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# Relationships between Balance, Gait, and Falls in Dementia Subtypes: A Comprehensive Geriatric Assessment Study

## Demans Alt Tiplerinde Denge, Yürüyüş ve Düşmeler Arasındaki İlişkiler: Bir Ayrıntılı Geriatrik Değerlendirme Çalışması

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**ABSTRACT**

**Aim:** We aimed to examine the relationship between balance, gait, and falls across the most common dementia subtypes.

**Materials and Methods:** A total of 260 older adults diagnosed with Alzheimer's disease (AD), dementia with lewy bodies (DLB), behavioral variant frontotemporal dementia, and normal pressure hydrocephalus (NPH), along with 338 cognitively healthy controls, were included in this retrospective, cross-sectional study. Comprehensive geriatric assessment results, including comorbidities, medications, balance-gait analysis, and neurocognitive testing, were compared.

**Results:** Statistical differences were observed between controls and dementia subtypes in sex, comorbidity burden, obesity, nutritional status, frailty, sarcopenia, slow walking speed, balance, postural instability (PI), falls, and use of walking assistive devices. DLB diagnosis was associated with falls, PI, and slow walking speed [odds ratio (OR): 4.67, 95% confidence interval (CI): 1.37-15.92; p=0.014; OR: 7.38, 95% CI: 1.67-32.50; p=0.008; and OR: 5.99, 95% CI: 1.66-21.53; p=0.006, respectively]. NPH diagnosis was associated with falls, performance-oriented mobility assessment, PI, slow walking speed, and use of walking assistive devices (OR: 5.70, CI: 95% 1.83-17.70; p=0.003; OR: 0.82, CI: 95% 0.73-0.93; p<0.003; OR: 14.87, CI: 95% 3.64-60.68; p<0.001; OR: 13.37, CI: 95% 3.65-49.02; p<0.001; and OR: 4.92, CI: 95% 1.15-21.07; p<0.031, respectively).

**Conclusion:** A comprehensive assessment of balance, gait, and falls, along with understanding their links to various etiological subtypes of dementia, can be useful in many clinical settings, such as monitoring disease progression and identifying at-risk individuals.

**Keywords:** Dementia, balance; gait, falls, comprehensive geriatric assessment

**ÖZ**

**Amaç:** En sık görülen demans alt tiplerinde denge, yürüme ve düşmeler arasındaki ilişkinin incelenmesi amaçlandı.

**Gereç ve Yöntem:** Bu retrospektif, kesitsel çalışmaya Alzheimer hastalığı (AH), Lewy cisimcikli demans (LCD), davranışsal varyant frontotemporal demans ve normal basınçlı hidrosefali (NBH) tanısı almış toplam 260 yaşlı birey ile bilişsel olarak sağlıklı 338 kontrol dahil edildi. Komorbiditeler, ilaçlar, denge-yürüme analizi ve nörokognitif testleri içeren kapsamlı geriatrik değerlendirme sonuçları karşılaştırıldı.

**Bulgular:** Kontroller ile demans alt tipleri arasında cinsiyet, komorbidite yükü, obezite, beslenme durumu, kırılganlık, sarkopeni, yavaş yürüme hızı, denge, postüral instabilite (Pİ), düşmeler ve yürümeye yardımcı cihaz kullanımı açısından istatistiksel olarak anlamlı farklılıklar saptandı. LCD tanısı düşmeler, Pİ ve yavaş yürüme hızı ile ilişkiliydi [olasılık oranı (OR): 4,67, %95 güven aralığı (GA): 1,37-15,92; p=0,014; OR: 7,38, %95 GA: 1,67-32,50; p=0,008 ve OR: 5,99, %95 GA: 1,66-21,53; p=0,006, sırasıyla]. NBH tanısı; düşmeler, performansa dayalı mobilite değerlendirmesi, Pİ, yavaş yürüme hızı ve yürümeye yardımcı cihaz kullanımı ile ilişkiliydi (OR: 5,70, %95 GA: 1,83-17,70; p=0,003; OR: 0,82, %95 GA: 0,73-0,93; p<0,003; OR: 14,87, %95 GA: 3,64-60,68; p<0,001; OR: 13,37, %95 GA: 3,65-49,02; p<0,001 ve OR: 4,92, %95 GA: 1,15-21,07; p<0,031, sırasıyla).

