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Relationship Between Cognitive Impairment and Postural Stability in Elderly Population

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Abstract

Background: Cognitive decline and postural instability frequently coexist in later life, yet the cognitive domains that most strongly influence balance and the added value of integrated cognitive-motor training remain insufficiently defined in older Indian populations. Objective: To examine the relationship between cognitive impairment and postural stability, identify cognitive predictors of balance dysfunction, compare prospective fall incidence, and evaluate an eight-week combined cognitive-balance training programme against balance training alone. Methods: Thirty adults aged 55-75 years were assessed at baseline: 15 with cognitive impairment and 15 cognitively healthy controls. Cognition was evaluated with the Mini-Mental State Examination and Montreal Cognitive Assessment. Postural stability was assessed using the Berg Balance Scale and single-task and dual-task Timed Up and Go tests, with serial subtraction used as the cognitive task. Falls were recorded prospectively for eight weeks. Participants with cognitive impairment were then randomized to combined cognitive-balance training (n=8) or balance-only training (n=7), delivered for 60 minutes, three times weekly, for eight weeks. Group comparisons, correlations, multiple regression, Fisher exact tests, and repeated-measures analysis of variance were used. Results: Compared with cognitively healthy participants, the cognitively impaired group had lower Berg Balance Scale scores (43.2 +/- 6.1 vs 51.8 +/- 3.9; p<0.001; d=1.68), slower single-task Timed Up and Go performance (14.1 +/- 2.7 vs 9.4 +/- 1.6 s; p<0.001; d=2.14), and greater dual-task cost (34.0% +/- 9.5% vs 18.1% +/- 7.2%; p<0.001; d=1.87). Executive function was the only significant independent cognitive predictor of balance (standardized beta=0.51; p<0.001; model R2=0.61). Falls occurred in 40.0% of cognitively impaired and 13.3% of cognitively healthy participants (p=0.109). Combined training produced greater improvement than balance-only training in Berg Balance Scale score (+6.5 vs +2.7 points; time-by-group p<0.001; partial eta-squared=0.58), dual-task Timed Up and Go (-5.2 vs -1.5 s; p<0.001; partial eta-squared=0.55), and dual-task cost (35.2% to 21.4% vs 33.1% to 34.0%; p=0.004). Attendance exceeded 85%, with no dropouts and no serious adverse events. Conclusion: Cognitive impairment, particularly executive dysfunction, is strongly associated with poorer postural stability and greater cognitive-motor interference.

Combined cognitive-balance training appears feasible and more effective than balance training alone, although larger controlled trials are required to confirm effects on falls.

Keywords: cognitive impairment; postural stability; older adults; executive function; dual-task performance; falls; cognitive-motor training

1. Introduction

Population ageing is accompanied by rising rates of cognitive decline, mobility limitation, and falls. Postural stability is not a purely automatic motor function; it depends on the integration of visual, vestibular, and proprioceptive information with central processing, anticipatory control, and rapid motor responses. These processes increasingly require attention and executive control when the environment is complex or when a person performs more than one task at a time. Consequently, deterioration in cognition may compromise balance even before severe dementia or obvious neurological disability develops [1-4].

Falls are a major cause of injury, hospitalization, disability, fear of falling, and loss of independence among older adults [5,6]. Cognitive impairment increases this risk through several pathways, including impaired hazard perception, delayed response selection, poor judgement, reduced ability to divide attention, and difficulty adapting gait or posture to unexpected disturbances. Systematic evidence indicates that older people with cognitive impairment are substantially more likely to fall than cognitively healthy peers, with executive dysfunction, attention, and processing speed emerging as important contributors [7,8].

The cognitive-motor relationship becomes particularly evident during dual-task activity. Everyday mobility commonly involves walking while speaking, calculating, searching for an object, monitoring traffic, or negotiating obstacles. Under such conditions, motor and cognitive tasks compete for limited attentional resources. Dual-task gait slowing and postural deterioration may therefore reveal vulnerabilities that remain hidden during conventional single-task balance testing [9-11].

Shared neural circuitry provides a biological explanation for this interaction. The prefrontal cortex, anterior cingulate, basal ganglia, cerebellum, and connecting white-matter pathways contribute to both executive control and movement regulation [12-15]. Age-related vascular changes, neurodegeneration, and neurotransmitter dysfunction may impair these networks simultaneously, producing parallel declines in cognition, gait, and balance.

