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EFFECTS OF BIODEX BALANCE SYSTEM TRAINING ON NEUROLOGICAL DISABILITY: ENHANCING BALANCE AND FUNCTIONAL ABILITIES

Original Research

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ABSTRACT

Background: Neurological disorders commonly impair balance, mobility, and functional independence, contributing to elevated fall risk and long-term disability. Conventional physiotherapy offers therapeutic benefit but often lacks the precision of objective assessment and real-time biofeedback needed for targeted motor relearning. The Biodex Balance System (BBS) is a computerized training platform that provides dynamic balance challenges with integrated sensory feedback. Its use may enhance postural control and functional outcomes among individuals with neurological impairment.

Objective: To evaluate the effects of Biodex Balance System training on balance, mobility, and functional independence in patients with neurological disability.

Methods: This prospective interventional study was conducted at tertiary care hospital over a period of six months. Fifty-five patients aged 18–70 years with neurological disability underwent six weeks of BBS-assisted balance training (three supervised sessions per week), alongside routine physiotherapy. Pre- and post-intervention measures included postural stability indices, Berg Balance Scale (BBS), Timed Up and Go (TUG) test, and Functional Independence Measure (FIM). Data were analyzed using paired t-tests, while multivariable logistic regression identified predictors of functional improvement.

Results: The mean age of participants was 54.2 ± 9.6 years, with stroke being the most prevalent condition (38.2%). Postural stability improved significantly, with the overall stability index decreasing from 3.92 ± 1.21 to 2.46 ± 0.98 ($p<0.001$). Berg Balance Scale scores increased from 37.4 ± 6.8 to 46.2 ± 5.9 ($p<0.001$), and the proportion scoring ≥45 rose from 25.5% to 69.1%. TUG times improved from 21.8 ± 5.6 seconds to 15.3 ± 4.7 seconds ($p<0.001$). Total FIM scores increased from 83.1 ± 13.5 to 96.9 ± 12.8 ($p<0.001$). Significant predictors of improvement included younger age (aOR 2.42), shorter illness duration (aOR 2.85), stroke diagnosis (aOR 1.98), and baseline BBS <40 (aOR 2.11).

Conclusion: Biodex Balance System training effectively enhances balance, mobility, and functional independence in individuals with neurological disability. Its integration into rehabilitation programs may reduce fall risk, promote greater independence, and improve recovery, particularly when initiated early in the course of disability.

Keywords: Biodex Balance System, Disability Evaluation, Neurological Rehabilitation, Postural Balance, Psychomotor Performance, Recovery of Function, Rehabilitation Therapy.

INTRODUCTION

Neurological disorders such as stroke, Parkinson's disease, multiple sclerosis, and traumatic brain injury remain major contributors to long-term disability worldwide, often leaving individuals with persistent deficits in balance, coordination, and overall motor control (1). These impairments not only elevate the risk of falls but also restrict participation in daily activities, promote physical inactivity, and contribute to psychological consequences including loss of confidence and fear of falling (2). Conventional rehabilitation programs, while foundational in clinical care, frequently rely on therapist-guided exercises and task-oriented activities that may lack the precision needed for objective assessment of postural control. Limited opportunities for real-time feedback and challenges in maintaining sustained patient engagement further reduce their long-term effectiveness (3). In recent years, the shift toward evidence-based, technology-assisted rehabilitation has highlighted the need for solutions that provide accurate monitoring, quantifiable performance metrics, and interactive feedback to support motor relearning. The Biodex Balance System (BBS) is one such advancement, offering computerized postural stability testing and dynamic training modules that can systematically vary platform stability to tailor difficulty levels according to patient needs (4). By integrating proprioceptive and visual feedback, the system facilitates corrective motor strategies and enhances neural pathway engagement, which is particularly valuable for individuals with neurological impairment where sensory integration is often compromised (5). Existing studies have demonstrated that BBS-based interventions can reduce postural sway, improve balance confidence, and promote more efficient movement patterns, with many reporting improvements in gait, functional independence, and fall prevention (6). Evidence from populations with stroke and Parkinson's disease suggests that BBS enhances mobility scores and quality-of-life measures beyond what is achieved through conventional therapy alone (7). Its interactive design has also been shown to bolster patient motivation and adherence—two factors that significantly influence the success of long-term neurorehabilitation (8). Despite encouraging findings, widespread implementation of BBS remains limited, particularly in resource-constrained regions where cost, equipment availability, and trained personnel pose notable challenges. Furthermore, much of the existing research is drawn from small or condition-specific samples, leaving gaps regarding the broader application of BBS across diverse neurological groups (9). There remains a clear need for prospective, real-world studies that evaluate its effectiveness in improving balance and functional abilities in varied neurological populations (10). Addressing this gap, the present study was undertaken to explore the impact of Biodex Balance System training on balance, mobility, and functional independence among patients with neurological disability. This study is to evaluate the effects of Biodex Balance System training on balance, mobility, and functional independence in patients with neurological disability.