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**Sonuç:** Denge, yürüme ve düşmelerin kapsamlı biçimde değerlendirilmesi ve bunların farklı etiyolojik demans alt tipleriyle ilişkilerinin anlaşılması; hastalık progresyonunun izlenmesi ve risk altındaki bireylerin belirlenmesi gibi birçok klinik alanda yararlı olabilir.

**Anahtar Kelimeler:** Demans, denge, yürüme, düşme, ayrıntılı geriatrik değerlendirme

## INTRODUCTION

Balance is the postural adjustment needed to keep the center of gravity over the support surface, both at rest and during activity. Both static and dynamic balance are impaired in older adults due to issues with postural control impairments[1]. Balance problems occur in 13% of patients aged 65, 35% of patients aged 75, and 46% of patients aged 85[2]. In a study conducted with older individuals, the frequency of falls was 33.6%[3]. The fall rate among older adults with dementia is twice that of a cognitively healthy population, and nearly two-thirds of individuals with dementia fall each year[4].

Postural balance problems are common in neurodegenerative disorders. Balance relies on the integration of somatosensory, vestibular, and visual inputs. A disorder in any of these systems negatively affects postural control[5]. In neurodegenerative diseases, postural abnormalities arise through numerous mechanisms, including damage to motor and sensory pathways, loss of proprioception, impaired vestibular and visual integration, changes in muscle tone, and delayed reflexes[6-8]. Postural instability (PI), often identified through physical examination, is commonly observed in Parkinson's disease and Parkinson's-plus syndromes [dementia with lewy bodies (DLB), multiple system atrophy, corticobasal degeneration, and progressive supranuclear palsy][9]. Additionally, PI aids in the diagnosis, monitoring, and therapeutic evaluation of normal-pressure hydrocephalus (NPH)[10].

The ability to walk is essential for many basic social functions needed for independence. Gait control is a complex process that involves the integration of motor, perceptual, and cognitive systems[11]. A gait disorder is defined as when the patient walks slower than expected for their age or when abnormalities in movement, such as balance issues, are observed[12]. The normal walking speed ranges from 1.2 to 1.4 m/s, although it can vary with age, sex, and body size. Speeds below 0.8 m/s are linked to limited mobility and higher mortality risk[13,14]. Walking assistive devices improve gait by alleviating pain or compensating for balance deficits. Additionally, studies have shown that using walking aids can provide benefits by reducing cognitive load[15]. However, no studies in the current literature compare the use of walking assistive devices among Alzheimer's disease (AD), DLB, frontotemporal dementia (FTD), and NPH.

Older adults with mobility limitations, such as slower walking speeds, face a higher risk of falls. Research has identified both intrinsic (individual) and extrinsic (environmental) factors that contribute to falls. However, the complexity of these factors makes it difficult to manage at-risk older adults effectively[16]. The physical consequences of falls include fractures, dislocations, sprains, bruises, open wounds, and head injuries. Indirect consequences include pressure sores, pneumonia, and other infections that may result from hospitalization. Fear of falling—defined as persistent anxiety about falls that prevents individuals from performing activities, they are capable of—relates to loss of independence, depression, low self-esteem, and diminished self-confidence. This fear is part of the long-term complications that can result from falls in older adults. An injurious fall can lead to increased caregiving needs, loss of independence, and reduced social participation. These issues impose a significant burden on older adults, their families, caregivers, and society as a whole[17].

Despite growing awareness that dementia is a global public health issue, there is currently no cure. As a result, early detection of potentially modifiable factors, such as physical performance deficits and falls, is increasingly important[18]. Although the link between dementia and balance issues in older adults is well-established, few studies have shown how different dementia subtypes impact balance, gait, and falls. Our study aimed to evaluate balance and gait in older adults with different types of dementia, identify those at high fall risk, and explore related factors.

