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Relationship Between Balance, Gait, and Activities of Daily Living in Older Adults With Dementia

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Abstract

Introduction: Gait characteristics are closely associated with executive functions including basic and high-level cognitive processes such as attention, working memory, decision-making, and problem-solving. Impaired cognitive function resulting from dementia is associated with loss of balance and poor activities of daily living (ADLs). If associations between gait parameters, balance, and ADLs are observed, then quantitative gait analysis may be optimal for reinforcing balance and ADL assessments in people with dementia. This study aimed to determine the association between balance, gait, and ADLs in older adults with dementia. **Materials and Methods:** A cross-sectional study was conducted in 46 older adults who have been diagnosed with dementia. Measurements including the Mini-Mental Statement Examination-Korean version (MMSE-K), Berg Balance Scale (BBS), 10-meter walk test (10MWT), Modified Barthel index (MBI), and GAITRite were used to assess cognitive function, balance, walking speed, ADLs, and gait parameters, respectively. The Pearson product correlation coefficient (*r*) was used for correlation analysis. **Results and Discussion:** Among the gait parameters, velocity was positively associated with the BBS, 10MWT, and MBI ($r = 0.341$-0.516, $P > .05$). Step length ($r = 0.301$-0.586, $P > .05$), stride length ($r = 0.329$-0.580, $P > .05$), and walk ratio ($r = 0.324$-0.556, $P > .05$) were positively associated with the MMSE-K, BBS, 10MWT, and MBI. A moderate positive association between single support time and MBI was observed ($r = 0.308$, $P = .039$). Additionally, a moderate negative association between double support time and the MBI was observed ($r = -0.349$, $P = .019$). This study presents the first empirical evidence on the association between balance, gait, and ADLs in older adults with dementia. **Conclusions:** This study identified important associations between balance, gait, and ADL assessments in people with dementia. Further studies involving targeted interventions addressing gait parameters and improving balance and functional performance in people with dementia are required in the future.

Keywords
activities of daily living, balance, dementia, gait parameters, older adults

Introduction

Dementia is a neurological syndrome characterized by progressive deterioration in global cognitive function, self-care function, and social behavior.[1] Approximately 60% and 20% of people with dementia have Alzheimer disease (a neurodegenerative process) and vascular dementia (repeated infarcts in the brain tissue), respectively,[2] while mixed types such as Alzheimer/vascular dementia and dementia with Lewy bodies are the other common presentations. Dementia is significantly more common in older people compared to younger people.[3] The worldwide prevalence of people with dementia is expected to increase almost twice every 20 years, reaching 40.8 million in 2020 and 90.3 million in 2040.[4] Therefore, dementia is recognized as a global public health problem worldwide.[5]

Dementia affects balance, gait performance, and activities of daily living (ADLs).[6,7] Cognitive impairment is associated with a lack of balance due to a reduction in a person's ability to problem-solve, make decisions, and perform tasks

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concurrently. Bruce-Keller et al revealed that a loss of balance is significantly more common in people with early-stage dementia compared to healthy adults.[8] Moreover, several studies demonstrated that deficits in motor ability, specifically gait disturbance, may be present in early-stage dementia.[9,10] Gait performance is a complex process that requires the integration of both sensorimotor and cognitive systems. However, delayed cognitive processing may be affected to compensate for the impairments of sensorimotor systems and negotiation of motor planning and reactions required for maintaining balance in unstable environments.[11] Several investigators have reported a clear association between cognitive impairments and gait disturbance in older adults.[5,12] Additionally, dementia is accompanied by increased functional disability over time, associated with loss of independence, ultimately leading to decline in ADLs, including basic ADLs (B-ADLs) and instrumental ADLs (I-ADLs).[13] The deterioration in B-ADLs impacts the quality of life of caregivers and is a significant burden on health care systems.[14]