METHODS

This prospective interventional study was conducted at a tertiary care hospital over a period of 6 months and was designed to evaluate the effects of Biodex Balance System (BBS) training on balance, mobility, and functional independence in patients with neurological disability. A total of 55 participants were recruited through non-probability consecutive sampling. Eligible patients were adults aged 18–70 years with a confirmed neurological condition associated with balance impairment, such as stroke, multiple sclerosis, Parkinson's disease, or traumatic brain injury. Only individuals who were able to stand with or without minimal support for at least one minute and who provided written informed consent were included. Patients were excluded if they had severe musculoskeletal deformities affecting gait or posture, uncontrolled cardiovascular disease such as unstable angina or uncontrolled hypertension, significant cognitive impairment that interfered with their ability to follow training instructions, or active vestibular disorders unrelated to their primary neurological diagnosis. Baseline data collection involved recording demographic and clinical characteristics including age, gender, primary diagnosis, and duration of illness. Pre-intervention assessments were performed using standardized outcome measures: postural stability indices obtained through the Biodex platform, the Berg Balance Scale (BBS), the Timed Up and Go (TUG) test, and the Functional Independence Measure (FIM). Following baseline evaluation, each participant underwent a structured BBS training protocol comprising three supervised sessions per week for six consecutive weeks. Training sessions were individualized, incorporating progressive adjustments in platform stability and integrating visual biofeedback tasks to enhance sensorimotor engagement. Throughout the intervention period, participants continued receiving conventional physiotherapy centered on mobility, strength, and functional practice, ensuring that all patients received standard rehabilitative care in addition to the technology-assisted program.

Post-intervention assessments were conducted immediately after the six-week program using the same standardized instruments applied at baseline to determine changes in balance performance, mobility, and functional independence. Additionally, subjective patient feedback regarding perceived improvement and satisfaction with the training was collected using a structured five-point Likert-scale questionnaire to complement objective findings. All collected data were processed and analyzed using SPSS version 22.0 (SPSS Inc., Chicago, IL). Continuous variables—including balance indices, TUG times, and FIM scores—were presented as means with standard deviations. Pre- and post-intervention differences were evaluated using paired t-tests, while categorical variables such as gender and satisfaction levels were expressed as frequencies and percentages and compared using chi-square tests. Logistic regression analysis was performed to identify independent predictors of significant functional improvement after the intervention, adjusting for age, gender, diagnosis, and baseline disability. A p-value ≤0.05 was considered statistically meaningful. The study received ethical approval from the Institutional Research Ethics Committee of the relevant institute. Written informed consent was obtained from all participants prior to enrolment, and strict adherence to confidentiality and anonymity was maintained throughout the study in accordance with ethical research standards.