Although the association between cognition and balance is increasingly recognized, important uncertainties remain. First, the relative contribution of executive function, attention, and memory to postural stability is not fully established. Second, relatively few studies in Indian settings have combined cognitive screening, dual-task balance assessment, prospective fall recording, and an intervention component. Third, it remains clinically important to determine whether adding structured cognitive and dual-task exercises to conventional balance training produces greater functional gains than balance training alone.

The present study therefore examined the relationship between cognitive impairment and postural stability in adults aged 55-75 years, identified the cognitive domain most strongly associated with balance dysfunction, compared short-term fall incidence between cognitively impaired and cognitively healthy participants, and tested the preliminary effectiveness and feasibility of an eight-week combined cognitive-balance training programme.

2. Materials and Methods

2.1 Study Design and Participants

A two-phase study was conducted. Phase I used a cross-sectional comparative design to assess cognition, postural stability, dual-task performance, and prospective falls in cognitively impaired and cognitively healthy older adults. Phase II used a randomized, parallel-group, pretest-posttest design in which the cognitively impaired participants received either combined cognitive-balance training or balance training alone.

Thirty adults aged 55-75 years were recruited from community and institutional settings, including geriatric outpatient services, senior citizen groups, day-care centres, assisted-living facilities, and old-age homes. Fifteen participants were categorized as cognitively impaired and 15 as cognitively healthy. Cognitive impairment was defined by a documented diagnosis of mild cognitive impairment or mild dementia, an MMSE score of 18-23, or a MoCA score below 26 after educational adjustment. Cognitively healthy participants had an MMSE score of at least 24 or a MoCA score of at least 26.

Participants were required to stand and walk independently without an assistive device and to understand test instructions in Hindi or English. Exclusion criteria included advanced Parkinson disease, stroke with residual major motor deficit, multiple sclerosis, cerebellar ataxia, severe lower-limb musculoskeletal disease, recent lower-limb fracture, unstable cardiovascular disease, severe uncorrected visual impairment, active vestibular disorder, profound cognitive impairment, or participation in another structured balance or cognitive rehabilitation programme.

2.2 Outcome Measures

Cognitive function was assessed with the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA). The MoCA provided domain-specific scores for visuospatial/executive ability, attention, delayed recall, language, and orientation. The executive, attention, and memory subscores were used in correlation and regression analyses [16,17].

Postural stability was assessed with the 14-item Berg Balance Scale (BBS; range 0-56, higher scores indicating better balance) and the Timed Up and Go (TUG) test [18,19]. TUG was performed first under a single-task condition and then under a dual-task condition while the participant counted backward by threes from a randomly selected number. Three trials were completed for each condition, and the average time was used. Dual-task cost was calculated as: [(dual-task TUG - single-task TUG) / single-task TUG] x 100.

At baseline, participants reported falls during the previous 12 months. During the eight-week study period, falls were recorded prospectively using weekly diaries completed by participants or caregivers and verified through weekly telephone calls or visits. A fall was defined as an unexpected event resulting in the participant coming to rest on the ground, floor, or a lower level, excluding overwhelming hazards or major intrinsic medical events.

2.3 Intervention

After baseline assessment, the 15 cognitively impaired participants were randomized using a computer-generated sequence and concealed opaque envelopes to combined cognitive-balance training (n=8) or balance-only training (n=7). Both groups attended 60-minute supervised sessions three times per week for eight weeks (24 sessions). Sessions included a 5-minute warm-up, a 50-minute training block, and a 5-minute cool-down.

The combined group completed approximately 25 minutes of cognitive activity and 25 minutes of balance activity, with part of each component performed concurrently as dual-task training. Cognitive exercises targeted executive control, attention, memory, cognitive flexibility, inhibition, verbal fluency, serial calculation, pattern recognition, trail making, and recall. Balance exercises included reduced-base standing, foam-surface activities, weight shifting, tandem walking, single-leg stance progressions, reaching, sit-to-stand practice, and dynamic walking tasks. Examples of integrated tasks included standing on foam while counting backward and performing lateral weight shifts while naming items from a category. Task difficulty was progressively increased.

