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Effect of Cognitive Control and Dual-Task Training on Gait Stability and Fall Risk
In Older Adults: A Cross-Sectional Study

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Objective: With the proportion of the elderly population in Korea reaching 17.5% in 2022 and projected to increase to 20.6% by 2025, 30.1% by 2035, and 43% by 2050, the accelerated aging of the population is raising societal concerns about elderly care. Maintaining mobility is crucial for a healthy and independent old age.

Design: Cross-sectional study

Methods: This study investigates the effects of dual-task performance on gait variables and cognitive function in older adults. This cross-sectional study involved 60 older adults aged 65 and above, categorized into a dementia group (Korean version of Montreal Cognitive Assessment (MoCA-K) score ≤ 22) and a control group (MoCA-K score ≥ 23). Cognitive and gait functions were assessed using the GAITRite system (GAITRite system, CIR Systems Inc., USA), measuring gait variables (speed, stride length, etc.) before and after dual-task performance. The assessments were conducted under a single-blind condition, and data were analyzed using SPSS (ver. 25.0, SPSS Inc., USA).

Results: The dementia group scored lower on cognitive assessments compared to the control group ($p < 0.05$). In dual-task performance evaluations, the dementia group exhibited longer total task times and lower accuracy than the control group ($p < 0.001$), while reaction times were longer but not statistically significant. GAITRite system analysis revealed that the dementia group had reduced gait speed and stride length compared to the control group ($p < 0.05$). However, the difference in gait time was not statistically significant. The study results indicate that older adults with dementia show significant differences in cognitive function and gait performance, with notable impacts under dual-task conditions.

Conclusions: These findings underscore the effect of cognitive decline on gait and provide valuable insights for predicting gait and cognitive function deterioration in dementia, which can aid in developing fall prevention strategies.

Key Words: Task performance and analysis, Executive function, Gait analysis, Aged

Introduction

In 2022, individuals aged 65 and older accounted for 17.5% of South Korea's total population. This figure is projected to rise to 20.6% by 2025, marking the country's transition to a super-aged society, with expectations of reaching 30.1% by 2035 and exceeding 43% by 2050 [20]. This rapid aging phenomenon has elevated societal interest in elderly care, making it a focal point for national policy [35]. As aging accelerates, there is an increasing demand for medical and caregiving services within communities [18]. Although the community care policy is being actively promoted as a systematic alternative for elderly care, significant improvements are still needed [18]. Globally, the importance of health and quality of life in old age

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is gaining attention from both socioeconomic and public health perspectives, highlighting the need to prioritize factors that extend healthy lifespans in the elderly [12].

Most elderly individuals experience physical, psychological, and social aging, leading to decreased daily living abilities and cognitive and perceptual declines, thereby reducing social and physical activities. Consequently, the elderly are more vulnerable physically, psychologically, and socio- environmentally compared to younger populations [14]. Mobility, which includes the frequency and degree of independence in movement, is fundamental to human freedom and rights, playing a crucial role in the activities of life and social organization [17]. Particularly for the elderly, maintaining mobility is essential for achieving necessary activities and sustaining social connections, significantly contributing to a healthy life [19].

Mobility can be categorized into functional mobility and community mobility [1]. Functional mobility involves transitioning from one posture to another, moving from one place to another, and functional walking, which are activities fundamental to survival, health, and basic daily living activities (BADL) [3]. Community mobility, part of instrumental activities of daily living (IADL), encompasses walking within the community, using public transportation, and employing personal transportation methods such as driving or cycling [9]. Another concept, life-space mobility, extends beyond mere walking ability to encompass the geographical range of movement from one's sleeping room (Life-space 0) to areas beyond the community (Life-space 5), integrating the range, frequency, and independence level of daily movement [6,13]. Community mobility can serve as a task means or become a task itself, emphasizing the need for the elderly to maintain or improve their physical fitness for daily activities (ADL). Evaluating the elderly's mobility is crucial as it is strongly associated with physical function and life satisfaction, serving as a critical factor in ensuring safety and enhancing the quality of life (QoL) during daily activities [14,16].