## MATERIALS AND METHODS

### Participants

Data from 598 patients who visited our geriatric clinic for any reason and underwent a comprehensive geriatric assessment (CGA) were retrospectively and cross-sectionally analyzed from July 2018 to June 2021. This number represents the final cohort after applying all inclusion and exclusion criteria. The control group included individuals without a diagnosed dementia subtype; some participants had mild cognitive impairment clinical dementia rating scale (CDR 0.5) or very mild dementia (CDR 1.0). Patient demographics, comorbidities, medications, laboratory data, and CGA parameters were obtained from medical records. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its later amendments. The University This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its later amendments. Dokuz Eylül University Ethics Committee granted permission to carry out the study (decision no: 2021/18-14, date: 09.06.2021).. As this was a

retrospective study of patients included in our CGA database, a formal a priori power or sample-size calculation was not performed; however, all eligible patients during the study period were included to maximize statistical power. Written informed consent was obtained from all patients, and all data were anonymized before analysis.

### Exclusion Criteria

Patients under 65 years of age, those with sequelae of cerebrovascular disease, those with severe musculoskeletal, orthopedic, or peripheral neuromuscular disorders that impair walking and balance (major lower extremity amputation, recent hip fracture/surgery, severe osteoarthritic pain, spinal stenosis with neurogenic claudication), those with uncorrected severe visual impairment or active vestibular disorder, those with an acute, clinically unstable illness at the time of evaluation (e.g., decompensated heart failure, recent stroke or transient ischemic attack, subdural hematoma, delirium, gastrointestinal bleeding, sepsis, acute renal failure, acute coronary syndrome, respiratory failure, liver failure), those under the influence of significant sedative medication during the assessment, patients who are non-ambulatory or unable to stand or walk safely even with standard assistive devices, and patients who are unable to understand and follow the simple instructions required for the standard walking assessment were excluded from the study. Additionally, patients with mixed dementia and those with non-AD, non-DLB, non-basicFTD (bvFTD), non-NPH dementia, and patients with missing data in medical records were also excluded.

### Diagnosis of Dementia Subtypes

Clinical, laboratory, radiographic (cranial computed tomography, magnetic resonance imaging, or positron emission tomography), and neurocognitive tests were performed for all cases. For neurocognitive evaluation, the Montreal Cognitive Assessment (MoCA)[19], CDR[20] and the clock drawing test[21] were used.

Dementia (major neurocognitive disorder) was diagnosed based on the diagnostic criteria of Diagnostic and Statistical Manual of Mental Disorders[22]. Then, probable AD[23,24], probable DLB[25,26], bvFTD[27], and NPH[28,29] were diagnosed according to current diagnostic criteria. A geriatrician evaluated all patients, and CGA was performed. Dementia was diagnosed by a geriatrician trained in neurodegenerative diseases.

### Comprehensive Geriatric Assessment

Age, sex, education level, medications, comorbidities, Charlson Comorbidity index (CCI)[30], and falls were recorded. Polypharmacy was defined as the regular use of five or more medications, in line with common geriatric literature. Obesity was defined as body mass index (BMI) ≥30 kg/m$^2$. Mahoney and Barthel[31] and Lawton and Brody[32] scales were used to assess basic and instrumental activities of daily living. Data were recorded for measurements of Romberg, PI, balance and gait analysis performance-oriented mobility assessment (POMA)[33], and orthostatic hypotension[34,35], a routine component of physical assessment in CGA. PI was evaluated using the retropulsion test[36]. The use of a cane, crutches, a walker, and a wheelchair as assistive devices for walking was reviewed in the file. Recurrent falls were defined as two or more falls in the past year (≥2), in line with the majority of the literature[37]. Walking speed below 0.8 m/sec on the 4-meter walking test was recorded as slow walking speed[16]. Participants' nutritional status was assessed using the Mini Nutritional Assessment-Short Form (MNA-sf). Patients with an MNA-sf score of 11 or below were regarded as malnutrition or malnutrition risk. Sarcopenia was diagnosed according to the European Working Group on Sarcopenia in Older People-2[38] criteria. For muscle strength and skeletal muscle index cut-off values, the values established for the Turkish population were used[39]. A FRIED[40] score of three or higher was considered frailty. Hospital biochemistry laboratory records for all participants were also obtained. All biochemical tests were performed on a Diagnostic Modular Systems autoanalyzer (Roche E170 and P-800). 25(OH) vitamin D was measured using radioimmunoassay.

