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# A Case Study on Relationship Between Cognitive Impairment and Postural Stability in the Elderly

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**ABSTRACT**
**Background:** Postural instability and cognitive decline are associated geriatric disorders that lower quality of life and increase the risk of falls. This study examined the relationship between balance and cognitive impairment, determined which cognitive domain is most predictive of instability, and assessed whether an eight-week combined cognitive–balance training program is better for older adults with cognitive impairment than balance training alone.
**Methods:** The Montreal Cognitive Assessment (MoCA), Berg Balance Scale (BBS), and Timed Up and Go (TUG) were among the baseline tests that thirty community-dwelling people aged 55 to 75 years (15 cognitively impaired, 15 cognitively healthy) performed under single-task and dual-task (serial subtraction) settings. Over the course of eight weeks, falls were prospectively documented. After that, the cognitively challenged individuals were randomly assigned to either balance-only training ($n = 7$) or combined cognitive–balance training ($n = 8$) for eight weeks (3 sessions per week). Changes in BBS and dual-task TUG were the main results.
**Results:** Significantly inferior balance (BBS: 43.2±6.1 vs. 51.8±3.9, $p<0.001$, $d=1.68$), slower single-task TUG (14.1±2.7 vs. 9.4±1.6 sec, $p<0.001$), and higher dual-task cost (34.0% vs. 18.1%, $p<0.001$, $d=1.87$). The incidence of falls was 40.0% vs 13.3% ($p=0.109$). The sole independent cognitive predictor of BBS was executive function ($\beta=0.51$, $p<0.001$, model $R^2=0.61$). Following the intervention, the combined training group demonstrated considerably higher gains on dual-task TUG (−5.2 vs. −1.5 sec, $p<0.001$, $\eta^2=0.55$) and BBS (+6.5 vs. +2.7 points, $p<0.001$, $\eta^2=0.58$), with a notable decrease in dual-task cost (35.2% to 21.4%) not seen in the balance-only group. The greatest beneficiaries were those with weaker baseline executive function. There were no significant adverse events and adherence was above 85%.
**Conclusions:** The most significant cognitive factor influencing postural instability in the elderly is executive impairment. When compared to traditional balance training alone, combined cognitive-balance training greatly enhances balance and dual-task performance, which supports its inclusion in fall prevention programs for older persons with cognitive decline.
**Keywords:** cognitive impairment, postural stability, elderly, falls, executive function, dual-task training

## 1. INTRODUCTION

With a projected 2.1 billion individuals over 60 by 2050, the world's population is rapidly aging. Age-related disorders, particularly cognitive decline and postural instability, are on the rise in tandem with this demographic change. These conditions often co-occur and work together to raise the risk of falls, disability, and loss of autonomy [1,2]. One in three community-dwelling individuals aged ≥65 fall each year, and the incidence increases to one in two for those over 80 [3]. Falls are the primary cause of injury-related hospitalization among older people. Co-occurring cognitive impairment increases the likelihood of falls by at least double, increases the severity of injuries including hip fractures, and reduces the success of rehabilitation [4].

Shared neural foundations underpin the connection between postural control and cognition. Both executive activities and the control of upright posture and walking include activation of the prefrontal cortex, basal ganglia, and cerebellum [5,6]. White matter hyperintensities, cortical atrophy, and neurotransmitter depletion are age-related or pathological alterations in these areas that concurrently impair cognitive and motor function. As a result, even moderate cognitive impairment (MCI) is linked to slower walking, more postural instability, and more trouble staying balanced in demanding situations [7].

The attentional requirements of postural control are made clear by dual-task paradigms, which include performing a cognitive activity and a motor task simultaneously. Excessive dual-task interference causes slower walking, more postural sway, and worse cognitive accuracy in older individuals, especially those with cognitive impairments [8]. Falls can be reliably predicted by this interference [9]. For integrating sensory data and producing suitable motor responses in real time, executive function—which includes planning, inhibition, cognitive flexibility, and working memory—seems to be the most important cognitive domain [10].