Walking is a complex mobility skill that integrates and processes information from multiple systems to maintain postural stability, requiring sensory and cognitive systems' involvement. Daily life mobility necessitates continuous adaptation or response to changing environmental conditions. For instance, one must cross the street when the traffic light turns green or change direction to avoid obstacles. Aging increases the cognitive effort required for such tasks, with a significant reliance on processing speed, particularly in executive function and working memory, which markedly decline with age [21,22]. Given the variability in daily environments, executing walking as a series of mechanical repetitions is impractical. Hence, community mobility involves adapting to personal goals and environmental demands, often including cognitive dual-task such as remembering a shopping list or engaging in conversation while walking [5].

Dual-task, which involves performing two or more tasks simultaneously, has been used extensively to assess inhibitory control, an executive function [23]. Executive function, crucial for planning and executing personal behavior, uses cognitive processes to generate and modify movements [24]. Inhibitory control, a key component of executive function, focuses attention selectively and effectively controls and modifies thoughts and behaviors to achieve set goals [4]. Executive function is closely associated with gait regulation [25,26]. Cognitive decline due to aging is common among older adults and increases with age, becoming more pronounced in individuals with conditions such as dementia [16]. While cognitive decline does not necessarily lead to dysfunction, evaluating executive function through both neuropsychological tests and ADL is essential for accurate diagnosis [26].

Effective dual-task performance requires appropriate attention allocation to multiple activities simultaneously [2,23]. Early cognitive impairments in attention, executive function, and task memory during dual-tasking can result in slower gait and instability, making dual-task performance a valuable predictor of dementia progression and fall risk [27]. Dual-task assessments typically involve evaluating tasks performed concurrently with walking, such as obstacle walking or carrying objects while walking [29]. Obstacle walking, a dual-task type, necessitates higher prefrontal cortex activation compared to regular walking, requiring advanced sensory and motor information processing to plan and organize gait patterns according to environmental characteristics [30].

Increased cognitive load during dual-task walking alters gait strategies, commonly reducing gait speed. Performing concurrent tasks while walking demands greater cognitive capacity than walking alone, leading to impaired gait or task performance when cognitive demands exceed individual capabilities [28]. Attention allocation during dual-task performance impacts both task and gait, with cognitive load-induced gait speed reduction observed even in healthy adults [3]. Gait speed and its variability under cognitive load are utilized as variables for assessing executive function and cognitive decline [17].

Studies investigating the relationship between cognition and gait speed in the elderly have shown significant differences in complex walking scenarios, emphasizing the role of executive function. For instance, differences in Trail Making Test scores among elderly groups did not show significant differences in normal walking but did in obstacle walking, highlighting the executive function's importance in complex situations [31]. Coppin et al. reported a correlation between Trail Making Test scores and dual-task performance during walking, while Holtzer et al. found associations between cognitive test battery scores and dual-task gait speed, particularly in executive function and memory [7,28].

These findings suggest that frontal lobe dysfunction is linked to gait kinematic impairments, with dual-task gait variables correlating with executive function, especially inhibitory control [11]. Lower Trail Making Test scores during obstacle walking was associated with reduced gait speed, confirming the correlation between executive function tests and dual-task gait speed, particularly in challenging environments [17]. Executive function, associated with the prefrontal cortex and anterior cingulate cortex, is crucial for flexible thinking, response inhibition, and creative thinking [16,17,19]. Age-related anatomical changes in the frontal lobe can lead to executive function decline, affecting gait and increasing fall risk [26].

Given these insights, it is essential to explore how dual-task performance affects gait and cognitive functions in the elderly, particularly among those with and without dementia. This study aims to investigate the relationship between executive function, specifically inhibitory control, and dual-task performance on gait variables among elderly individuals. Understanding these interactions can provide valuable information for predicting gait and cognitive function decline, aiding in the development of non-invasive, efficient methods for dementia prediction and fall prevention. Ultimately, this research aims to contribute to enhancing the health and quality of life of the elderly, providing critical information to support their independence amidst the rising aging population.