### Statistical Analysis

Statistical analyses were conducted using SPSS v 29.0 for Windows (SPSS Inc., Chicago, IL). Patients were divided into five groups: control (cognitively healthy), AD, bvFTD, DLB, and NPH. Descriptive statistics for these groups were reported as mean ± standard deviation for continuous variables and as percentages (%). Continuous variables were compared using ANOVA. Categorical variables were evaluated using Pearson's $\chi^2$ or Fisher's exact test. Logistic regression was performed to examine whether measures, including falls, POMA score, slow walking speed, PI, and use of walking assistive devices, were independently associated with each dementia subtype (compared with controls). Regression models were built using backward stepwise logistic regression. Age and sex were forced into the model; other covariates were entered using backward stepwise selection with entry $p<0.05$ and removal $p>0.10$. For each dementia subtype, the risk relative to the control group was expressed as the odds ratio (OR). Results with $p<0.05$ were considered statistically significant.

## RESULTS

After selecting participants based on the inclusion and exclusion criteria, a total of 598 older adults were included in the study: 260 with dementia (136 AD, 31 bvFTD, 51 DLB, 42 NPH) and 338 cognitively healthy individuals serving as the control group. There were statistically significant differences between the control group and the dementia subtype groups in sex, BMI,

**Table 1.** Characteristics of participants among groups

| | | Control group (n=338) | AD (n=136) | bvFTD (n=31) | DLB (n=51) | NPH (n=42) | p |
|---|---|---|---|---|---|---|---|
| **Demographics** | | | | | | | |
| Age* (years) | | 76.36 (5.77) | 75.85 (7.89) | 76.74 (8.53) | 78.11 (6.02) | 77.04 (6.53) | 0.316 |
| Sex, % male | | 35.80 | 50.70 | 61.30 | 43.10 | 45.20 | **0.006** |
| Education* (years) | | 7.80 (4.78) | 7.88 (4.65) | 6.74 (4.44) | 6.22 (4.23) | 7.02 (5.11) | 0.137 |
| Polypharmacy (%) | | 55.30 | 61.00 | 64.50 | 70.60 | 73.80 | 0.059 |
| CCI* | | 1.45 (1.37) | 1.97 (1.52) | 2.41 (1.62) | 2.33 (1.62) | 2.95 (1.69) | **<0.001** |
| Obesity % | | 31.60 | 13.50 | 29.20 | 32.40 | 50.00 | **0.001** |
| **Comorbidities** | | | | | | | |
| Osteoarthritis % | | 36.50 | 15.10 | 9.70 | 17.40 | 28.90 | **<0.001** |
| Cerebrovascular disease % | | 7.10 | 4.40 | 12.90 | 3.90 | 11.90 | 0.245 |
| Diabetes mellitus % | | 34.60 | 28.70 | 29.00 | 27.50 | 50.00 | 0.097 |
| Hypertension % | | 76.00 | 58.80 | 48.40 | 58.80 | 69.00 | **<0.001** |
| Peripheral artery disease % | | 5.30 | 4.40 | 6.50 | 3.9 | 9.5 | 0.743 |