There are still a number of holes in the evidence. The precise contributions of various cognitive areas to balance impairment have not been well studied. Furthermore, while integrated cognitive-motor training has shown potential in Western populations, its effectiveness in the Indian context—where cultural and demographic factors may differ—has not been sufficiently studied. Therefore, the current study sought to: (1) compare postural stability and dual-task performance between cognitively impaired and healthy older adults; (2) determine which cognitive domain is most strongly linked to balance impairment; and (3) assess whether an eight-week combined cognitive–balance training program improves cognitively impaired individuals more than balance training alone.

## 2. METHODS

### 2.1 Study Design

A mixed-method design with two phases was used. Cognitively healthy and cognitively impaired older individuals were compared cross-sectionally in Phase I. Participants with cognitive impairments were assigned to either combined cognitive-balance training or balance-only training in Phase II, a randomized parallel-group experimental pre-test/post-test intervention trial.

### 2.2 Participants

In an Indian city, thirty community-dwelling individuals between the ages of 55 and 75 were specifically chosen from outpatient geriatric clinics, senior daycare facilities, and community outreach initiatives. Severe neurological conditions (e.g., advanced Parkinson's disease, stroke with residual hemiparesis), severe musculoskeletal disorders restricting ambulation, uncontrolled cardiovascular disease, severe uncorrected visual or vestibular impairment, and current involvement in structured exercise or cognitive rehabilitation programs were among the exclusion criteria.

Those with a confirmed diagnosis of MCI or mild dementia, or those with a score of 18–23 on the Mini-Mental State Examination (MMSE) and a score of less than 26 on the Montreal Cognitive Assessment (MoCA), made up the cognitively impaired group ($n = 15$). MMSE $\geq 24$ and MoCA $\geq 26$ were seen in the cognitively healthy group ($n = 15$). Age, gender, BMI, education, and comorbidities were matched between the groups. Written informed permission was given by each participant; verbal agreement and proxy approval from a legally appointed representative were acquired for persons with cognitive impairment. The Institutional Ethics Committee authorized the research, which complied with the Declaration of Helsinki.

### 2.3 Baseline Assessments

Structured interviews were used to gather clinical and demographic information, including fall history. The MMSE and MoCA were used to evaluate cognitive function; the MoCA domain subscores (visuospatial/executive, attention, memory, and language) were noted. The executive function measure was the Visuospatial/Executive subscore (Trail Making B, cube copy, clock drawing).

The Timed Up and Go (TUG) test and the Berg Balance Scale (BBS; 0–56, higher values indicate better balance) were used to assess postural stability. Both single-task (walk only) and dual-task (walk while serially subtracting 3s from a random number) conditions were used for TUG. The dual-task cost (DTC) was computed as

$$\text{DTC}(\%) = \frac{\text{Dual-task TUG} - \text{Single-task TUG}}{\text{Single-task TUG}} \times 100$$

Falls were prospectively documented via weekly diaries over eight weeks.

### 2.4 Randomization and Intervention

Using a computer-generated sequence and hidden opaque envelopes, the 15 cognitively challenged individuals were randomly assigned to either balance-only training ($n = 7$) or combined cognitive–balance training ($n = 8$). For eight weeks (24 sessions), both groups participated in 60-minute supervised sessions three times a week. The sessions included a 5-minute warm-up, a 50-minute main block, and a 5-minute cool-down.

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The combined training group worked on balancing exercises for 25 minutes and cognitive activities (executive function, memory, and attention exercises) for another 25 minutes. Importantly, simultaneous dual-task practice (e.g., standing on a foam pad while counting backwards, weight shifting while identifying category objects) took place during the last ten minutes of each half. For 25 minutes, the balance-only group engaged in the identical balancing exercises. The remaining 25 minutes were spent on mild range-of-motion and flexibility exercises that were never paired with a cognitive assignment. Over the course of the eight weeks, exercise difficulty was gradually raised.

### 2.5 Post-Intervention Assessments

The same battery (MMSE, MoCA, BBS, single-task TUG, dual-task TUG) was used to evaluate all 30 participants within three days of the program's conclusion. Standardized test instructions were closely adhered to in order to reduce bias, although assessors were not blinded to group allocation for the intervention arm.