Materials and Methods

1. Subject

The protocol of this study was designed as a cross-sectional study, and 60 elderly aged 65 years or older were recruited from a day-care center in Anseong, and 60 people who met the selection and exclusion criteria were selected. Inclusion criteria for study selection were: (1) aged 65 and above, (2) ability to understand and follow simple verbal instructions, (3) independent walking ability for over 10 meters without aids, and (4) no significant physical impairments such as vision or hearing loss. Exclusion criteria were: 1) severe orthopedic conditions affecting gait, (2) presence of apraxia, and (3) recent participation in similar studies. The number of study subjects was calculated using G-power (G*Power 3.1.9.7, Kiel University, Germany), and the number of subjects required for analyzing the cognitive-motor dual-task gait and balance assessment was determined. The gait variables (velocity, step length) of the GAITRite system (GAITRite system, CIR Systems Inc., USA) were set as the primary hypothesis, and the effect size was 0.5, the significance level was 0.05, and the test power was based on the evidence that a correlation effect size of 0.5 or more is a large effect. A total of 24 subjects were required under the 0.8 condition [39], but in this study, 30 subjects were recruited for each group considering a dropout rate of 20%. The study was conducted with the consent of all subjects participating in the study and with the approval of the Bioethics Committee of Sahmyook University (SYU 2023-11-016-001).

2. Procedure

Participants were divided into two groups based on cognitive function assessments: those with dementia, defined by Korean version of the Montreal Cognitive Assessment (MoCA-K) scores of 22 or below, and a control group with MoCA-K scores of 23 or higher. Each group underwent comprehensive cognitive and gait function assessments. Dual-task performance was evaluated by having participants complete the task 10 times. The study was conducted in a single-blind manner, with assessments performed in an isolated space to prevent bias. The participants were elderly individuals residing in a daycare center in the Gyeonggi region who met the inclusion criteria. Those with MoCA-K scores of 22 or below were assigned to the dementia group, while those with scores of 23 or above were placed in the control group. All participants completed cognitive and gait function assessments, including a dual-task performance evaluation while walking, which was repeated 10 times to ensure reliability. The dual-task involved responding to a visual signal (e.g., a traffic light) while walking, and the performance was measured using specific metrics such as total performance time, reaction time, and accuracy. Participants who could not continue due to changes in their medical condition or who had less than 80% participation were excluded from the final study.

3. Measurements

A. Cognitive Function Assessment

To assign groups based on the presence of dementia, the MoCA-K was used, which evaluates seven cognitive domains: visuospatial/executive function, naming, memory, attention, language, abstraction, and orientation. The total score was 30 points, with an additional point for those with six or fewer years of education. The cutoff score for screening mild cognitive impairment was 22 points or lower, indicating cognitive decline. The reliability was Cronbach's $\alpha = .83$, and the translated MoCA-K had a Cronbach's α of .81 to .84. The criterion validity between MoCA-K and MMSE was $r = .65$ ($p < .001$),

(a) Function Assessment (b) Dual-task Performance

Figure 1. Experiment environments

and with the Clinical Dementia Rating (CDR) scale was r = .62 ($p < .001$) [11].

B. Executive Function Assessment

a. Inhibitory Control Test (Korean-Color Word Stroop Test; K-CWST)

This test is designed to evaluate the efficiency of the inhibition process managed by the frontal lobe. The standardized metrics used in the K-CWST include the number of correct responses in the word-reading condition (word-correct number), the response time per correct item in the word-reading condition (word-time second; total response time in word-reading condition/number of correct responses in word-reading condition), the number of correct responses in the color-naming condition (color-correct number), and the response time per correct item in the color-naming condition (color-time second; total response time in color-naming condition/number of correct responses in color-naming condition). Higher correct response numbers and shorter response times per correct item in the color-word Stroop test indicate better inhibition function. The Cronbach's α for the Stroop test tool was 0.76 for the word-reading condition and 0.66 for the color-naming condition, demonstrating its reliability as an assessment tool [8].

