C	89.31	3.03	92.04	3.83	4.01	0.008*
GMFM D	78.56	6.48	80.41	6.59	2.592	0.029*
GMFM E	72.20	12.95	72.76	12.33	1.408	0.193 ^{NS}
GMFM total	87.92	3.93	88.88	3.97	3.128	0.012*
Wee-FIM	99.60	10.96	100.00	10.43	1.500	0.168 ^{NS}

Table 4- Pre and Post comparison in outcome measures of Group B

- a) *p<0.05, considered statistically significant
- b) NS= non-significant
- c) Group A: Trunk Stabilisation Exercises with BOSU Ball
- d) Group B- Trunk Stabilisation Exercises Without BOSU Ball
- e) PBS- Pediatric Balance Scale
- f) GMFM-88
- g) Wee FIM- Functional Independence for children

The comparison of Pre-intervention and post-intervention scores of GMFM C and D and total between group B showed a statistically significant difference but no significant difference was found for Domain E of GMFM. The comparison of Pre-intervention and post-intervention scores of Wee FIM between group B showed a statistically non-significant difference as shown

The comparison of post-intervention score minus pre-intervention score of PBS, GMFM C, E and total between Group A and Group B showed a significant difference, but the comparison of difference of pre-intervention score and post-intervention score of Wee FIM and GMFM D between Group A and Group B showed a non-significant difference as shown in Table 5.

Variable	Group A pre	Group A post	Group B pre	Group B post	Mean difference Group A	Mean difference Group B	T value	P value
PBS	49.2	51.4	48.2	49.3	2.2	1.1	2.278	0.035*
GMFM C	91.7	95.38	89.31	92.04	3.68	2.73	2.351	0.030*
GMFM D	81.83	85.99	78.56	80.41	4.16	1.85	1.756	0.096 ^{NS}
GMFM E	80.67	83.76	72.2	72.76	3.09	0.56	2.415	0.027*
GMFM Total	90.64	92.7	87.92	88.88	2.06	0.96	2.503	0.022*
Wee FIM	107.9	109.1	99.6	100	1.2	0.4	1.576	0.132 ^{NS}

Table 5 Comparison of Mean Difference Scores of Pediatricbalance scale, Gross motor function measure Wee FIM between Group A and Group B

- a) *p < 0.05, considered statistically significant
- b) NS= non-significant
- c) Group A: Trunk Stabilisation Exercises with BOSU Ball
- d) Group B- Trunk Stabilisation Exercises Without BOSU Ball
- e) PBS- Pediatric Balance Scale
- f) GMFM-88(C, D, E and Total)- Gross Motor Functions Measure
- g) Wee FIM- Functional Independence Measure for Children

The graph representing comparison of pre and post intervention for PBS, GMFM-88 and Wee FIM are given in Fig-3. Fig-4 and Fig-5 respectively.

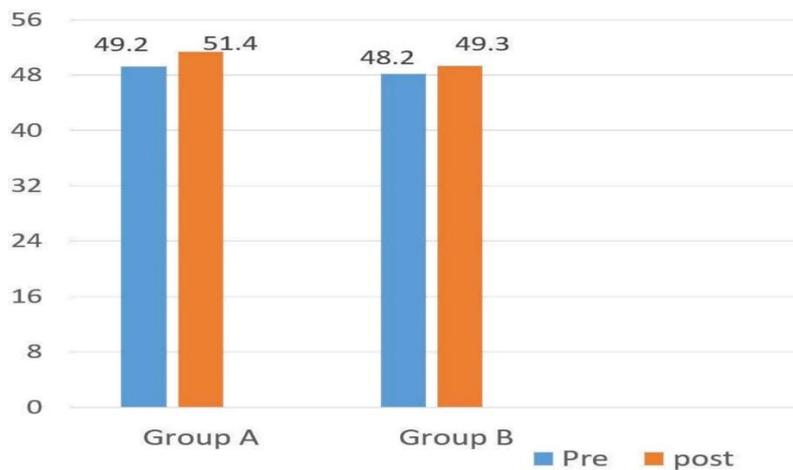


Figure 3- Pre and Post intervention measures of Group A and Group B for Pediatric Balance Scale

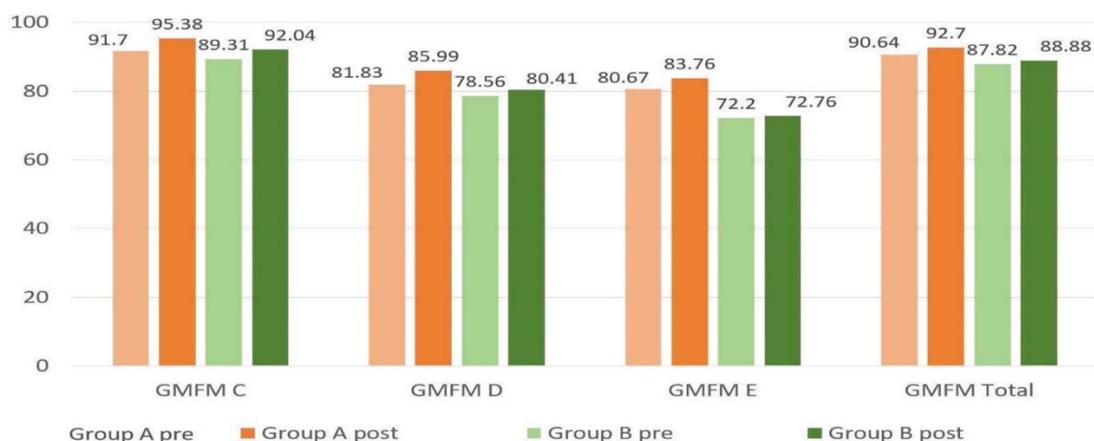


Figure 4- Pre and Post intervention measures of group A and Group B for GMFM-88(C, D, E, Total)