| Congestive heart failure % | | 8.00 | 5.10 | 6.50 | 5.90 | 9.50 | 0.796 |
| Coronary artery disease % | | 21.60 | 16.20 | 12.90 | 21.60 | 19.00 | 0.581 |
| Depression % | | 30.00 | 25.70 | 35.50 | 43.10 | 31.00 | 0.222 |
| **Drugs** | | | | | | | |
| Antipsychotic % | | 2.30 | 19.90 | 12.90 | 29.40 | 14.30 | **<0.001** |
| Antidepressant % | | 10.70 | 58.20 | 64.50 | 66.70 | 45.20 | **<0.001** |
| Antihypertensive drugs % | | 63.90 | 64.70 | 58.10 | 64.70 | 81.00 | 0.236 |
| **Comprehensive geriatric assessment** | | | | | | | |
| OH % | | 32.20 | 28.60 | 23.30 | 38.30 | 20.00 | 0.308 |
| Malnutrition and malnutrition risk % | | 23.20 | 45.90 | 38.70 | 60.80 | 39.00 | **<0.001** |
| Frailty % | | 25.90 | 38.50 | 45.50 | 56.30 | 48.60 | **<0.001** |
| Sarcopenia confirmed % | | 4.20 | 26.00 | 10.00 | 12.90 | 17.90 | **<0.001** |
| CDR % | 0.0 | 55.30 | 5.30 | 0 | 0 | 17.10 | **<0.001** |
| | 0.5 | 34.30 | 25.00 | 16.70 | 16.30 | 34.10 | |
| | 1.0 | 10.40 | 34.10 | 60.00 | 34.70 | 36.60 | |
| | 2.0 | 0 | 25.80 | 20.00 | 36.70 | 7.30 | |
| | 3.0 | 0 | 9.80 | 3.30 | 12.20 | 4.90 | |
| Clock drawing test* | | 4.43 (0.90) | 2.80 (1.71) | 2.81 (1.46) | 1.85 (1.45) | 3.15 (1.79) | **<0.001** |
| MoCA* | | 24.26 (3.34) | 15.82 (6.79) | 19.87 (5.19) | 13.66 (4.45) | 20.81 (4.04) | **<0.001** |
| BADL* | | 94.06 (7.55) | 89.08 (14.94) | 91.12 (9.37) | 79.11 (21.41) | 82.26 (20.66) | **<0.001** |
| IADL* | | 19.26 (4.37) | 12.41 (6.33) | 12.35 (6.37) | 9.66 (6.24) | 14.35 (6.64) | **<0.001** |
| **Laboratory** | | | | | | | |
| Hemoglobin* | | 12.84 (1.26) | 12.97 (1.32) | 13.29 (1.27) | 12.73 (1.16) | 12.59 (1.61) | 0.146 |
| 25 (OH) vit D* | | 21.89 (11.58) | 19.28 (10.46) | 21.94 (11.72) | 20.40 (12.08) | 20.24 (9.28) | 0.217 |
| Vitamin B12* | | 398.97 (225.80) | 378.16 (230.25) | 339.06 (178.16) | 327.69 (164.50) | 416.00 (268.28) | 0.152 |
| TSH* | | 1.96 (3.91) | 4.74 (35.93) | 1.32 (1.45) | 1.44 (0.79) | 1.45 (1.35) | 0.557 |
| eGFR* | | 70.79 (16.70) | 71.93 (18.25) | 77.66 (23.01) | 72.06 (18.19) | 70.96 (22.47) | 0.384 |
| **Gait and balance** | | | | | | | |
| Slow gait speed % | | 29.70 | 41.80 | 32.30 | 62.50 | 81.00 | **<0.001** |
| POMA* | | 25.11 (4.11) | 23.77 (5.29) | 24.61 (3.90) | 21.64 (7.15) | 20.78 (6.64) | **<0.001** |

**Table 1.** Continued

| | Control group (n=338) | AD (n=136) | bvFTD (n=31) | DLB (n=51) | NPH (n=42) | p |
|---|---|---|---|---|---|---|
| Postural instability % | 4.70 | 20.60 | 22.60 | 39.20 | 45.20 | **<0.001** |
| Falls % | 31.40 | 29.40 | 41.90 | 68.60 | 66.70 | **<0.001** |
| Walking assistive devices % | 14.10 | 11.50 | 7.70 | 22.50 | 30.80 | 0.023 |