b. Task Switching and Planning Ability Test (Korean-Trail Making Test for the elderly; K-TMT-e)

The Task Switching and Planning Ability Test, specifically the K-TMT-e, assesses cognitive flexibility and executive function, particularly the efficiency of task switching and planning. The standardized metrics used in the K-TMT-e include the number of correct connections in the task-switching condition (task- correct number) and the response time per correct connection in the task-switching condition (task-time second; total response time in the task-switching condition/number of correct connections in the task-switching condition). Higher correct connection numbers and shorter response times per correct connection in the K-TMT-e indicate higher cognitive flexibility and planning ability. The reliability of the K-TMT-e tool is supported with Cronbach's α of .76 for the task-switching condition and .66 for the planning condition [8].

C. Gait Function Assessment

a. Berg Balance Scale (BBS)

The BBS was used to assess balance ability in elderly individuals. It evaluated 14 tasks ranging from low-level tasks like maintaining balance while seated to higher-level tasks like standing on one leg or stepping forward. The tasks included standing up from a sitting position, standing without support, sitting upright without leaning on the backrest, transitioning from standing to sitting, moving from one chair to another, standing with eyes closed, standing with feet together, reaching forward with an outstretched arm, picking up an object from the floor, turning to look behind, turning 360 degrees in place, placing alternating feet on a stool, standing with one foot in front of the other in a tandem stance, and standing on one leg. Each task was scored on a 5-point scale from 0 to 4, with a maximum total score of 56. The scale demonstrated high intra-rater reliability (r = 0.99) and inter-rater reliability (r = 0.98) [15].

b. Timed Up and Go Test (TUG)

The TUG Test was used to measure dynamic balance by timing participants as they stood up from a chair, walked 3 meters, turned around, walked back, and sat down. Participants began seated in a chair with armrests and a backrest, then rose to a standing position, walked 3 meters at a comfortable pace, turned around, walked back to the chair, and sat down again. The total time taken to complete this sequence was recorded. The test demonstrated high reliability, with intra-rater reliability at r = 0.99 and inter-rater reliability at r = 0.98, confirming its consistency and accuracy in measuring dynamic balance [10].

D. Dual-Task Performance Assessment

Dual-task performance was assessed using a custom-designed dual-task involving a visual signal (traffic light) during walking. Performance metrics included total performance time, reaction time, and accuracy, measured using the GAITRite system.

a. Dual-task Performance

In this study, the designed dual-task involves the use of visual signals (traffic lights) familiar in daily

