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EFFECTS OF CORE STABILITY EXERCISES ON STATIC AND DYNAMIC BALANCE IN CHILDREN WITH DEVELOPMENTAL DELAY

Original Research

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ABSTRACT

Background: Developmental delay affects a child's ability to achieve motor, cognitive, and psychosocial milestones, often leading to impaired balance and functional limitations. Weakened core muscles contribute to poor postural control, increasing the risk of falls and difficulties in performing daily activities. While conventional therapy addresses motor impairments, targeted interventions focusing on core stability require further investigation for optimizing balance rehabilitation in children with developmental delay.

Objective: To evaluate the effects of core stability exercises on static and dynamic balance in children with developmental delay and compare them with conventional therapy.

Methods: A randomized controlled trial was conducted over six months with 30 children aged 6–12 years, meeting specific inclusion criteria. Participants were randomly assigned to either an experimental group receiving an 8-week structured core stability exercise program or a control group undergoing conventional therapy. Balance assessments were conducted pre- and post-intervention using the Pediatric Balance Scale (PBS), Timed Up and Go (TUG) test, and Pediatric Reach Test (PRT). Statistical analyses were performed using Wilcoxon Signed-Rank and Mann-Whitney U tests, with a significance level set at $p<0.05$.

Results: Both groups showed significant within-group improvement in PBS (31.77 ± 8.87 to 36.60 ± 8.78, $p<0.05$), TUG (33.70 ± 14.29 to 29.60 ± 14.28, $p<0.05$), and PRT (16.60 ± 5.01 to 19.40 ± 4.96, $p<0.05$). However, between-group analysis showed no statistically significant difference ($p>0.05$), indicating that both interventions were equally effective.

Conclusion: Core stability exercises and conventional therapy significantly improve balance in children with developmental delay, with no superiority of one intervention over the other. Future research should explore long-term outcomes and combined rehabilitation approaches for optimizing balance training.

Keywords: Balance, core stability exercises, developmental delay, motor function, pediatric rehabilitation, postural control, static and dynamic balance.

INTRODUCTION

Core stability and balance are essential components of motor development, particularly in children with developmental delay (DD). Developmental delay is characterized by a failure to achieve developmental milestones within expected timeframes, often affecting motor, cognitive, and psychosocial domains. Among these, motor impairments can significantly impact a child's ability to perform activities of daily living, such as standing, walking, and sitting, ultimately diminishing their quality of life. Core stability, which refers to the strength and coordination of muscles surrounding the trunk and pelvis, plays a crucial role in postural control and movement. Deficiencies in core muscle strength have been linked to poor balance, compromised functional mobility, and an increased risk of falls in children with DD (1,2). Given the fundamental role of balance in movement and stability, interventions aimed at enhancing core strength are of great clinical relevance in pediatric rehabilitation. Balance can be broadly classified into static and dynamic components. Static balance involves maintaining stability in a stationary position, while dynamic balance pertains to stability during movement. Effective balance control is largely governed by the central nervous system (CNS), which integrates sensory input with motor responses to maintain equilibrium. However, children with DD often exhibit impairments in CNS function, leading to difficulties in core muscle activation and balance control (3). These impairments contribute to instability and hinder the ability to engage in routine physical activities, necessitating targeted therapeutic interventions to improve postural control and overall mobility (3).

Core stability and balance are intrinsically linked, as the core serves as the foundation for all movements. The center of gravity (COG) is located within the core region, and its regulation is vital for maintaining equilibrium under both static and dynamic conditions. Previous studies have demonstrated that core stability exercises (CSE) can significantly enhance trunk strength, postural control, and overall balance (4,5). Among the established protocols, Jeffery's core stability exercise regimen, which incorporates progressive levels of difficulty, has been particularly effective in strengthening core muscles and improving balance in children with disabilities (6). The application of CSE has been widely supported in the literature, with studies demonstrating their efficacy in various pediatric populations. For instance, CSE combined with treadmill training has been shown to improve functional balance in children with Down syndrome (7), while an 8-week CSE program has been reported to enhance both static and dynamic balance in primary school children (8). These findings underscore the potential benefits of core stability training as a non-invasive, structured intervention for children with DD. Despite the established role of core stability in balance control, there remains a need for more targeted research exploring its effects on children with developmental delay. Many existing studies focus on specific populations, such as children with Down syndrome or cerebral palsy, but fewer investigations have examined the broader DD population. Moreover, while some research has demonstrated the benefits of CSE, the optimal duration, frequency, and intensity of such interventions remain unclear. Further exploration is required to establish evidence-based guidelines for integrating CSE into pediatric rehabilitation programs (8).