*Mean (SD); AD: Alzheimer's disease, BADL: Basic activities of daily living, bvFTD: Behavioral variant frontotemporal dementia, CCI: Charlson Comorbidity index, CDR: Clinical dementia rating, DLB: Dementia with lewy bodies, eGFR: Estimated glomerular filtration rate, IADL: Instrumental activities of daily living, MoCA: Montreal cognitive assessment, NPH: Normal pressure hydrocephalus, OH: Orthostatic hypotension, POMA: Performance-oriented mobility assessment, SD: Standard deviation, TSH: Thyroid-stimulating hormone

obesity, malnutrition, malnutrition risk, frailty, sarcopenia, slow walking speed, POMA, PI, falls, and use of walking assistive devices (Table 1).

Additionally, the use of antidepressant and antipsychotic medications was significantly lower in the control group compared to the dementia groups (p<0.001; p<0.001, respectively). Laboratory data (hemoglobin, 25(OH) vitamin D, vitamin B12, thyroid-stimulating hormone, and estimated glomerular filtration rate showed no significant differences between the control and dementia subgroups. The results of activities of daily living, MoCA, CDR, and clock drawing tests, which are part of the neurocognitive assessment, showed significant differences between the control and dementia subgroups (p<0.001 for each).

According to the regression analysis, no significant relationship was found between falls, POMA, PI, slow walking speed, use of a walking assistive device, and the AD and bvFTD groups, separately.

DLB was significantly associated with falls, PI, and slow walking speed (OR: 4.67, CI: 95%: 1.37-15.92; p=0.014; OR: 7.38, CI: 95%: 1.67-32.50; p=0.008; and OR: 5.99, CI: 95%: 1.66-21.53; p=0.006, respectively) (Table 2).

NPH was significantly associated with falls, POMA, PI, slow walking speed, and the use of a walking assistive device (OR: 5.70 CI: 95% 1.83-17.70; p=0.003; OR: 0.82 CI: 95% 0.73-0.93; p<0.003; OR: 14.87 CI: 95% 3.64-60.68; p<0.001, OR: 13.37 CI: 95% 3.65-49.02; p<0.001; and OR: 4.92 CI: 95% 1.15-21.07; p<0.031, respectively) (Table 2). In the fully adjusted analyses, AS and FTD were not significantly associated with the outcomes. Full model results, including ORs and 95% CIs for all dementia subtypes, are provided in Supplementary Table S1.

## DISCUSSION

In this cross-sectional and retrospective study, we observed that older adults with AD, bvFTD, DLB, and NPH had a higher prevalence of malnutrition and malnutrition risk, frailty, sarcopenia, slow walking speed, PI, falls, use of walking aids, and use of antidepressants and antipsychotics, along with lower POMA scores compared to cognitively healthy older adults. We also demonstrated that DLB was associated with falls, PI, and slow walking speed. In contrast, NPH was associated with falls, PI, lower POMA scores, slow walking speed, and use of walking assistive devices.

Current evidence highlights the significant role of multiple cognitive domains, especially attention and executive functions, in explaining the high variability in mobility performance among cognitively healthy and dementia-diagnosed older adults[41]. The relationship between motor and cognitive impairments has garnered significant interest from researchers and healthcare providers because it could facilitate early detection of those at highest risk for dementia and enable personalized interventions to best preserve cognitive function best[42]. Falls are a significant public health issue worldwide due

**Table 2.** Comparison of falls, POMA scores, postural instability, slow gait speed, and use of walking assistive devices across DLB and NPH patients

| | Control | DLB | | | NPH | | |
|---|---|---|---|---|---|---|---|
| | OR (95% CI) | OR | 95% CI | p | OR | 95% CI | p |
| Falls | Reference (control) | **4.671** | 1.371-15.920 | **0.014** | **5.706** | 1.838-17.709 | **0.003** |
| POMA | | 1.039 | 0.905-1.194 | 0.588 | **0.827** | 0.731-0.937 | **0.003** |
| Postural instability | | **7.385** | 1.678-32.502 | **0.008** | **14.870** | 3.644-60.684 | **<0.001** |
| Slow gait speed | | **5.994** | 1.668-21.533 | **0.006** | 13.375 | 3.650-49.020 | **<0.001** |
| Walking assistive device | | 0.895 | 0.171-4.698 | 0.896 | **4.928** | 1.152-21.072 | **0.031** |