RESULTS

The study included 55 participants with a mean age of 54.2 ± 9.6 years, of whom 52.7% were male. Most patients (58.2%) were within the 41–60-year age bracket, while 27.3% were older than 60 years and 14.5% were younger than 40 years. Stroke was the most frequent neurological condition (38.2%), followed by Parkinson's disease (25.5%), multiple sclerosis (21.8%), and traumatic brain injury (14.5%). The mean duration of illness was 3.8 ± 2.6 years, and baseline characteristics did not differ significantly between males and females. Postural stability demonstrated significant improvements following six weeks of Biodex Balance System training. The overall stability index improved from 3.92 ± 1.21 to 2.46 ± 0.98, while anterior–posterior stability improved from 2.71 ± 1.03 to 1.84 ± 0.87. Medial–lateral stability similarly improved from 2.18 ± 0.95 to 1.53 ± 0.74. All changes were highly significant (p<0.001). Balance function, assessed through the Berg Balance Scale, increased from 37.4 ± 6.8 at baseline to 46.2 ± 5.9 post-training, with a mean improvement of 8.8 points. The proportion of patients achieving scores ≥45 increased from 25.5% to 69.1%, indicating a marked reduction in fall-risk category. Mobility outcomes also improved. Timed Up and Go (TUG) test performance improved from 21.8 ± 5.6 seconds to 15.3 ± 4.7 seconds (p<0.001). The number of patients completing the test in under 15 seconds increased from 18.2% to 52.7%, illustrating improved safety and functional movement efficiency. Functional independence increased across motor and cognitive domains. Motor FIM scores improved from 56.3 ± 10.2 to 67.8 ± 9.6, and cognitive FIM scores rose from 26.8 ± 4.1 to 29.1 ± 3.7. Total FIM scores improved significantly from 83.1 ± 13.5 to 96.9 ± 12.8 (p<0.001), reflecting gains in daily functional capacity.

Multivariable logistic regression identified several predictors of significant improvement. Patients younger than 60 years demonstrated more than double the odds of functional improvement (aOR 2.42), and those with stroke diagnosis had nearly twice the likelihood of better outcomes (aOR 1.98). Duration of illness ≤3 years was a strong predictor (aOR 2.85), while baseline low balance (BBS <40) also predicted better post-training gains (aOR 2.11). Gender did not significantly influence improvement. Patient-reported satisfaction with the Biodex Balance System training demonstrated a strongly positive trend. The majority of participants expressed favorable perceptions of the intervention, with 67.3% reporting high satisfaction and an additional 21.8% indicating moderate satisfaction. Only a small proportion (10.9%) expressed low satisfaction or neutrality. Most patients described improvements in balance confidence, mobility, and overall stability during daily tasks, aligning closely with the objective gains observed in clinical measures. No significant differences in satisfaction levels were noted across gender or diagnostic groups, suggesting comparable acceptability of the intervention among diverse neurological conditions. These subjective responses provided supportive evidence for enhanced perceived benefit and engagement with the BBS training program.

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Table 1: Baseline Demographic and Clinical Characteristics of Patients (N = 55)

Variable	Total (N=55)	Male (n=29)	Female (n=26)	p-value
Age, years, mean ± SD	54.2 ± 9.6	55.1 ± 8.9	53.2 ± 10.2	0.46
Age group, n (%)				
18–40 years	8 (14.5)	5 (17.2)	3 (11.5)	0.41
41–60 years	32 (58.2)	17 (58.6)	15 (57.7)	
>60 years	15 (27.3)	7 (24.2)	8 (30.8)	
Primary diagnosis, n (%)				
Stroke	21 (38.2)	11 (37.9)	10 (38.5)	0.88
Multiple sclerosis	12 (21.8)	7 (24.1)	5 (19.2)	
Parkinson's disease	14 (25.5)	7 (24.1)	7 (26.9)	
Traumatic brain injury	8 (14.5)	4 (13.8)	4 (15.4)	
Duration of illness (years), mean ± SD	3.8 ± 2.6	3.7 ± 2.5	3.9 ± 2.7	0.72

Table 2: Pre- and Post-Training Postural Stability Indices (N = 55)

Outcome	Pre-training (mean ± SD)	Post-training (mean ± SD)	Mean Difference	p-value
Overall Stability Index	3.92 ± 1.21	2.46 ± 0.98	–1.46	<0.001
Anterior–Posterior Stability	2.71 ± 1.03	1.84 ± 0.87	–0.87	<0.001
Medial–Lateral Stability	2.18 ± 0.95	1.53 ± 0.74	–0.65	<0.001

Table 3: Pre- and Post-Training Berg Balance Scale (BBS) Scores (N = 55)

Parameter	Pre-training (mean ± SD)	Post-training (mean ± SD)	Mean Difference	p-value
Berg Balance Scale (max 56)	37.4 ± 6.8	46.2 ± 5.9	+8.8	<0.001
Patients with BBS ≥45, n (%)	14 (25.5)	38 (69.1)	+43.6%	<0.001