The balance-only group received the same balance protocol and an equivalent duration of supervised contact, but cognitive exercises were replaced by light flexibility and range-of-motion activity. Balance exercises were not paired with cognitive tasks. Groups were supervised in small sessions, with approximately one supervisor for every four participants. Attendance and adverse events were recorded.




2.4 Statistical Analysis

Data were analysed using IBM SPSS Statistics version 26.0. Continuous variables were summarized as mean +/- standard deviation and categorical variables as frequency and percentage. Normality was assessed using the Shapiro-Wilk test and Q-Q plots. Baseline group comparability was assessed using independent-samples t tests, Mann-Whitney U tests, chi-square tests, or Fisher exact tests as appropriate.

Between-group differences in BBS, single-task TUG, dual-task TUG, and dual-task cost were analysed using independent-samples t tests, with Cohen d used to describe effect magnitude. Pearson correlations examined relationships between MoCA domains and balance measures. Multiple linear regression predicted BBS score from executive function, attention, memory, age, and number of comorbidities. A hierarchical model evaluated the incremental contribution of cognitive domains. Intervention effects were tested using repeated-measures analysis of variance with time as the within-subject factor and training group as the between-subject factor. Partial eta-squared was reported for interaction effects. Statistical significance was set at $p<0.05$.

2.5 Ethical Considerations

The thesis reports that the study received approval from the relevant Institutional Ethics Committee and followed the Declaration of Helsinki. Written informed consent was obtained from participants capable of consent. For participants with cognitive impairment, verbal assent and written consent from a legally authorized representative or caregiver were obtained. The ethics approval number and institutional name should be inserted before journal submission.

3. Results

3.1 Participant Characteristics

The cognitively impaired and cognitively healthy groups were comparable in age, sex distribution, body mass index, number of comorbidities, medication use, and years of education (all $p>0.05$). As expected, the cognitively impaired group had significantly lower MMSE and MoCA scores. A history of at least one fall in the preceding year was more common in the cognitively impaired group (53.3% vs 20.0%), although the difference narrowly missed statistical significance ($p=0.058$).

Table 1. Baseline demographic and clinical characteristics. (%).

Variable	Cognitively impaired (n=15)	Cognitively healthy (n=15)	p value
Age, years	66.8 +/- 5.9	65.9 +/- 5.7	0.677
Sex, male/female	8/7	7/8	0.715
BMI, kg/m2	26.1 +/- 3.3	25.8 +/- 3.0	0.797
Education, years	8.9 +/- 3.2	10.5 +/- 3.5	0.208
Comorbidities, n	2.1 +/- 1.0	1.8 +/- 0.9	0.408
Medications, n	3.3 +/- 1.6	2.9 +/- 1.5	0.484
MMSE score	21.2 +/- 3.1	28.3 +/- 1.5	<0.001
MoCA score	19.6 +/- 2.7	26.5 +/- 1.8	<0.001
Fall history in previous year	8 (53.3%)	3 (20.0%)	0.058