CI: Confidence interval, DLB: Dementia with lewy bodies, NPH: Normal pressure hydrocephalus, OR: Odds ratio, POMA: Performance-oriented mobility assessment

Regression model: Age, sex, obesity, sarcopenia, malnutrition, hypertension, osteoarthritis, antidepressant, and antipsychotic use for POMA (continuous), OR represents change in odds of being in the dementia group per 1-point higher POMA score. OR <1 indicates lower POMA scores (worse mobility) are associated with higher odds of dementia

to their high prevalence, morbidity, mortality, healthcare costs, and clinical complications. Many subtypes of dementia exhibit motor impairment as the disease progresses[43]. The occurrence of falls and fall injuries increases with age and is higher in individuals with dementia. All types of dementia are associated with varying degrees of reduced physical and cognitive abilities. In a study by Farup et al.[44] the prevalence of falls across dementia subtypes was 22.4% in early-onset AD, 33.6% in late-onset AD, 50.6% in mixed [AD and vascular dementia (VAD)], 55.3% in VAD, 28.6% in FTD, and 55% in DLB. They suggested that age, comorbidities, and dementia features help explain the differences in fall rates among dementia groups.

In our study, we observed that DLB was associated with falls, PI, and slow walking speed. This finding is consistent with previous studies demonstrating greater gait impairment in DLB than in ADClick or tap here to enter text. DLB patients have extrapyramidal symptoms and signs (akinesia, rigidity) that slow walking and significantly alter spatial and temporal parameters, such as step length[45].

Our results indicate that NPH is associated with falls, PI, slow walking speed, and use of walking aids. It is well known that urinary incontinence and cognitive impairment in NPH patients are accompanied by gait apraxia and falls[46]. Therefore, this is a predictable outcome. Gait disturbance in NPH typically represents a hypokinetic gait with slow walking speed, reduced step length, and increased step width[47]. Our research revealed a link between NPH and low POMA scores. The stronger association of NPH with slow gait and PI, compared with DLB, likely reflects differences in their pathophysiology. In NPH, frontal-subcortical disconnection causes a hypokinetic, short-stepped, and wide-based gait with impaired postural reflexes, whereas DLB gait impairment is mainly due to extrapyramidal motor dysfunction[25,28]. Although our study did not categorize patients by disease stage, gait and balance disturbances generally worsen as the disease progresses in both conditions. Several studies support the finding that POMA (gait, balance, and total) scores are lower in patients diagnosed with idiopathic NPH and may improve with therapeutic cerebrospinal fluid drainage[48]. Although previous studies have suggested that POMA performance is linked to falls in patients with dementia, our cross-sectional design does not allow direct conclusions about the test's predictive (prognostic) value. Nevertheless, our findings emphasize the association between lower POMA scores and a history of falls, underscoring its usefulness as a practical tool for evaluating balance and gait in older adults with dementia. It is important to note that performance on this test depends heavily on participants' understanding and adherence to instructions[49].

Our regression results did not show a significant association between AD diagnosis and factors such as falls, gait issues, or balance problems. In a cohort study of 11,466 people, Sverdrup et al.[50] found that older adults with AD exhibited better physical performance than those with other forms of dementia subtypes. This is consistent with our results. Furthermore, studies highlight the relationship between AD and physical performance decline, showing that among patients with mild cognitive impairment, those with gait, balance, and motor issues are at greater risk of developing AD[51]. Another study supports the notion that gait disturbance in AD is associated with disease stage. Ala and Frey investigated documented gait disturbance in patients with autopsy-proven AD. They found that 16% and 32% of patients with moderate and severe disease, respectively, experienced gait disturbances, while none of the patients with mild AD reported them[52]. Verghese et al.[53] showed in their research that walking speed was slower in patients with AD who had the Apolipoprotein E4 genotype and declined more rapidly than in those without this allele. The lack of significant differences in fall and gait parameters between the control group and the AD or bvFTD groups may be affected by patient selection. Our cohort included patients with mild-to-moderate disease severity, and those with severe functional impairments were less common. Additionally, bvFTD patients mainly exhibit behavioral and executive symptoms rather than motor deficits, which might explain the lack of significant associations. Selection criteria and the exclusion of patients with vascular or mixed dementias may also have contributed to these results.