Table 4: Timed Up and Go (TUG) Test Results (N = 55)

Parameter	Pre-training (mean ± SD)	Post-training (mean ± SD)	Mean Difference	p-value
TUG time (seconds)	21.8 ± 5.6	15.3 ± 4.7	–6.5	<0.001
Patients achieving <15 sec, n (%)	10 (18.2)	29 (52.7)	+34.5%	<0.001

Table 5: Functional Independence Measure (FIM) Scores (N = 55)

Parameter	Pre-training (mean ± SD)	Post-training (mean ± SD)	Mean Difference	p-value
Motor subscale (max 91)	56.3 ± 10.2	67.8 ± 9.6	+11.5	<0.001
Cognitive subscale (max 35)	26.8 ± 4.1	29.1 ± 3.7	+2.3	0.01
Total FIM score (max 126)	83.1 ± 13.5	96.9 ± 12.8	+13.8	<0.001

Table 6: Predictors of Significant Functional Improvement (Multivariable Logistic Regression, N = 55)

Predictor	Adjusted Odds Ratio (aOR)	95% CI	p-value
Age <60 years	2.42	1.16–5.02	0.02
Male gender	1.21	0.62–2.38	0.54
Diagnosis: Stroke vs. others	1.98	1.02–3.87	0.04
Duration of illness ≤3 years	2.85	1.44–5.66	0.002
Baseline BBS <40	2.11	1.08–4.14	0.03

Table 7: Patient Satisfaction After Six Weeks of Biodex Balance System Training (N = 55)

Satisfaction Level (5-point Likert Scale)	n (%)
Very satisfied	21 (38.2%)
Satisfied	16 (29.1%)
Neutral	6 (10.9%)
Dissatisfied	7 (12.7%)
Very dissatisfied	5 (9.1%)