Values are mean +/- SD or n

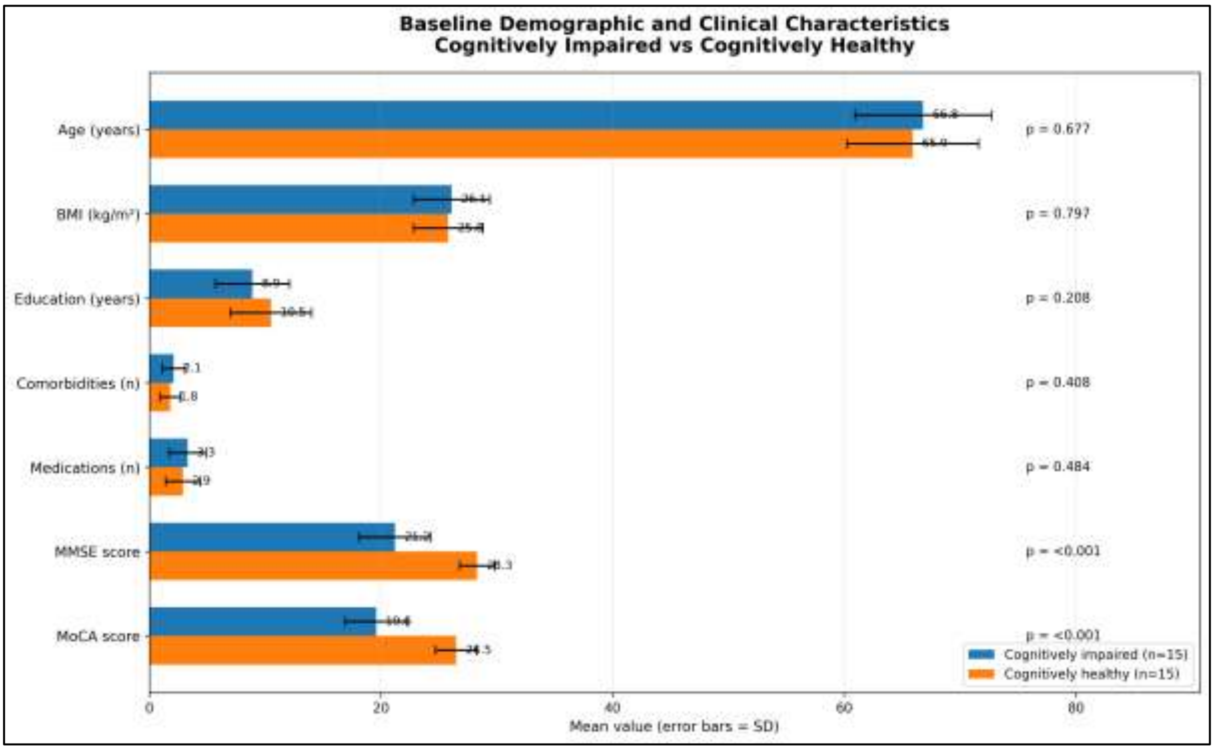

Figure 1: Baseline demographic and clinical characteristics Cognitively Impaired vs Cognitively Healthy

3.2 Cognitive Impairment and Postural Stability

Postural stability was markedly poorer in the cognitively impaired group. Mean BBS score was 8.6 points lower than in cognitively healthy participants, with a large effect size. Single-task TUG was 4.7 seconds slower, and the between-group difference increased to 7.8 seconds when serial subtraction was added. Dual-task cost was almost twice as high in the cognitively impaired group.

Table 2. Comparison of postural stability and mobility outcomes.

Outcome	Cognitively impaired (n=15)	Cognitively healthy (n=15)	Mean difference	p value	Cohen d
BBS score	43.2 +/- 6.1	51.8 +/- 3.9	-8.6	<0.001	1.68
Single-task TUG, s	14.1 +/- 2.7	9.4 +/- 1.6	4.7	<0.001	2.14
Dual-task TUG, s	18.9 +/- 3.4	11.1 +/- 2.0	7.8	<0.001	2.85
Dual-task cost, %	34.0 +/- 9.5	18.1 +/- 7.2	15.9	<0.001	1.87

BBS, Berg Balance Scale; TUG, Timed Up and Go.