This study aims to examine the effects of core stability exercises on static and dynamic balance in children with developmental delay. By conducting a randomized controlled trial, the research seeks to determine whether a structured CSE program can enhance postural control, reduce fall risk, and improve functional mobility in this population. The findings are expected to contribute valuable insights for clinicians, therapists, and researchers, ultimately guiding the development of more effective rehabilitation strategies for children with developmental delay.

METHODS

This study employed a randomized controlled trial (RCT) design to evaluate the effects of core stability exercises (CSE) on static and dynamic balance in children with developmental delay (DD). The RCT framework ensured a robust comparison between the experimental and control groups, minimizing bias and enhancing the reliability of findings. The study was conducted at the Rising Sun Institute for Special Children, Lahore, over six months, following approval from the institutional review board (IRB). Informed consent was obtained from the parents or guardians of all participants before enrollment, ensuring adherence to ethical research practices (9). A total of 30 children, aged 6 to 12 years, were recruited based on specific inclusion and exclusion criteria to ensure homogeneity in the sample. Inclusion criteria required participants to have a Pediatric Balance Scale (PBS) score between 20 and 42, the ability to walk independently, and the cognitive ability to follow instructions. Exclusion criteria included the presence of neurological disorders affecting the lower limbs, uncontrolled seizures, vestibular dysfunction, or any condition that could hinder participation in the exercise

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protocol. All participants underwent a baseline assessment of balance abilities using standardized tools before being randomly assigned to either the experimental or control group (10).

Randomization was performed using a lottery-based method to eliminate selection bias. The experimental group received core stability exercises following Jeffery's protocol, a structured, progressive exercise regimen targeting abdominal and trunk muscle strengthening to enhance postural control. Sessions were conducted three times a week for eight weeks, with each session lasting between 45 to 60 minutes. The intervention followed a progressive approach, beginning with basic exercises and advancing to more challenging stability drills over time. The control group received conventional therapy, which included standard balance training, weight shifting, step standing, and gait training. These sessions were also conducted three times a week but lasted only 20 minutes per session, considering the lower intensity level of conventional therapy compared to the structured CSE program. The discrepancy in session duration between the two groups was based on the varying demands of each intervention, ensuring an appropriate workload for participants (11). Balance outcomes were assessed using validated tools, including the Pediatric Balance Scale (PBS), the Timed Up and Go (TUG) test, and the Pediatric Reach Test (PRT). Baseline measurements were recorded prior to the intervention, and post-treatment assessments were conducted at the end of the eight-week period to evaluate improvements. Data analysis was performed using the Statistical Package for Social Sciences (SPSS) version 28. Descriptive statistics summarized demographic and baseline characteristics, while paired t-tests were used to assess within-group differences. Independent t-tests evaluated between-group differences, with a significance level set at $p<0.05$ (12). A CONSORT flow diagram was constructed to provide a transparent overview of participant progression through each phase of the study, including enrollment, randomization, intervention allocation, follow-up, and final analysis. This ensured comprehensive reporting and allowed for a clear understanding of participant distribution and retention across the study. The systematic methodological approach adopted in this trial ensures that findings contribute to evidence-based clinical practices aimed at improving balance and functional mobility in children with developmental delay (13).