### 2.6 Statistical Analysis

SPSS version 26.0 was used to analyze the data, with a significance level of $p<0.05$. Fisher's exact tests, chi-square, independent t-tests, and Mann-Whitney U tests were used to evaluate baseline group comparability. BBS, TUG, and DTC were compared across groups using independent t-tests; Cohen's d effect values were shown. The relationships between MoCA domains and balancing measurements were investigated using Pearson correlations. In addition to hierarchical regression to evaluate incremental contributions, multiple linear regression was used with BBS as the dependent variable and executive function, attention, memory, age, and comorbidities as predictors. A 2x2 repeated-measures ANOVA was used to analyze the effects of the intervention, with time (baseline, post-intervention) as the within-subjects factor and group (combined, balance-only) as the between-subjects factor. Effect sizes were measured using partial eta squared ($\eta^2$). An independent t-test was used in a subgroup analysis to assess BBS improvement within the combined group stratified by baseline executive function (low vs. high).

## 3. RESULTS

### 3.1 Baseline Characteristics

The baseline profiles are summarized in Table 1. Age, gender, BMI, education, comorbidities, and number of medicines were all closely matched between the two groups (all $p>0.05$). The MMSE (21.2±3.1 vs. 28.3±1.5, $p<0.001$) and MoCA scores (19.6±2.7 vs. 26.5±1.8, $p<0.001$) were considerably lower in the cognitively impaired group. The impaired group had a higher history of at least one fall in the previous year (53.3% vs. 20.0%, $p=0.058$).

**Table 1: Baseline demographic and clinical characteristics (n=15 per group).**

| Variable | Cognitively Impaired | Cognitively Healthy | p value |
|---|---|---|---|
| Age (years) | 66.8±5.9 | 65.9±5.7 | 0.677 |
| Gender (M/F) | 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 | 21.2±3.1 | 28.3±1.5 | <0.001 |
| MoCA | 19.6±2.7 | 26.5±1.8 | <0.001 |
| Fall history (≥1 fall in past year) | 53.3% | 20.0% | 0.058 |

### 3.2 Postural Stability and Dual-Task Performance

Across all metrics, the cognitively impaired group showed significantly worse mobility and balance (Table 2). The average difference in BBS scores was 8.6 points (43.2±6.1 vs. 51.8±3.9, p<0.001, d=1.68). TUG for a single job was 4.7 seconds slower (14.1±2.7 vs. 9.4±1.6 sec, p<0.001, d=2.14). Under dual-task, the difference between the groups grew: dual-task TUG was 18.9±3.4 vs. 11.1±2.0 sec (p<0.001, d=2.85), and the impaired group's DTC was almost twice as high (34.0±9.5% vs. 18.1±7.2%, p<0.001, d=1.87).

**Table 2: Postural stability parameters in cognitively impaired vs. healthy groups.**

| Parameter | Cognitively Impaired | Cognitively Healthy | Mean Difference (95% CI) | p value | Cohen's d |
|---|---|---|---|---|---|
| BBS (0–56) | 43.2±6.1 | 51.8±3.9 | −8.6 (−12.3 to −4.9) | <0.001 | 1.68 |
| Single-task TUG (sec) | 14.1±2.7 | 9.4±1.6 | 4.7 (2.9 to 6.5) | <0.001 | 2.14 |
| Dual-task TUG (sec) | 18.9±3.4 | 11.1±2.0 | 7.8 (5.5 to 10.1) | <0.001 | 2.85 |
| Dual-task cost (%) | 34.0±9.5 | 18.1±7.2 | 15.9 (9.8 to 22.0) | <0.001 | 1.87 |

### 3.3 Fall Incidence

40.0% (6/15) of the cognitively impaired group and 13.3% (2/15) of the healthy group fell at least once during the eight-week prospective period (p=0.109, Fisher's exact test). While no healthy individual had more than one fall, the handicapped group experienced nine falls overall, including two recurring fallers. The threefold increased fall rate is consistent with clinical importance even if it is not statistically significant in this small group.

### 3.4 Cognitive Predictors of Balance

BBS and TUG showed a strong correlation with all MoCA domain scores (Table 3). The greatest relationships were seen between executive function and BBS (r=0.76), single-task TUG (r=−0.74), and dual-task TUG (r=−0.80) (all $p<0.01$). The smallest correlations were seen in memory (r=0.41 with BBS).

**Table 3: Pearson correlations between MoCA domain scores and balance measures (n=30).**

| Cognitive Domain | BBS | Single-task TUG | Dual-task TUG |
|---|---|---|---|
| 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 | 0.54** | −0.51** | −0.56** |
| Language | 0.48** | −0.45* | −0.49** |

*p<0.05, **p<0.01.