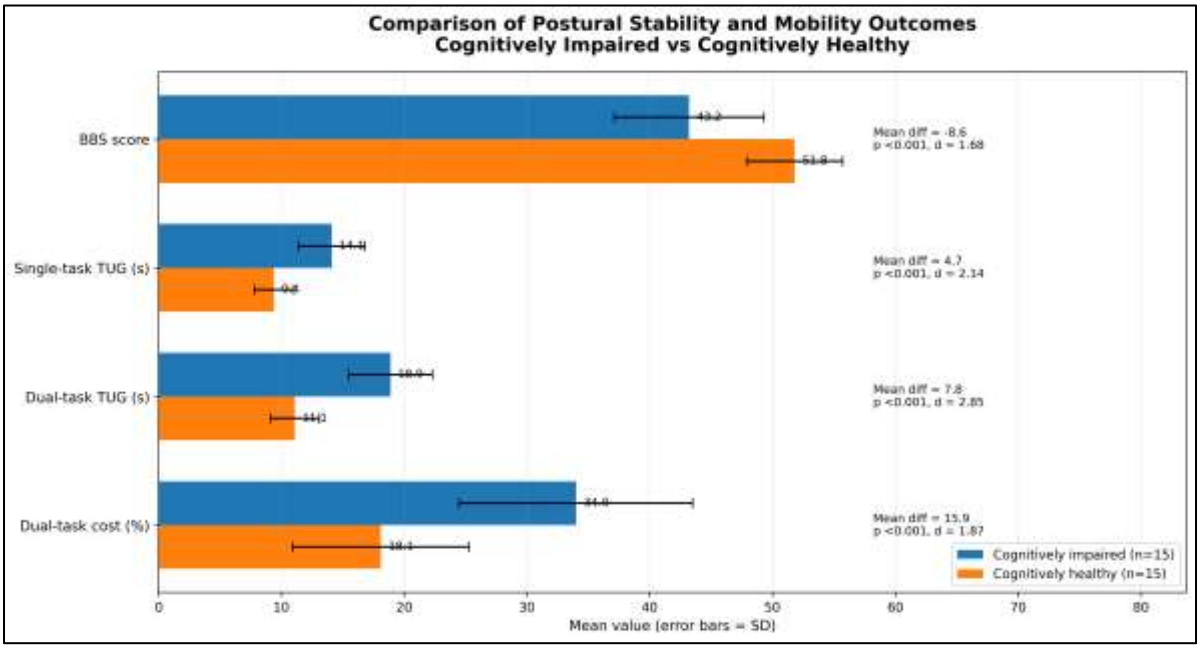

Figure 2: **Comparison of postural stability and mobility outcomes *Cognitively Impaired vs Cognitively Healthy***

3.3 Falls During Prospective Observation

During the eight-week prospective observation period, 6 of 15 cognitively impaired participants (40.0%) and 2 of 15 cognitively healthy participants (13.3%) experienced at least one fall (Fisher exact p=0.109). The impaired group sustained nine falls in total compared with two in the healthy group. Two cognitively impaired participants were recurrent fallers, whereas no recurrent falls occurred in the healthy group. Because of the small sample, the study was underpowered for fall incidence, and the finding should be interpreted as a clinically important trend rather than definitive evidence.

3.4 Cognitive Predictors of Balance

Global cognition and each examined MoCA domain were associated with balance and mobility, but executive function showed the strongest correlations. Executive function correlated positively with BBS (r=0.76) and inversely with single-task TUG (r=-0.74) and dual-task TUG (r=-0.80). Memory showed weaker relationships. In the multivariable model, executive function was the only significant independent predictor of BBS score (standardized beta=0.51, p<0.001). The overall model explained 61% of BBS variance (adjusted R2=0.58). Hierarchical analysis showed that executive function added 29% explained variance beyond demographics, memory, and attention.

Table 3. Correlations between cognitive measures and postural outcomes (n=30).

Cognitive measure	BBS r	Single-task TUG r	Dual-task TUG r
MoCA total	0.73**	-0.71**	-0.76**
Executive function	0.76**	-0.74**	-0.80**
Attention	0.64**	-0.62**	-0.67**
Memory	0.41*	-0.38*	-0.44*
Visuospatial function	0.54**	-0.51**	-0.56**
Language	0.48**	-0.45*	-0.49**