RESULTS

The study was conducted over six months, during which 35 children with developmental delay were initially recruited. Following screening, 30 participants met the inclusion criteria and were randomly allocated into two groups, with 15 children in each. The mean age of participants was 7.87 ± 1.75 years, and the gender distribution included 16 males (53.33%) and 14 females (46.67%). Tests of normality using the Shapiro-Wilk test indicated that the data were not normally distributed ($p < 0.05$), necessitating the use of non-parametric statistical analyses. Baseline and post-intervention balance assessments were conducted using the Pediatric Balance Scale (PBS), Timed Up and Go (TUG) test, and Pediatric Reach Test (PRT). Pre-treatment mean PBS scores were recorded at 31.77 ± 8.87, which improved to 36.60 ± 8.78 post-treatment. Similarly, mean TUG scores improved from 33.70 ± 14.29 pre-intervention to 29.60 ± 14.28 post-intervention, while PRT scores increased from 16.60 ± 5.01 to 19.40 ± 4.96. These results demonstrated overall improvement in balance metrics following the intervention.

Percentile distributions for specific PBS items showed an increase in median scores, reflecting improved postural control. For the "Sitting to Standing" task, the median score increased from 3.00 to 4.00, while for "Turning 360 Degrees," the median improved from 2.00 to 3.00. Within-group analysis using the Wilcoxon Signed-Rank Test indicated significant improvements in both groups post-intervention ($p < 0.05$). However, between-group analysis using the Mann-Whitney U Test showed no statistically significant differences between the experimental and control groups, with p-values greater than 0.05 across all assessments. This suggests that while both core stability exercises and conventional therapy were effective in enhancing balance, neither intervention demonstrated clear superiority. Figures illustrating intervention exercises showed participants performing core stability exercises, such as seated trunk rotations on a Swiss ball and supported one-leg standing. Similarly, conventional therapy exercises, including step-standing, were performed by the control group. These images documented the application of prescribed interventions.

Table 1: Gender Frequency and Percentage

Gender	Frequency	Percentage
Male	16	53.33%
Female	14	46.67%

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Table 2: Descriptive Statistics for PBS, TUG, and PRT

Test	N	Mean	SD	Min	Max
Pre-PBS	30	31.77	8.87	20.0	42.0
Post-PBS	30	36.60	8.78	24.0	49.0
Pre-TUG	30	33.70	14.29	10.0	55.0
Post-TUG	30	29.60	14.28	8.0	50.0
Pre-PRT	30	16.60	5.01	10.0	27.0
Post-PRT	30	19.40	4.96	12.0	30.0

Table 3: Percentile Distribution for PBS Scores

Variable	25th Percentile	Median	75th Percentile
Pre-Sitting to Standing	2.00	3.00	4.00
Post-Sitting to Standing	3.00	4.00	4.00
Pre-Turning 360	1.00	2.00	2.25
Post-Turning 360	1.00	2.00	3.00