Recently, several studies reported that impairments of balance and gait have consistently been associated with cognitive impairment and are also known risk factors for falls.[11,12,15] Taylor et al found that 138 cognitively impaired older adults showed worse balance performance (sway on floor, sway on foam, controlled leaning balance, and near tandem standing ability) than 276 age- and sex-matched cognitively intact community-dwelling older adults.[11] Savica et al showed that spatiotemporal parameters of gait were associated with a significant decline in global cognition and in specific domains including memory, executive function, visuospatial, and language in 3426 cognitively normal subjects.[12] A study related with ADLs showed a linear association between I-ADLs and Mini-Mental Statement Examination (MMSE) in 107 people with Alzheimer disease at a 6- and 12-month follow-up.[15]

Several researchers have studied the association between cognitive function, balance, and gait. However, to the best of our knowledge, a previous study investigating the association between balance, ADLs, and gait in older adults with dementia has not been conducted yet. Furthermore, if associations between gait parameters, balance, and ADLs exist, then quantitative gait analysis may be optimal for reinforcing balance and ADL assessments in people with dementia. Therefore, this study aimed to determine the association between balance, gait, and ADLs in older adults with dementia. Based on the background information on balance, gait, and ADLs in people with dementia, it was hypothesized that cognition, balance, and ADLs are associated with gait parameters that could predict balance and ADLs in people with dementia.

Methods

Patients

Forty-six patients diagnosed with dementia (of various etiologies) in their records were recruited from an elderly daycare center. A sample size of 46 was derived using α (2-tailed; 0.05), power (0.95), or β (0.05) and expected correlation coefficient (0.50) values according to the study by Hulley et al.[16] The inclusion criteria were as follows: patients aged greater than 55 years, patients diagnosed with dementia according to the Clinical Dementia Rating Scale and *International Classification of Diseases-Tenth Edition*, patients with MMSE-Korean version (MMSE-K) score of less than 23, and patients who were able to walk 10 m with or without a walking aid. The exclusion criteria were as follows: patients who were medically unstable, patients with neuropsychotic condition or other neurological diagnoses associated with cognitive impairment, and patients with severe communication problems and cardiopulmonary diseases. Details about the patients' characteristics are presented in Table 1. All patients and their families were informed about the detailed purpose and procedures of the study prior to participation, and all patients subsequently provided informed consent for inclusion in the study. Experimental procedures used in this study were approved and monitored by the Institutional Review Board of Woosuk University (WS-2019-13).

Table 1. Demographic and Clinical Characteristics of Patients.

Characteristics	Data (N = 46)
Age (years)	81.8 ± 7.6[a]
Height (cm)	158.4 ± 9.9
Weight (kg)	55.6 ± 9.9
Female/male	26 (56.5)/20 (43.5)[b]
MMSE-K	15.4 ± 5.1 (4-23)[c]
Mild cognitive impairment	7 (15.2%)[b]
Moderate cognitive impairment	32 (69.6%)
Severe cognitive impairment	7 (15.2%)
BBS	33.7 ± 10.9 (9-53)[c]
10MWT (m/sec)	0.76 ± 0.30 (0.24-1.41)
MBI	64.3 ± 21.4 (8-93)

Abbreviations: BBS, Berg Balance Scale; MBI, Modified Barthel Index; MMSE-K, Mini-Mental Statement Examination (Korean version); 10MWT, 10-Meter Walk Test.
[a]Data are mean ± SD.
[b]n (%).
[c]Mean ± SD (range).

Experimental Procedures

All patients who met the inclusion criteria were allocated in this study. All measurements were conducted in a measuring room to exclude environment impacts. Demographic data including age, height, and weight were measured by health care professionals in the facility (elderly daycare center). Measurement tools for examining the cognition, balance, walking speed, ADLs, and gait included MMSE-K, Berg Balance Scale (BBS), 10-meter walk test (10MWT), Modified Barthel index (MBI), and GAITRite, respectively. The sequence of the examination occasions was randomized by drawing lots of 5 pencils with the tests written to prevent bias and minimize learning effect. Measurement data were obtained by a well-trained physical therapist (working for more than 10 years) in the facility, and the results were not described until the examinations were completed. During the tests, all measurements were performed twice and with a resting time of 3 to 5 minutes on a chair between examinations to prevent fatigue; the average measurement was used for the data analysis.