**p<0.05; **p<0.01.*

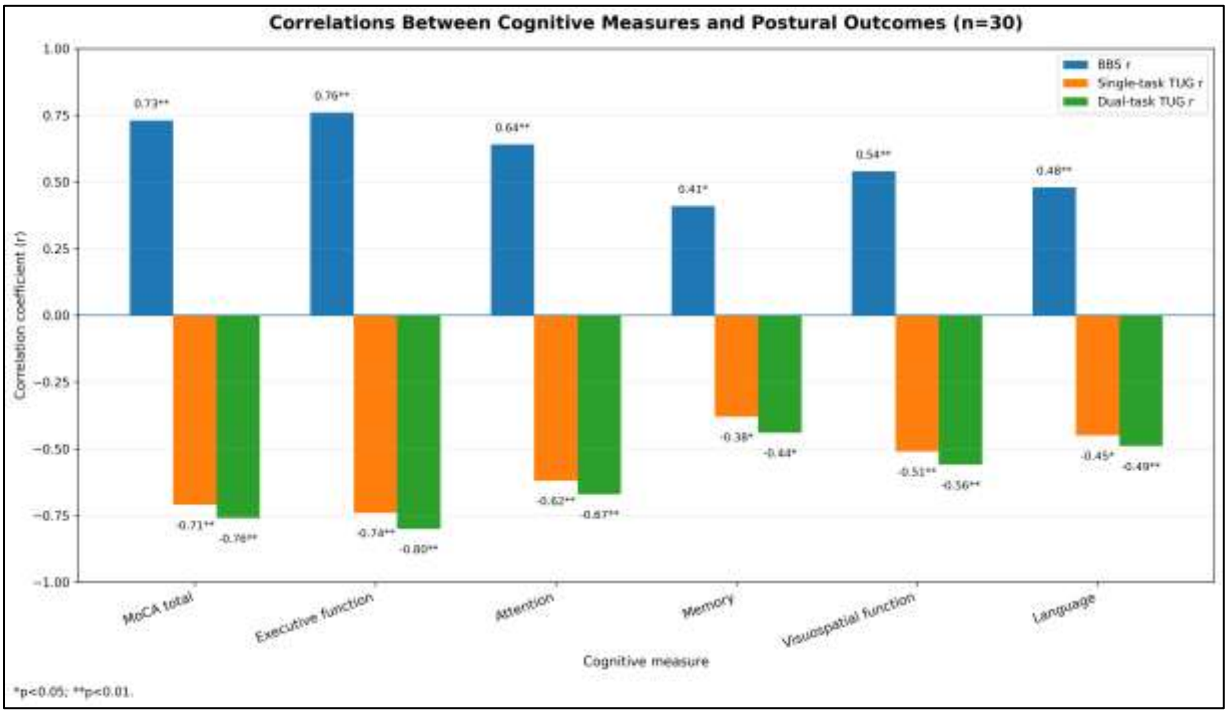

Figure 3: Correlations between cognitive measures and postural outcomes (n=30)

3.5 Intervention Effects

At baseline, the two intervention subgroups were comparable. Repeated-measures analysis demonstrated significant time-by-group interactions for BBS, single-task TUG, dual-task TUG, and dual-task cost. The combined group improved by 6.5 BBS points, exceeding the clinically important threshold reported for older populations, whereas the balance-only group improved by 2.7 points. The combined group also improved dual-task TUG by 5.2 seconds and reduced dual-task cost by 13.8 percentage points. In contrast, dual-task cost did not improve in the balance-only group.

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Table 4. Pre-intervention to post-intervention changes after eight weeks.

Outcome	Combined training (n=8)	Balance-only (n=7)	Time-by-group p	Partial eta-squared
BBS score	43.1 +/- 6.0 to 49.6 +/- 4.5	43.3 +/- 6.4 to 46.0 +/- 5.2	<0.001	0.58
Single-task TUG, s	14.2 +/- 2.4 to 11.0 +/- 1.8	13.9 +/- 3.1 to 12.7 +/- 2.6	0.012	0.39
Dual-task TUG, s	19.2 +/- 3.0 to 14.0 +/- 2.2	18.5 +/- 3.8 to 17.0 +/- 3.2	<0.001	0.55
Dual-task cost, %	35.2 +/- 9.8 to 21.4 +/- 7.0	33.1 +/- 9.1 to 34.0 +/- 10.2	0.004	0.49

BBS, Berg Balance Scale; TUG, Timed Up and Go.