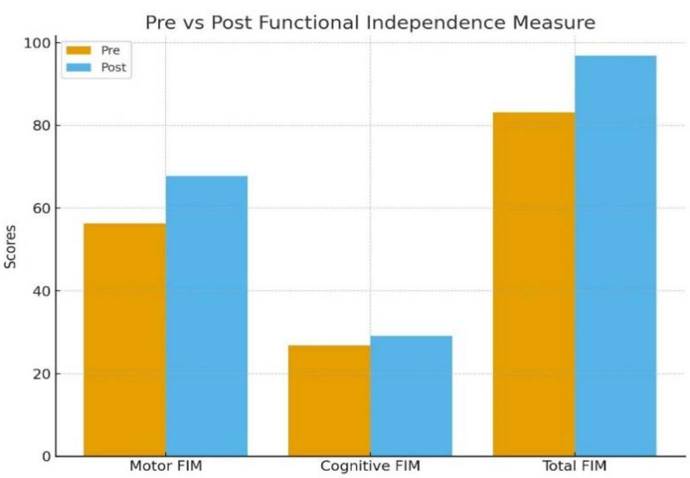

Figure 2 Pre vs Post Functional Independence Measure

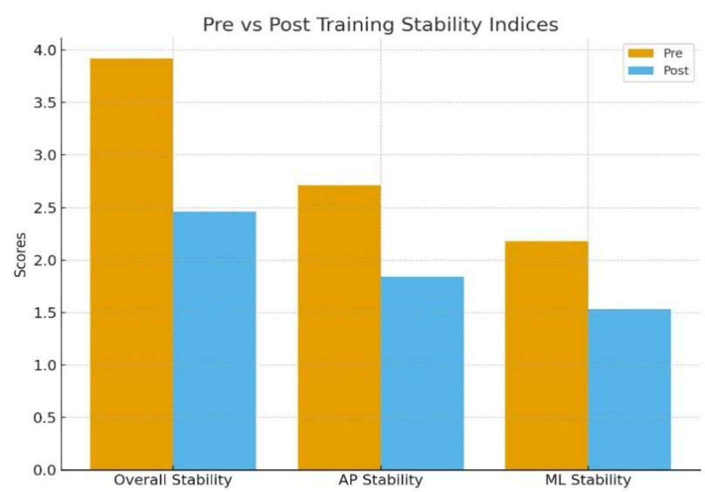

Figure 2 Pre vs Post Training Stability Indices

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DISCUSSION

The findings of this study demonstrated that Biodex Balance System training produced significant improvements in balance, mobility, and functional independence among patients with neurological disabilities. The marked reductions observed in overall stability indices and directional sway reflected substantial gains in postural control, supporting the utility of technology-assisted balance rehabilitation. These results aligned with earlier investigations in which Biodex-based interventions enhanced proprioceptive function and reduced postural sway in individuals with neurological disorders (11,12). Improvements across both anterior–posterior and medial–lateral stability suggested that the intervention promoted multidimensional balance recovery rather than isolated axis-specific gains, reinforcing the notion that BBS provides comprehensive neuromotor stimulation. Enhancements in Berg Balance Scale scores further strengthened the evidence for functional benefit, with nearly nine points of improvement and a considerable rise in the proportion of participants crossing the clinically meaningful threshold associated with lower fall risk. Similar trends have been reported in previous work where balance training incorporating real-time feedback contributed to better balance confidence and fall-risk reduction in populations with stroke and Parkinson's disease (13-15). Improvements in Timed Up and Go performance indicated that these balance changes translated into practical gains in mobility and gait safety, echoing findings from earlier studies that observed faster and safer ambulatory performance following BBS training (16). Furthermore, the increase in both motor and cognitive components of the Functional Independence Measure suggested broader functional impact, likely driven by enhanced confidence, postural stability, and engagement in daily activities. Previous rehabilitation research also highlighted that technology-assisted balance interventions contributed to improved independence and quality of life among neurological patients (17,18).

Predictor analysis offered meaningful insights by showing that younger individuals, those with shorter duration of illness, and those with stroke derived the greatest functional gains. These patterns aligned with established evidence showing that earlier intervention and younger age are strongly associated with better neurorehabilitation outcomes (19). Patients with lower baseline balance scores also achieved greater gains, reflecting the principle that individuals with more pronounced deficits possess greater recovery potential when provided with targeted and progressively challenging interventions (20). Several strengths supported the robustness of this study, including the prospective design, the use of validated assessment tools across multiple functional domains, and the incorporation of both objective and subjective outcome measures. The structured and progressive nature of the BBS training protocol also ensured consistency in therapeutic delivery. Nonetheless, certain limitations must be acknowledged. The absence of a control group receiving only conventional physiotherapy limited the ability to isolate the specific contribution of BBS training. The heterogeneity of neurological diagnoses introduced variability in recovery potential, although this also improved the generalizability of findings to real-world clinical populations. The sample size, although adequate for exploratory analysis, remained modest for subgroup comparisons. Additionally, the duration of follow-up was short, preventing evaluation of long-term retention of balance and functional gains. Future studies would benefit from randomized controlled designs, larger and diagnosis-specific samples, and extended follow-up periods to determine the sustainability of training effects. Integration of biomechanical and neurophysiological measures could also deepen understanding of underlying mechanisms (21,22). Despite the constraints, the present findings supported the clinical relevance of Biodex-based balance training as an adjunct to conventional therapy. By delivering real-time visual feedback, adjustable task difficulty, and multidimensional postural challenges, BBS facilitated motor relearning in ways that traditional physiotherapy alone may not achieve. The consistent improvements across balance, mobility, and functional independence reinforced its potential value within multidisciplinary neurological rehabilitation programs.

CONCLUSION

The findings of this study conclude that Biodex Balance System training serves as an effective adjunct to conventional rehabilitation by enhancing postural stability, balance performance, mobility, and overall functional independence in individuals with neurological disability. The intervention demonstrated clear functional benefits across multiple domains, with improvements influenced by patient-related factors such as age, underlying diagnosis, illness duration, and baseline balance status. These outcomes highlight the practical value of integrating technology-assisted balance training into multidisciplinary rehabilitation programs, where its real-time feedback and progressive challenge can help reduce fall risk, promote greater independence, and support meaningful recovery. The study underscores the importance of adopting innovative, patient-tailored rehabilitation strategies that can elevate the quality of care and optimize long-term outcomes for neurological populations.

AUTHOR CONTRIBUTION

Author	Contribution
Danish Ali Mir*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Muhammad Ammar Khan	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
Muhammad Tawab Khalil	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Zeeshan Nawaz	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ahsan Ali Amjad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Shoaib Tahir	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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