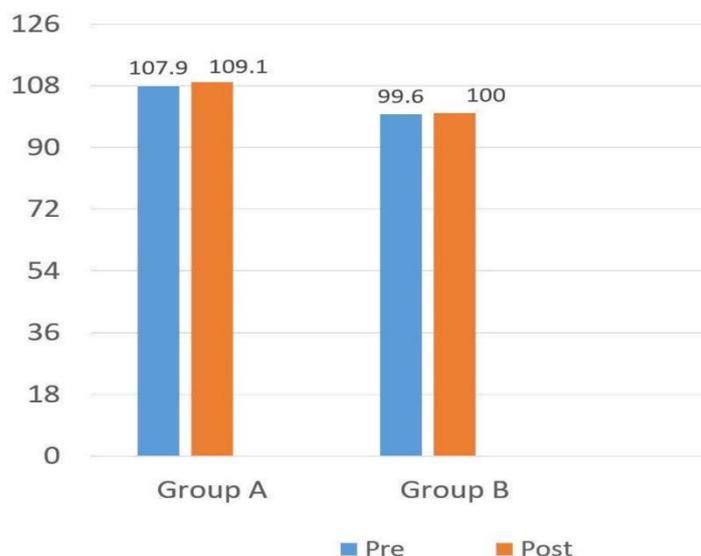


Figure 5- Pre and Post intervention measures of group A and Group B for Wee FIM

DISCUSSION

The findings of our study suggest that while both the types of intervention were beneficial, the addition of BOSU ball in group A led to more substantial improvement in the motor functions particularly in GMFM E and GMFM total which indicates that the dynamic surface offers additional challenges and benefits that enhances motor functions and brings improvement more than the static surface exercises.

This study found out that Group A subjects, who performed trunk stabilization exercises on BOSU ball showed significant improvements in balance and gross motor functions. This corresponds to Elanchezian and Swapnakumari's (2019) [23] findings on Swiss ball exercises for children with CP, linking improvements to the instability of the surface, which needs greater muscle activation. Similar benefits were noted in the studies by Song EJ et al. (2021) [24], Reddy S and Balaji (2020) [25], and Sanad D.A (2022) [9], emphasizing enhanced trunk stability and balance. But Sim YJ et al. (2015) [16] observed non-significant improvements, which may be attributed to the study's small sample size. In general, dynamic surface exercises contributes to improved balance, motor functions and trunk stability.

In Group B, significant improvement was observed in the scores of PBS for balance, but not in the Wee FIM scores. This aligns with the study conducted by Elhamrawy et al. (2024) [26], which also reported significant improvement in the scores of balances due to core stabilization exercises, which might have caused the improvement in the activation of lower trunk muscles. However, the non-significant improvement in Wee FIM could have been due to the intervention's focus on balance and gross motor functions rather than focusing on ADLs. Similar results were found in the study done by Rana FM et al. (2022) [27], which observed significant improvements in balance due to improved truncal stability and neuromuscular coordination. Also, improvements in the scores of GMFM C, D, and GMFM total were noted, similar to the findings by Park et al. (2023) [28], who associated these with better trunk control and stability, though no significant changes were observed in GMFM E, possibly due to the fact that walking and running requires enhanced dynamic balance.

No significant differences were observed in the scores of GMFM D and Wee FIM between Group A and Group B, but the significant improvements were seen in the scores of balance (PBS), motor functions for sitting (GMFM C), walking, running and

jumping(GMFM E) as well as in overall Gross motor functions(GMFM total) in Group A when compared to group B which indicate that the exercises using BOSU ball are more effective in enhancing balance and gross motor functions when compared to the exercising not using BOSU ball. These findings also align with researches done by Lee et al. (2021) [29] and Samal SN et al. (2021) [30], highlighting the benefits of using unstable surface training platform in improving balance and motor functions. Despite these improvements, significant differences were not seen in ADLs (Wee FIM) scores due to common conventional treatment provided to both groups.

Exercising on an unstable surface like BOSU ball makes the muscles to work harder for maintain balance and enhancing truncal stability, coordination, and strength. This training improves balance and dynamic skills like walking by enabling continuous adjustment and control in unstable environments.

CONCLUSION

Trunk stabilization exercises involving a BOSU ball can be significant in enhancement of balance and gross motor functions such as sitting, walking, as well as overall gross motor skills in children with SDCP when compared to the trunk stabilization exercises performed without a BOSU ball. However, both types of exercise approaches showed similar improvements in standing function and ADLs, suggesting that while using a BOSU ball for exercises provide extra advantage for specific motor skills, both exercise approaches contribute equally to functional independence in daily activities. The limitations of this study were that the pressure of the BOSU ball was not measured but the same BOSU ball was used throughout the study, and the sample was limited to children with GMFCS levels I and II, which may have impacted the generalizability of the findings, and the long-term effects of the intervention were not assessed.

Future researches could consider how varying pressure or inflation levels of the

BOSU ball can influence the results. Longitudinal studies are also recommended to assess the sustainability of improvements in balance, gross motor functions, and ADLs. Furthermore, future investigations could include children across all GMFCS levels to evaluate the effectiveness of BOSU ball exercises across varying severities and levels of spastic diplegic cerebral palsy.

Declaration by Authors

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