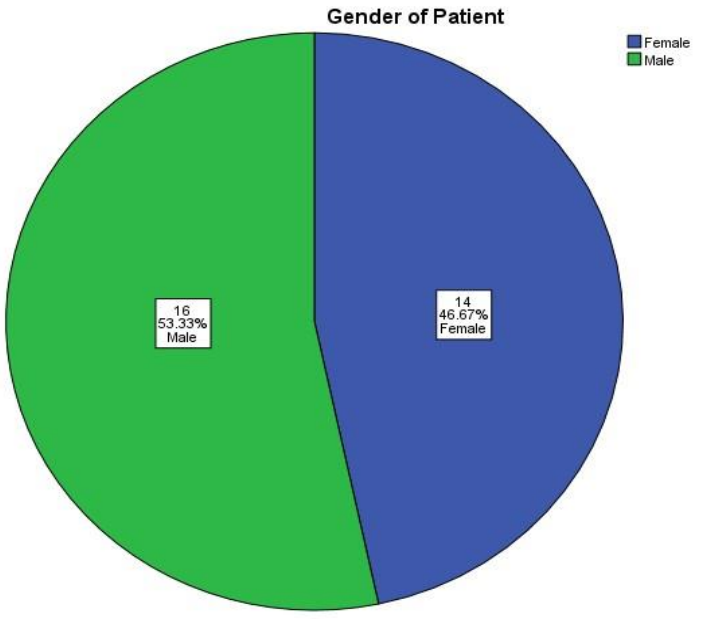

Figure 1 Gender of Patient

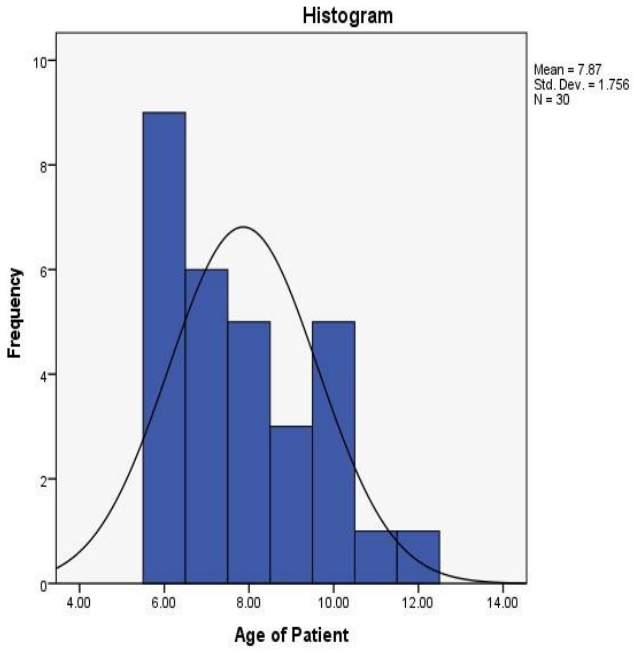

Figure 2 Age of Patients

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Table 4: Mann-Whitney U Test Results

Test	Experimental Group	Control Group	p-value
Pre-PBS Score	16.57	14.43	0.501
Post-PBS Score	17.23	13.77	0.280
Pre-TUG Score	12.63	18.37	0.074
Post-TUG Score	12.77	18.23	0.088

Figure 3 Patient was doing CSE, sitting on a Swiss ball contracting the abdominals with trunk rotations (week 6th and 8th week).3