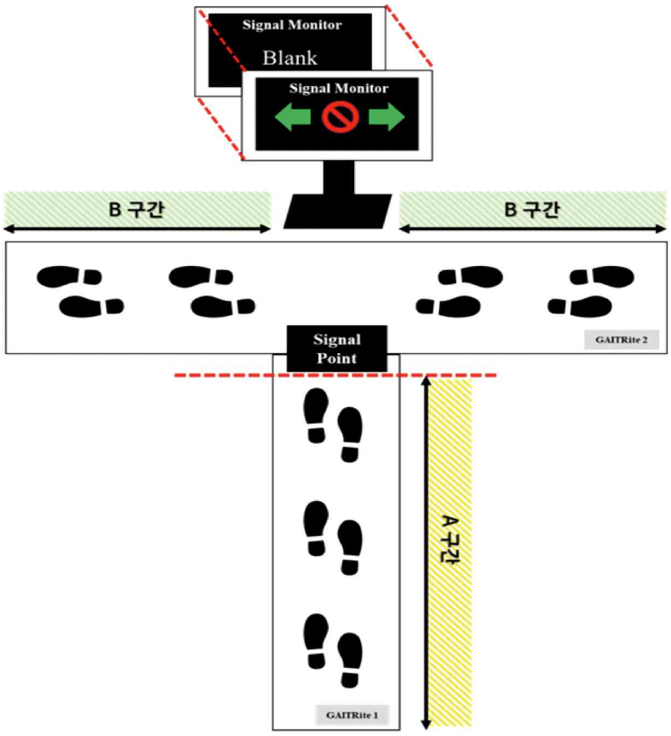

Figure 2. Dual-task Performance

life to simulate cognitive task engagement during walking, as might occur in real-world scenarios. The starting and target points were marked, and the GaitRite system was deployed to extract and analyze spatiotemporal gait parameters before and after the cognitive task engagement (see Fig 2). A monitor was positioned at a height and angle directly in front of the participant, displaying visual signals (traffic lights) in random order. These signals included a red stop signal and green walking signals for left and right directions. Participants were instructed to stop at the stop signal and switch direction according to the walking signal. Each participant performed one set, consisting of 10 trials (randomly ordered as 3/3/4). Dual-task performance was evaluated based on total completion time, response time (time from signal display to first step), and accuracy.

b. GAITRite system

To measure spatiotemporal gait abilities accurately and objectively during dual-task performance, the GAITRite system was used. This system consists of a walkway with a width of 61 cm and a length of 366 cm, embedded with 13,824 electronic sensors, and a sampling rate set at 100 Hz. Collected data were transmitted to a connected computer and analyzed using the GAITRite Platinum software. The spatiotemporal gait variables analyzed included velocity (cm/s), cadence (steps/min), step length (cm), stride length (cm), step time (sec), swing time (sec), and stance time (sec). The system has a high reliability with an inter-rater reliability of $r=.92$ and an intra-rater correlation coefficient of above 0.96 [7].

4. Statistical analysis

Data analysis will be conducted using SPSS (ver. 25.0, SPSS Inc., USA). The general characteristics of the subjects were analyzed using descriptive statistics, and the Kolmogorov-Smirnov test will be used to assess the normal distribution of all parameters. Differences in cognitive and gait functions between the two groups, differences in dual-task performance, and differences in spatiotemporal gait variables before and after cognitive task intervention will be analyzed using independent t-tests. The significance level (α) will be set at 0.05.

Result

1. Participants

Participants were classified into either the dementia group (n = 30) or the control group (n = 30) based on their scores from the Korean version of the Montreal Cognitive Assessment (MoCA-K). The general characteristics, including demographic information and other relevant factors, were collected for both groups. Specifically, the variables assessed were age (years), gender distribution (male/female), height (cm), weight (kg), body mass index (BMI, kg/m²), fall history (percentage), and education level (years) (Table 1).

2. Executive Function Assessment

The K-CWST results revealed no significant differences between the dementia group and the control group for both the Word-correct number and Word-time second ($p > 0.05$). In contrast, the K-TMT-e assessment showed that the dementia group had significantly lower task-switching abilities compared to the control group ($p < 0.05$) (Table 2).

3. Gait Function Assessment

The BBS and TUG tests indicated that the dementia group had poorer balance and slower dynamic balance performance compared to the control group. Specifically, the BBS scores were lower in the dementia group compared to the control group ($p < 0.05$). However, the differences in TUG times between the dementia group and the control group (were not statistically significant (Table 3).

4. Dual-Task Performance Assessment

Dual-task performance was evaluated by measuring the total performance time, reaction time, and accuracy during the cognitive task intervention. The dementia group demonstrated significantly slower performance

Table 1. General characteristics of participants (n = 60)

Characteristics	DG(n = 30)	CG (n = 30)	p
MoCA-K Score	18.5 ± 2.3	25.6 ± 2.1	< 0.000
Age (years)	75.2 ± 6.3	73.4 ± 5.8	0.254
Gender (M/F)	12/18	13/17	0.785
Height (cm)	158.3 ± 9.1	159.1 ± 8.7	0.722
Weight (kg)	61.5 ± 11.3	60.7 ± 10.8	0.758
BMI (kg/m²)	24.6 ± 3.2	23.9 ± 3.1	0.472
Fall history (%)	46.7	43.3	0.813
Education (years)	9.2 ± 3.6	9.8 ± 3.1	0.559