Measurements

Mini-mental state examination. The MMSE-K was developed to evaluate cognitive function. This assessment tool comprises 30 subtitles on cognitive fields including orientation (time and place), memory (registration and recall), attention and calculation, language function, and understanding and judgment. Scores were adjusted according to the patient's educational level and ranged from 0 to 30. A higher score indicates better cognitive function, and a lower score indicates poor function. In a previous study, a total of 19 to 24 points were required to establish the diagnosis of an impairment of cognitive function. The MMSE-K is advantageous because it has strong or excellent test–retest reliability ($r = 0.76$-0.90), inter-rater reliability (intraclass correlation coefficient [ICC] = 0.94-0.99), and concurrent validity ($r = 0.83$-0.92) for the evaluation of cognitive function in mild cognitive impairment, Alzheimer disease, and healthy adults.[17]

Berg balance scale. The BBS evaluates the balance ability of older adults based on the performance of various functional tasks. The BBS comprises 14 functional items such as sitting to standing, standing unsupported, chair transfers, standing with eye closed, tandem standing, and single leg standing; 0 to 4 points are given for each item, and the total score is 56. A score of 0 indicates a lack of ability to execute the task, while a score of 4 shows the achievement of the task successfully according to the programmed criterion. A higher score indicates better balance ability. Good to excellent test–retest and inter-rater reliability (ICC = 0.72-0.99) was reported among people with dementia.[18,19]

10-meter walk test. The 10MWT is usually used for the assessment of walking speed. It requires a 16-m walking path including 3 m for acceleration and deceleration at either side. Tape marks 3 meters before and after the 10-m path. The researcher instructed the patients to not stop before achieving the end line. This assessment tool requires significantly little equipment and is easily performed. Patients were instructed to walk at their self-selected speed. The researcher started the stopwatch as the patient passed a small, discrete, 3-m mark on the floor and stopped at a similar 10-m mark, so that only the mid 10-m walking was timed, thus excluding the acceleration and deceleration phases. The time of completion at the 10-m mark was measured by the researcher. Walking speed (meters/second) was calculated by dividing 10 m by the time measured. The 10MWT is a valid and reliable measurement because it has strong concurrent validity ($r = 0.74$) and excellent test–retest reliability (ICC = 0.90) in older adults.[20]

Modified Barthel index. The MBI is a measurement tool used to evaluate the level of functional independence in ADLs. This measurement tool comprises 10 subitems including feeding, transfer, personal hygiene, getting on/off toilet, bathing, walking on leveled ground, climbing stairs, dressing, and bowel and bladder control. Measurements were taken by family members or caregivers of those who joined the daycare center and by the personal care workers, nurses, therapists, and staff of those living in the residential care facility. Moreover, direct observations were conducted by the researcher as needed. Each item was given a score between 0 and 10, with a total score of 100. A higher score indicates higher levels of functional independence. The test–retest reliability has been shown to be moderate to strong (κ coefficients = 0.63-1.00) among local older adults.[21]

Gait measurement. GAITRite (AP1105, GAITRite EWPV CIR) instrumentation is used to evaluate gait parameters. We collected the gait parameters from GAITRite. The GAITRite comprises an electronic walkway of 4.88 m in length, 0.061 m in width, and 0.0064 m in height, and the GAITRite software (version 4.0) was used to analyze all the temporal and spatial parameters of gait to quantify the gait parameters. Data were sampled at 120 Hz and stored for subsequent analysis in a well-matched computer connected to a pressure-sensitive walkway. Each patient was instructed to walk at a comfortable pace without gait aids on the walkway, initiating and terminating their walk 1.5 m before and after the walkway, respectively. In this study, gait measurement focused on variable parameters of gait including individual spatial (step length and stride length), temporal (cadence, step time, swing time, stance time, single support time, and double support time), temporophasic (swing % of phase and stance % of phase), and spatiotemporal (velocity and walk ratio [WR]) parameters. Specific parameters of WR among the gait parameters should be provided. Walk ratio is calculated by dividing the step length with cadence.[22] Sekiya et al suggested that the WR can be an index for describing gait pattern or temporal and spatial coordination at a variety of speed. In other words, WR assesses the quality of gait, while gait speed measures performance. A low ratio suggests that an individual takes small steps and has a high step frequency. A higher ratio indicates that the individual takes longer steps, holds a lower frequency, or both. The GAITRite is a valid and reliable tool that has excellent validity (ICC > 0.93) and reliability (ICC > 0.94) related to walking speed, cadence, and step time.[23]