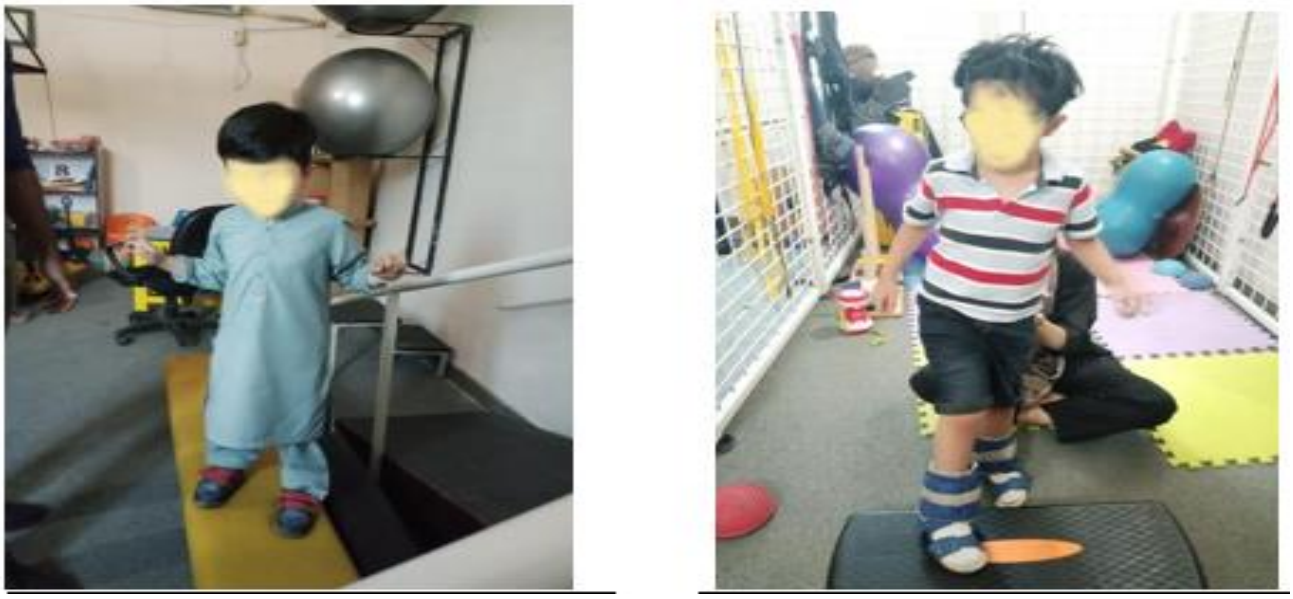

Figure 4 Patient performing stepping exercise (Conventional Therapy)

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Figure 5 Patient was doing one leg standing (Supported).

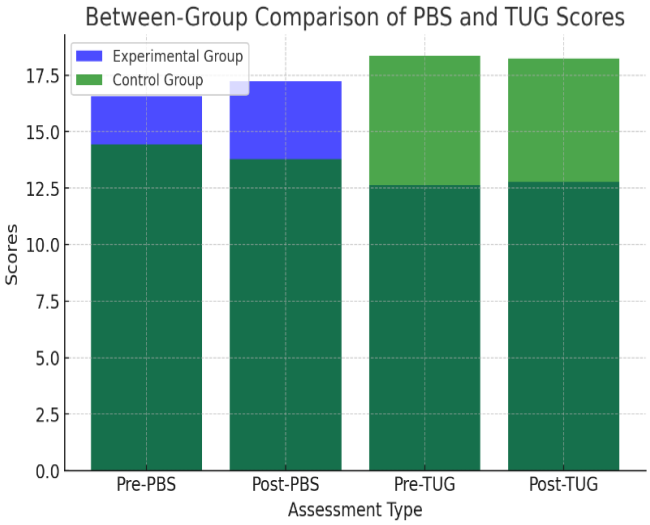

Figure 6 Comparison between Group of PBS and TUG Scores

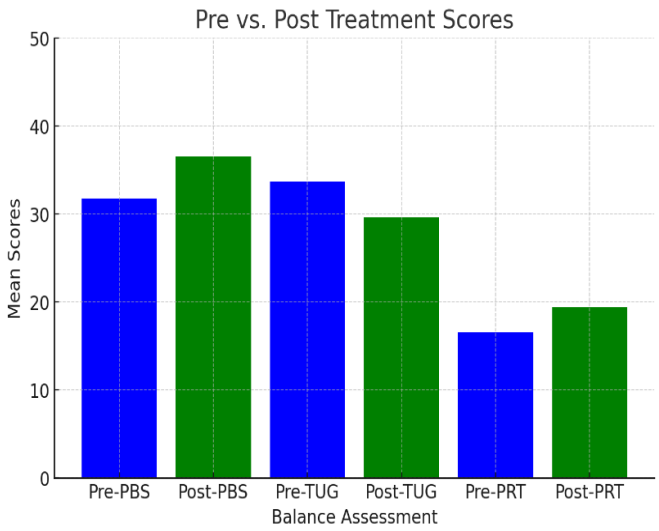

Figure 7 Pre VS Post Treatment Scores

DISCUSSION

The findings of the present study demonstrate that both core stability exercises and conventional therapy significantly improved static and dynamic balance in children with developmental delay. The improvements observed in Pediatric Balance Scale, Timed Up and Go test, and Pediatric Reach Test scores suggest that both interventions effectively enhanced postural control and functional mobility. The absence of a statistically significant difference between the two treatment groups indicates that conventional therapy may inherently incorporate elements of core stability training, resulting in comparable improvements. These findings align with previous research, which has emphasized the role of core stability in balance control and its contribution to motor function enhancement in pediatric populations with movement impairments (14,15). Core stability training has been extensively studied in children with motor impairments, with evidence supporting its efficacy in improving postural control and movement coordination. Studies have indicated that strengthening the trunk and abdominal muscles plays a crucial role in stabilizing the center of gravity, thereby enhancing static and

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dynamic balance. Similarly, conventional therapy, which includes weight shifting, step standing, and reaching exercises, has been shown to facilitate neuromuscular adaptations that contribute to improved balance performance. The similarity in outcomes between the two interventions suggests that conventional therapy, despite its different focus, may also activate core musculature and improve stability through functional movement training (16,17).