Executive function was shown to be the sole significant independent predictor (β=0.51, p<0.001) in multiple linear regression with BBS as the dependent variable (Table 4). Age (p=0.272), comorbidities (p=0.290), attention (p=0.069), and memory (p=0.346) did not achieve significance. 61% of the variation was explained by the whole model (Adjusted R2 = 0.58). Beyond demographics, memory, and attention, adding executive function at Step 4 accounted for an additional 29% of variation ($\Delta R^2$=0.29, p<0.001), according to hierarchical regression.

**Table 4: Multiple linear regression predicting BBS.**

| Predictor | B | β | t | p value |
|---|---|---|---|---|
| Executive Function | 3.15 | 0.51 | 4.21 | <0.001 |
| Attention | 1.42 | 0.21 | 1.89 | 0.069 |
| Memory | 0.63 | 0.10 | 0.96 | 0.346 |
| Age | −0.18 | −0.14 | −1.12 | 0.272 |
| Comorbidities | −1.24 | −0.16 | −1.08 | 0.290 |

Model $R^2$=0.61, Adjusted $R^2$=0.58, $F(5,24)$=7.52, p<0.001.

### 3.5 Intervention Effects

The two intervention subgroups were comparable at baseline on all variables. A significant time×group interaction was found for BBS ($F(1,13)$=18.23, p<0.001, $\eta^2$=0.58). The combined training group improved by 6.5 points (from 43.1±6.0 to 49.6±4.5), surpassing the minimal clinically important difference of 5 points, whereas the balance-only group improved by only 2.7 points (43.3±6.4 to 46.0±5.2) (Table 5).

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**Table 5: Pre–post changes in BBS and TUG following the 8-week intervention.**

| Outcome | Combined (n=8) | Balance-only (n=7) | Time×Group F (p) | η² |
|---|---|---|---|---|
| BBS | 43.1±6.0 → 49.6±4.5 (+6.5) | 43.3±6.4 → 46.0±5.2 (+2.7) | 18.23 (<0.001) | 0.58 |
| Single-task TUG (sec) | 14.2±2.4 → 11.0±1.8 (−3.2) | 13.9±3.1 → 12.7±2.6 (−1.2) | 8.45 (0.012) | 0.39 |
| Dual-task TUG (sec) | 19.2±3.0 → 14.0±2.2 (−5.2) | 18.5±3.8 → 17.0±3.2 (−1.5) | 15.77 (<0.001) | 0.55 |
| Dual-task cost (%) | 35.2±9.8 → 21.4±7.0 (−13.8) | 33.1±9.1 → 34.0±10.2 (+0.9) | 12.34 (0.004) | 0.49 |

Both groups improved on single-task TUG, but the combined group's improvements were greater (−3.2 vs. −1.2 sec, interaction p=0.012, $\eta^2$=0.39). The combined group's dual-task TUG increased by 5.2 seconds, whereas the balance-only group's improved by 1.5 seconds (p<0.001, $\eta^2$=0.55). In the combination group, the dual-task cost decreased by 13.8 percentage points (from 35.2% to 21.4%), but in the balance-only group, it was relatively constant (from 33.1% to 34.0%).

Participants with poor baseline executive function (MoCA executive subscore ≤3) showed substantially larger BBS improvement than those with better executive function (mean +8.5 vs. +4.5 points, p=0.025), according to a pre-planned subgroup analysis within the combined training group (n=8).

With no dropouts, adherence was good in both groups (combined: 87.5%, balance-only: 89.2%). During the first week, one member of the combined group complained of slight muscular discomfort, which went away on its own. There were no significant negative incidents.

## 4. DISCUSSION

This research offers strong evidence that clinically substantial reductions in postural stability and an increased vulnerability to dual-task interference are linked to cognitive impairment, even in its modest stages. The cognitively impaired group's 4.7-second slowdown on the single-task TUG puts them firmly in the high fall-risk category (≥12 seconds) [12], and the mean BBS difference of 8.6 points between groups much surpasses the least detectable change of 5 points observed for older individuals [11]. These results are consistent with comprehensive evaluations showing that cognitive impairment almost doubles the risk of falls and poor balance [4,13].