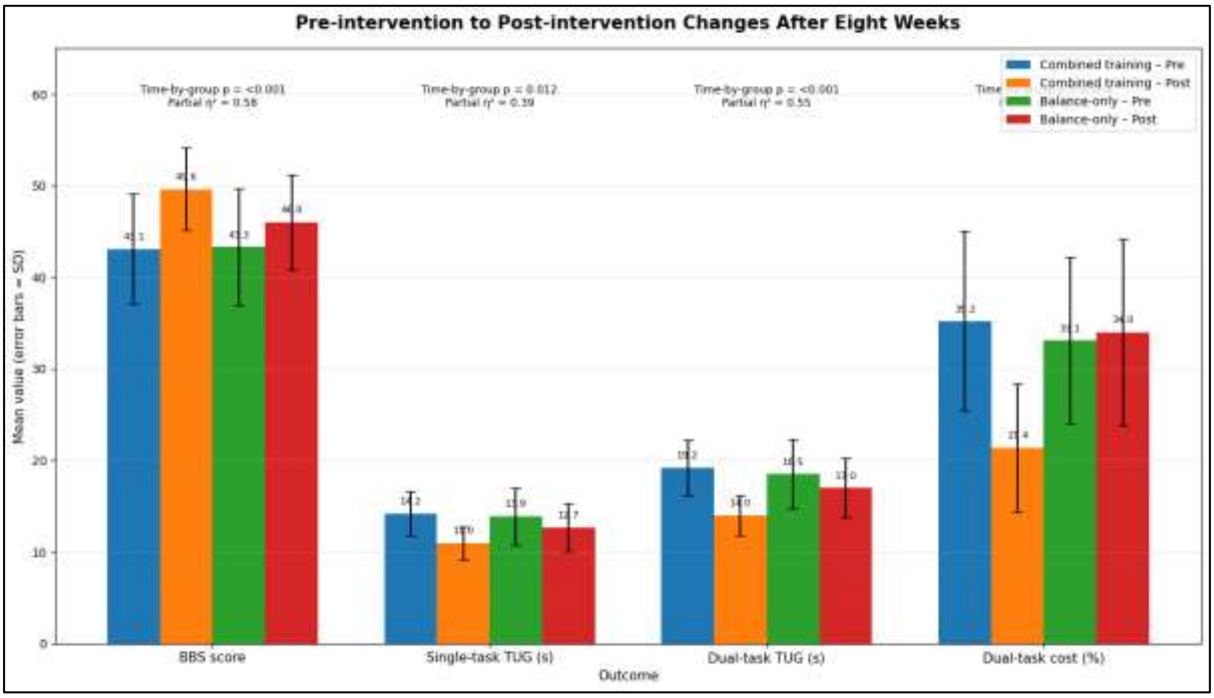

Figure 4: Pre-intervention to post-intervention changes after eight weeks

Within the combined group, participants with lower baseline executive function improved more on the BBS than those with higher executive function (+8.5 +/- 1.7 vs +4.5 +/- 1.3 points; p=0.025). During the intervention period, one participant in the combined group and four in the balance-only group fell (12.5% vs 57.1%; p=0.119). This fall comparison was exploratory and not statistically conclusive.

Attendance was high in both groups (87.5% +/- 8.1% and 89.2% +/- 7.6%, respectively), and there were no dropouts. One participant in the combined group reported mild transient muscular soreness; no serious adverse events were reported.

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4. Discussion

This two-phase pilot study produced four principal findings. First, cognitive impairment was associated with clinically and statistically poorer postural stability. Second, the magnitude of impairment increased substantially under dual-task conditions. Third, executive function was a stronger and more specific predictor of balance than memory. Fourth, combined cognitive-balance training produced larger improvements in balance and dual-task mobility than balance training alone, with high adherence and minimal adverse effects.

4.1 Cognitive Impairment and Postural Instability

The cognitively impaired group performed substantially worse on both BBS and TUG. The impaired group mean TUG time exceeded the commonly used 12-second threshold associated with elevated fall risk, and the between-group BBS difference exceeded the minimum detectable and clinically meaningful changes reported in older adults [20,21]. These findings agree with systematic reviews and observational studies showing that cognitive impairment is accompanied by poorer static and dynamic balance, increased postural sway, and higher fall risk [2,3,7,22].

The large effect sizes suggest that cognitive decline is not merely a background characteristic but a major functional determinant of balance. Shared neural networks may explain this association. Prefrontal, basal ganglia, cerebellar, and white-matter systems contribute to sensory integration, anticipatory postural adjustment, response selection, and correction of instability. Disruption of these systems by vascular or neurodegenerative pathology may simultaneously reduce cognitive flexibility and motor adaptability [12-15].

4.2 Dual-Task Interference

The near doubling of dual-task cost in cognitively impaired participants is clinically important because everyday walking rarely occurs in isolation. Conversation, navigation, calculation, environmental monitoring, and obstacle avoidance all place additional demands on attention. The present findings support the cognitive-motor interference model, in which posture and gait depend on a limited pool of attentional resources, particularly in older adults or when stability is challenged [9-11].

Single-task assessment alone may therefore underestimate fall risk. The difference between groups increased from 4.7 seconds during single-task TUG to 7.8 seconds during dual-task TUG. A simple dual-task TUG using serial subtraction or verbal fluency may reveal instability that is not evident during routine testing and may better represent real-world mobility.