Data analyses. Descriptive statistics include means and standard deviations. Pearson product correlation coefficient was used to investigate the associations between cognition, balance, gait, and ADLs measured by MMSE-K, BBS, 10MWT, MBI, and GAITRite. The Pearson product correlation coefficient, r, can take a range of values from 1 to -1, where 1 is total positive association, 0 is no linear association, and -1 is total negative association. An r value between 1 and 0.7 is defined as strong association, a value in the range of 0.7-0.3 indicates a moderate association, and a value in the range of 0.3-0.1 indicates a weak association. Finally, r values less than 0.1 were considered as negligible. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) for Windows version 18.0 (SPSS Inc), and a P value < .05 was considered statistically significant.

Results

Table 2 shows the associations between total MMSE-K, BBS, 10MWT, and MBI scores, representing cognition, balance, walking speed, and ADLs, respectively. A significant association was observed between MMSE-K and MBI ($r = 0.394$, $P = .007$), indicating a moderate positive association, while no significant associations were observed between MMSE-K and BBS ($r = -0.100$, $P = .947$) and 10MWT ($r = -0.047$, $P = .756$). A significant moderate negative association between BBS and 10MWT was observed ($r = 0.710$, $P = .000$). However, there was no significant association between BBS and MBI ($r = 0.263$, $P = .085$) and MBI and 10MWT ($r = 0.154$, $P = .306$; Table 2).

Associations between the gait parameters and MMSE-K, BBS, 10MWT, and MBI are presented in Table 3. The velocity of gait parameters was significantly associated with BBS ($r = 0.341$, $P = .025$), 10MWT ($r = 0.448$, $P = .001$), and MBI ($r = 0.516$, $P = .000$), indicating moderate positive associations. Step length and stride length in gait parameters were significantly associated (moderate association) with all of the other outcome measures. Step length was positively associated with MMSE-K ($r = 0.301$, $P = .045$), BBS ($r = 0.400$, $P = .008$), 10MWT ($r = 0.475$, $P = .001$), and MBI ($r = 0.586$, $P = .000$). Similarly, stride length was positively associated with MMSE-K ($r = 0.329$, $P = .027$), BBS ($r = 0.372$, $P = .014$), 10MWT ($r = 0.455$, $P = .002$), and MBI ($r = 0.580$, $P = .000$). A moderate positive association between single support time and MBI was observed ($r = 0.308$, $P = .039$). Additionally, a moderate negative association between double support time and MBI was observed ($r = -0.349$, $P = .019$). Walk ratio was positively associated with MMSE-K ($r = 0.324$, $P = .030$), BBS ($r = 0.383$, $P = .011$), 10MWT ($r = 0.362$, $P = .015$), and MBI ($r = 0.556$, $P = .000$), indicating moderate associations. However, other gait parameters including cadence, step time, swing and stance time, and swing and stance phase duration were not associated with MMSE-K, BBS, MBI, and 10MWT (Table 3).

Table 2. Correlation Between MMSE-K, BBS, 10MWT, and MBI.[a]

	BBS	10MWT	MBI
MMSE-K	−0.100 (0.947)	−0.047 (0.756)	0.394 (0.007)[b]
BBS	–	0.710 (0.000)[b]	0.263 (0.085)
10MWT	–	–	0.154 (0.306)

Abbreviations: BBS, Berg Balance Scale; MBI, Modified Barthel Index; MMSE-K, Mini-Mental Statement Examination (Korean version); 10MWT, 10-Meter Walk Test.
[a]Data are Pearson correlation coefficient (P) values.
[b]$P < .01$.