The cognitive–motor interference theory is highly supported by the disproportionate dual-task cost shown in the cognitively impaired group (34.0% vs. 18.1%). The between-group difference in TUG increased from 4.7 to 7.8 seconds under dual-task settings, suggesting that older persons with cognitive impairments have limited reserve to sustain safe mobility when attentional resources are split. This result is consistent with the work of Woollacott and Shumway-Cook, who proposed that attentional ability is necessary for postural control and that this need rises with age and cognitive decline [8]. The ecological validity is strong since everyday ambulation seldom takes place in solitude; it requires talking, looking around, and making decisions—tasks that put people with cognitive impairments at serious danger.

Notably, executive function was shown to be the only independent cognitive predictor of balance impairment. After adjusting for demographics, memory, and attention, executive function alone explained 29% of the variation in BBS in the regression model. Memory, which is often the main focus of dementia screening, did not significantly contribute on its own. This result is in line with neuroanatomical theories where executive control and the anticipatory and reactive postural changes required for balance are mediated by the dorsolateral prefrontal cortex and its connections to the basal ganglia [5,6]. Additionally, executive testing is a useful early indicator of fall risk since research indicates that executive deficiencies may occur before quantifiable changes in balance [10]. Clinically, this implies that a crucial fall-risk factor may be missed by the popular MMSE, which underrepresents executive function; the MoCA, with its specific executive questions, is better suitable for this group.

The prospective fall findings are clinically convincing, albeit not achieving statistical significance because of the small sample size: all repeated fallers were in the cognitively impaired group, and 40% of the impaired group fell compared to 13.3% of healthy controls. This threefold rise supports the necessity for proactive management and is consistent with larger cohort studies [4].

The efficacy of combined cognitive-balance training over balance training alone is the most therapeutically useful result. While the balance-only group gained just 2.7 points, a sub-threshold shift, the combined group's mean BBS increase of 6.5 points exceeded the minimum clinically significant difference. Additionally, the dual-task cost was cut in half by the combined intervention (from 35.2% to 21.4%), whereas there was no discernible improvement in the balance-only group. This shows that successful rehabilitation requires training the simultaneous integration of motor and cognitive tasks; just improving physical balance without addressing the cognitive demands of dual-task circumstances is inadequate. These findings are consistent with meta-analyses that demonstrate that dual-task training outperforms single-task training in terms of gait and balance [14].

There are significant therapeutic ramifications to the subgroup result that those with weaker baseline executive function improved most from combination training. It implies that with focused effort, the same deficiency causing instability—executive dysfunction—can be changed. This demonstrates the need of classifying patients according to executive function in order to provide intense dual-task therapies to those who stand to benefit the most, and it supports the idea of brain plasticity in aging.

The viability and safety of combined cognitive-balance training in older Indian persons with moderate cognitive impairment are confirmed by the high adherence rates and lack of severe side effects. Motivation and retention were probably boosted by the group-based structure, range of activities, and increasing challenge.

There are restrictions on this research. The limited sample size restricts generalizability and the capacity to identify a meaningful decrease in falls, particularly during the intervention period. Despite the strict use of defined standards, assessors were not blinded, which might induce bias. Long-term maintenance of improvements was not evaluated during the eight-week follow-up. Results may not apply to more advanced impairment since those with severe dementia or those in need of walking assistance were omitted. In order to improve accessibility, future studies should investigate tele-rehabilitation or home-based delivery modalities, as well as bigger, multicenter trials with longer follow-up and blinded outcome evaluation. The reasons behind training-induced benefits may be clarified by neuroimaging and biomarker research.

## 5. CONCLUSION

Postural instability and increased dual-task interference in older adults are substantially and independently correlated with cognitive decline, especially executive dysfunction. Dual-task balance testing and executive-focused cognitive screening should be part of the routine clinical evaluation of older persons with balance issues. Particularly for those with low baseline executive function, an eight-week combined cognitive-balance training program significantly improves balance and dual-task performance more than balance training alone. These results support the inclusion of concurrent cognitive and motor tasks in fall prevention programs for older persons with cognitive impairments. The most promising approach to maintaining mobility, independence, and quality of life in our aging population is to address the interconnected deterioration of mind and body via coordinated therapies.

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