Our findings show no association between bvFTD diagnosis and falls, gait, or balance problems. Patients with bvFTD, a subtype of frontotemporal lobar degeneration, typically present with a neurobehavioral syndrome. Clinical diagnostic criteria for bvFTD include early declines in social and interpersonal behavior, early impairments in personal behavior regulation, emotional blunting, and loss of insight. Although motor and gait abnormalities have been reported, they usually do not involve a frontal gait pattern. On the other hand, Samra et al.[54] reported that bvFTD patients experienced stepping difficulties more frequently than those with ADClick or tap here to enter text. Some patients diagnosed with DLB or bvFTD had a CDR stage of 0. This likely reflects CDR's limitations in detecting early-stage or non-amnestic presentations and underscores the importance of interpreting CDR stage alongside other cognitive and functional assessments in these groups.

Patients with VAD or mixed dementia were excluded from our study. This is because recent epidemiological and clinicopathological data suggest a significant overlap between cerebrovascular disease and AD, and that both pathologies have additive or synergistic effects[55]. Cases of true VaD without

significant mobility issues are rare, and diagnosing VaD overall remains challenging due to the absence of validated criteria and variability in clinical presentation[56]. We believe this situation could confuse distinguishing between working groups.

### Study Limitations

Our current study has several limitations. First, because it is cross-sectional and retrospective, we cannot establish a cause-and-effect relationship. Although we aimed to exclude patients with VaD, we may have overlooked individuals with subclinical cerebrovascular disease. We acknowledge that more comprehensive device-assisted analyses are needed to enable sensitive quantitative gait assessment in clinical practice. This study assessed balance and gait using standard clinical tools such as the POMA, Romberg test, walking speed, and the Retropulsion test. Future research using dual-task or sensor-based gait analysis might provide more sensitive measures of gait issues in dementia.

Beyond its limitations, our study also has notable strengths. It is among the few to assess multiple dementia subtypes within a single geriatric group using CGA measures. Assessing balance, gait, falls, nutritional status, frailty, sarcopenia, and functional abilities provides a comprehensive view of mobility and functional impairment across dementia subtypes. These strengths enhance the clinical relevance of our results and lay a strong foundation for future research.

## CONCLUSION

The ability to move independently greatly enhances overall well-being and autonomy in older adults. Enhancing our understanding of gait and balance disorders is crucial for optimizing health and function in seniors. This study contributes to the literature by examining multiple dementia subtypes within a single geriatric cohort using CGA parameters, enabling direct comparison of balance, gait, and fall-related features across subtypes. A detailed assessment of gait and balance, along with an understanding of their associations with various etiological subtypes of dementia, may aid early diagnosis and disease monitoring through cost-effective evaluations. Balance-gait disturbances and falls may serve as early markers to distinguish between dementia subtypes; however, larger future cohort studies with more participants are needed to confirm these findings.

### Ethics

**Ethics Committee Approval:** This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its later amendments. Dokuz Eylül University Ethics Committee granted permission to carry out the study (decision no: 2021/18-14, date: 09.06.2021).

**Informed Consent:** Written informed consent was obtained from all patients, and all data were anonymized before analysis.

### Footnotes

### Authorship Contributions

Concept: F.M., A.T.I., Design: D.K., A.T.I., Data Collection or Processing: F.M., Analysis or Interpretation: F.S.D., A.T.I., Literature Search: F.M., F.S.D., D.K., Writing: F.M., F.S.D., A.T.I.

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