Discussion

To the best of our knowledge, this study is the first empirical evidence investigating the association between balance, gait, and ADLs in older adults with dementia. As expected, significant associations were observed between cognition (MMSE-K) and ADLs (MBI) and between balance (BBS) and walking speed (10MWT) in people with dementia. In quantitative gait analysis, important associations were observed between gait parameters (eg, step length, stride length, and the quality of gait) and all clinical variables (e.g., cognition, balance, walking speed, and ADLs). Additionally, velocity was associated with other clinical measures, except for cognition, and single and

Table 3. Correlation Between Gait Parameters and MMSE-K, BBS, 10MWT, and MBI.[a]

	MMSE-K	BBS	10MWT	MBI
Velocity (cm/sec)	0.249 (0.099)	0.341 (0.025)[b]	0.488 (0.001)[c]	0.516 (0.000)[c]
Cadence (steps/min)	−0.102 (0.503)	−0.032 (0.837)	0.108 (0.480)	0.046 (0.763)
Step time (sec)	0.060 (0.698)	0.126 (0.422)	−0.101 (0.510)	−0.095 (0.535)
Step length (cm)	0.301 (0.045)[b]	0.400 (0.008)[c]	0.475 (0.001)[c]	0.586 (0.000)[c]
Stride length (cm)	0.329 (0.027)[b]	0.372 (0.014)[b]	0.455 (0.002)[c]	0.580 (0.000)[c]
Swing time (sec)	0.214 (0.158)	0.178 (0.254)	0.066 (0.666)	0.171 (0.261)
Stance time (sec)	−0.021 (0.891)	−0.040 (0.800)	−0.220 (0.147)	−0.148 (0.331)
Single support time (sec)	0.275 (0.067)	0.042 (0.788)	0.014 (0.927)	0.308 (0.039)[b]
Double support time (sec)	−0.207 (0.173)	−0.047 (0.766)	−0.239 (0.114)	−0.349 (0.019)[b]
Swing phase duration (%)	0.213 (0.159)	0.172 (0.271)	0.259 (0.086)	0.282 (0.060)
Stance phase duration (%)	−0.213 (0.160)	−0.172 (0.270)	−0.257 (0.088)	−0.281 (0.062)
Walk ratio[d]	0.324 (0.030)[b]	0.383 (0.011)[b]	0.362 (0.015)[b]	0.556 (0.000)[c]

Abbreviation: BBS, Berg Balance Scale; MBI, Modified Barthel Index; MMSE-K, Mini-Mental Statement Examination (Korean version); 10MWT, 10-Meter Walk Test.
[a]Data are Pearson correlation coefficient (P) values.
[b]$P < .05$.
[c]$P < .01$.
[d]Walk ratio = step length/cadence

double support time parameters were associated with ADLs. Therefore, our findings clearly indicate that alterations in gait parameters such as step length, stride length, and the quality of gait (WR) are closely associated with balance and ADLs in people with dementia.

Regarding the associations between cognition and ADLs and between balance and walking speed, the results of this study were consistent with the results of the previous studies.[24-26] A significant decline of cognition function was shown together with ADLs in this study. We suggest that cognition impairment is closely associated with the inability to perform ADLs in people with dementia.[24] Cognition impairment has severe implications on patients' independence.[25] Moreover, Chan and Pin found moderate positive associations between walking speed (10MWTs) and balance (BBS) in 39 older adults with dementia or Alzheimer disease. They reported findings of $r = 0.49$ (10MWT measured in 2-min walk test) and $r = 0.35$ (10MWT measured in 6-min walk test) between walking speed and balance.[26] This results demonstrated that strong association between balance and walking speed suggests that older adults with dementia walk shorter distances over a longer period of time when a loss of balance performance occurs.