The current study contributes to the growing body of literature supporting structured balance interventions for children with developmental delay. Research has demonstrated that motor control deficits in this population are linked to impairments in core muscle activation, leading to postural instability and increased fall risk. Interventions that target core musculature have been found to be beneficial in enhancing stability and reducing movement-related challenges. Studies examining progressive core training have reported improvements in dynamic balance and postural endurance, reinforcing the rationale for incorporating such exercises into rehabilitation programs. Similarly, functional movement-based interventions, such as conventional therapy, have been shown to enhance weight transfer mechanics, improve reaction times, and facilitate better postural adjustments, which may explain the comparable effectiveness observed in the present study (18,19). Despite these positive findings, several limitations should be considered when interpreting the results. The relatively small sample size may limit the generalizability of the findings to a broader population of children with developmental delay. Additionally, the study duration of eight weeks provides insight into short-term improvements; however, the long-term effects of core stability exercises and conventional therapy on balance maintenance remain unclear. Follow-up assessments over extended periods would provide valuable information regarding the sustainability of intervention benefits. Another limitation involves the variation in intervention session durations between the two groups, which may have influenced outcomes despite differences in exercise intensity. Standardizing training duration across groups in future research would enhance comparability and ensure a more precise evaluation of treatment effectiveness (20,21).

A key strength of this study is the randomized controlled trial design, which minimizes selection bias and enhances the validity of findings. The use of validated balance assessment tools strengthens the reliability of outcome measurements, providing objective evidence of functional improvements. Additionally, the inclusion of non-parametric statistical analyses appropriately accounted for the non-normal distribution of data, ensuring robust interpretation of results (22). Future research should explore individualized approaches to balance training, considering factors such as age, severity of motor impairment, and baseline functional ability to optimize intervention strategies. Investigations incorporating larger, more diverse sample populations would further validate findings and contribute to the development of standardized rehabilitation protocols. Moreover, examining the neuromuscular mechanisms underlying balance improvements in response to core stability exercises and conventional therapy would provide deeper insights into their physiological effects. Integrating advanced technologies, such as motion analysis systems and electromyography, could offer a more comprehensive understanding of postural adaptations and muscle activation patterns (23-25). The findings of this study reinforce the importance of structured balance training in pediatric rehabilitation, demonstrating that both core stability exercises and conventional therapy effectively improve balance in children with developmental delay. These results support the integration of tailored balance interventions into clinical practice, emphasizing the need for individualized training programs that address the specific needs of children with motor impairments. Further research focusing on long-term efficacy, optimal intervention parameters, and underlying neuromuscular adaptations will contribute to the advancement of evidence-based rehabilitation strategies (26,27).

CONCLUSION

This study demonstrated that both core stability exercises and conventional therapy effectively improved static and dynamic balance in children with developmental delay, highlighting their role in enhancing postural control and functional mobility. The findings suggest that conventional therapy may inherently incorporate elements of core stability training, leading to comparable outcomes between the two interventions. These results reinforce the importance of structured rehabilitation programs that target core muscle activation and movement coordination to support balance development in this population. The study contributes valuable insights for clinicians and therapists, emphasizing the need for individualized intervention strategies to optimize motor function and reduce fall risk in children with developmental impairments. Future research should explore long-term effects, optimal training protocols, and the integration of advanced rehabilitation techniques to further enhance therapeutic outcomes.

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AUTHOR CONTRIBUTIONS

Author	Contribution
Ammara Arooj	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Aitzaz Azam	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Maria Amjad	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Tooba Tanveer	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Zara Tariq	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Fariha Wahab	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Fatima Yasin Khan	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Qandeel Arshad	Writing - Review & Editing, Assistance with Data Curation

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