4.3 Executive Function as the Dominant Cognitive Predictor

Executive function showed the strongest associations with all balance outcomes and remained the only significant independent predictor after accounting for attention, memory, age, and comorbidity. The hierarchical model further indicated that executive function explained an additional 29% of BBS variance. This pattern is consistent with evidence that executive control is central to gait adaptation, inhibition of unsafe responses, task switching, allocation of attention, and selection of compensatory postural strategies [8,23].

The weaker independent contribution of memory is conceptually plausible. Delayed recall reflects storage and retrieval, whereas immediate balance correction requires online

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monitoring, divided attention, inhibition, planning, and rapid response selection. Clinically, this suggests that memory-oriented cognitive screening alone may miss an important component of fall risk. Instruments such as the MoCA, Trail Making Test Part B, clock drawing, or verbal fluency may provide useful executive information in older adults presenting with balance problems.

4.4 Effects of Combined Cognitive-Balance Training

The most clinically actionable finding was the superior response to combined training. The combined group achieved an average 6.5-point improvement in BBS, compared with 2.7 points after balance-only training. The difference was accompanied by large interaction effects and substantial improvement in dual-task TUG and dual-task cost. These results are consistent with meta-analytic evidence that dual-task exercise improves cognitive-motor interference more effectively than single-task physical training [24].

Several mechanisms may account for this effect. Repeated practice of simultaneous cognitive and motor tasks may improve attentional allocation, task prioritization, switching, and partial automatization of postural responses. Cognitive exercises may also strengthen executive networks needed for movement planning and adaptation. The finding that participants with lower baseline executive function improved most supports the possibility that targeted training addressed the specific impairment driving instability.

The intervention was also feasible. Attendance exceeded 85%, no participants withdrew, and only one mild transient adverse event occurred. Although fewer falls occurred in the combined group, the trial was too small to establish a statistically reliable fall-prevention effect. The observed risk pattern should therefore be viewed as hypothesis-generating.

4.5 Clinical Implications

The findings support three practical changes in geriatric and rehabilitation assessment. Cognitive screening, with attention to executive function, should accompany evaluation of older adults with gait disturbance, balance impairment, or falls. Balance assessment should include a dual-task condition rather than relying exclusively on single-task TUG or static balance tests. Finally, rehabilitation programmes should deliberately integrate cognitive challenges with balance and mobility practice, especially for people with executive dysfunction.

The tested dosage of three supervised 60-minute sessions per week for eight weeks provides a preliminary model. Low-cost activities such as backward counting during tandem stance, category naming during obstacle walking, or memory tasks during weight shifting may be incorporated into physiotherapy, community fall-prevention programmes, and senior day-care settings. Caregiver-supervised practice may help extend training into the home environment, provided that safety precautions are maintained.

4.6 Strengths and Limitations

Strengths include the integration of cognitive and motor assessment, the use of both single-task and dual-task outcomes, domain-specific cognitive analysis, prospective fall monitoring, an active intervention, effect-size reporting, and feasibility assessment. The two-phase structure allowed the study to examine both association and preliminary intervention response.

The principal limitation is the small sample, particularly the intervention groups of eight and seven participants. This limited statistical power for fall outcomes, precision of subgroup estimates, and generalizability. Recruitment from a single urban setting and the inclusion of independently ambulatory participants restrict application to rural populations, people using assistive devices, and those with more severe dementia. Outcome assessors were not blinded, and follow-up ended at eight weeks, so persistence of gains is unknown. BBS and TUG are clinically useful but do not provide instrumented measures of postural sway or gait variability. Finally, the ethics approval number and full institutional details were not included in the source document and must be added before submission.

5. Conclusion

Cognitive impairment in older adults was strongly associated with reduced postural stability, slower functional mobility, and greater deterioration under dual-task conditions. Executive function was the most important cognitive predictor of balance, whereas memory did not independently explain postural performance. An eight-week combined cognitive-balance training programme produced larger gains in BBS, single-task and dual-task TUG, and dual-task cost than balance training alone, with good adherence and no serious adverse effects. These findings support integrated cognitive-motor assessment and rehabilitation, but larger, blinded, multicentre trials with longer follow-up are needed to confirm effects on falls and long-term function.

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