Regarding the association between quantitative gait analysis and clinical tests, specific gait parameters including velocity, step length, stride length, and the quality of gait (WR) were associated with cognition, balance, and ADLs in older adults with dementia. Additionally, the functional inabilities to perform ADLs were associated with shorter single support time and longer double support time in this study. Bruce-Keller et al examined the association between decline in cognition and gait disturbance in 50 individuals with early-stage dementia and showed significant associations ($r = 0.31$-0.50) between cognition (MMSE) and gait parameters including velocity, cadence, and stride length (GAITRite).[8] Jayakody et al found that higher double support time variability and slower gait speed were associated with decline in memory in 410 older adults.[27] According to a meta-analysis study,[28] previous studies have focused on gait parameters, such as velocity, stride length, stride time, and stride time variation. Single task gait velocity and stride length significantly decreased in people with mild cognition impairment,[29,30] while stride time and stride time variation significantly increased.[31] Thus, several authors suggested that a variability in gait parameter is closely associated with cognitive decline. These results are supported by neurobiological evidence through brain imaging assessing the association between pathological gait and decline in cognition.[32] Normally, complex sequential behavior, in particular gait, is generated by a "central pattern generator" at the spinal level.[33] In higher brain function, the motor cortex of the frontal lobe and basal ganglia would be involved in the regulation of fine motor programs for controlling limb trajectory and foot placement.[34] In dementia-induced pathological gait, Nakamura et al reported that reduced mean values of regional cerebral blood flow in the frontal region were associated with decreased stride length at a moderate stage of Alzheimer disease. Furthermore, in more severe stages of Alzheimer disease, the decreased regional cerebral blood flow in the basal ganglia and frontal region was shown to be associated with increased double support time and decreased walking speed and stride length.[32] Dementia with cognitive impairment is also associated with the lesions of the hippocampus (memory) and prefrontal cortex (problem-solving, selective attention, and personality).[35]

The associations between quality of gait (WR) and balance ability may be affected by a decline in cognition. Changes in the quality of gait are associated with slower sustained gait speed, which disturbs gait and balance performance in mild to severe cognitive impairment.[36] Alterations in gait including slower gait speed, shortened steps, and increased stride variability are associated with risk of falls or loss of balance and aggravated under loading condition requiring high level of cognition function such as dual-task condition during dementia progression.[37] Several studies have suggested that gait is closely associated with executive functions including basic and high-level cognitive processes such as attention, working memory, decision-making, and problem-solving.[5,12] Additionally, the impaired executive function results in higher risk of falls and lower level of complex motor tasks, which leads to poor ADLs.[38] Gait analysis associated with dementia may be important for classifying those at the highest risk of falls during dementia progression; thus, fall prevention programs could be implemented.[8] Therefore, previous studies[8,36-38] support our finding that quantitative gait analysis, specifically step length, stride length, and the quality of gait, is closely associated with balance and ADLs in people with dementia.

Although our study has revealed significant findings, this study has a few limitations. First, measured gait parameter types were different between studies, and the results varied between this study and those of the previous studies. Further studies should identify the most important gait parameters associated with dementia to assess the degree of dementia progression and exercise programs in a large-scale clinical trial. Second, all measurement data of this study were collected by one examiner; hence, further studies with measurement data investigated by several examiners are required. Third, the stride time, stride variation, and double support time variability in gait parameters associated with dementia revealed more significant differences compared with healthy adults in previous studies.[27,31] However, this study showed stride time was not associated with cognition. Mini-Mental Statement Examination is commonly used as a cognitive screening test to evaluate the general cognition function. Finally, in this study, only B-ADLs were measured using MBI. Some studies have reported that IADLs should be assessed for people with dementia.[39] Hence, if a more sensitive assessment tool such as Montreal Cognitive Assessment[40] and IADL tool are used, persuasive results may be involved in further studies.

Conclusions

This study identified important associations between balance, gait, and ADL assessments in people with dementia. In particular, step length, stride length, and the quality of gait are closely associated with balance and ADLs in people with dementia. Further studies involving targeted interventions addressing gait parameters and improving balance and functional performance in people with dementia are required in the future.

Declaration of Conflicting Interests

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