DG: Dementia Group, CG: Control Group, MoCA-K: Korean version of the Montreal Cognitive Assessment, *$p < .05$, ** $p < .01$, *** $p < .001$

Table 2. Executive Function Assessment (n = 60)

Measurements	DG(n = 30)	CG (n = 30)	p
K-CWST Word-correct number	42.3 ± 8.4	44.7 ± 6.8	0.143
K-CWST Word-time second	1.23 ± 0.22	1.15 ± 0.19	0.177
K-TMT-e Part A completion time (sec)	52.4 ± 14.3	37.6 ± 10.8	0.000
K-TMT-e Part B completion time (sec)	105.6 ± 25.7	76.2 ± 18.5	< 0.000

DG: Dementia Group, CG: Control Group, K-CWST: Korean-Color Word Stroop Test, K-TMT-e: Korean-Trail Making Test for the elderly, *$p < .05$, ** $p < .01$, *** $p < .001$

Table 3. Gait Function Assessment (n = 60)

Measurements	DG (n = 30)	CG (n = 30)	*p*
BBS (score)	43.7 ± 5.8	48.5 ± 4.2	0.017
TUG (sec)	14.8 ± 3.2	12.7 ± 2.4	0.086

DG: Dementia Group, CG: Control Group, BBS: Berg Balance Scale, TUG: Timed Up and Go,*$p<.05$, ** $p<.01$, *** $p<.001$

Table 4. Dual-Task Performance Assessment (n = 60)

Measurements	DG(n = 30)	CG (n = 30)	*p*
Total performance time (sec)	27.6 ± 5.7	20.3 ± 3.9	< 0.00
Reaction time (sec)	4.2 ± 0.9	3.9 ± 0.7	0.075
Accuracy (%)	68.4 ± 12.5	84.7 ± 9.2	0.006

DG: Dementia Group, CG: Control Group, *$p<.05$, ** $p<.01$, *** $p<.001$

Table 5. Spatial-Temporal Gait Variables (n = 60)

Measurements	DG(n = 30)	CG (n = 30)	*p*
Gait velocity (cm/s)	82.5 ± 15.7	101.3 ± 14.8	0.000
Step length (cm)	49.2 ± 9.3	57.4 ± 8.5	0.000
Step time (sec)	0.98 ± 0.17	1.01 ± 0.15	0.334

DG: Dementia Group, CG: Control Group, *$p<.05$, ** $p<.01$, *** $p<.001$

and lower accuracy compared to the control group. The mean total performance time for the dementia group was 27.6 seconds, while the control group had a mean time of 20.3 seconds ($p<0.001$). Reaction times were longer in the dementia group had a mean time of 4.2 seconds compared to the control group had a mean time of 3.9 seconds, but this difference was not statistically significant. Accuracy was lower in the dementia group had a mean of 68.4% compared to the control group had a mean of 84.7% ($p<0.05$) (Table 4).

5. Spatial-Temporal Gait Variables

The GAITRite system revealed significant differences in spatial-temporal gait variables between the dementia and control groups during dual-task performance. The dementia group exhibited reduced gait velocity and shorter step length compared to the control group ($p<0.05$). However, the differences in step time between the groups were not statistically significant (Table 5).

Discussion

The results of this study reveal substantial differences in cognitive and gait functions between elderly individuals with dementia and those without, especially when assessed under dual-task conditions. These findings align with previous research indicating that cognitive impairments, such as those associated with dementia, adversely affect gait performance and increase the risk of falls [12,29]. The relationship between cognitive decline and impaired gait performance has been well documented. Coppin et al [6] and Holtzer et al. [12] demonstrated that gait speed decreases as cognitive load increases, particularly in older adults with cognitive impairments. Our study corroborates these findings by showing significant reductions in gait speed and stride length during dual-task performance in the dementia group compared to the control group.

In terms of cognitive function, our results demonstrated significant differences between the dementia and control groups, confirming the expected cognitive decline in individuals with dementia. The lack of significant differences in K-CWST scores suggests that while overall cognitive function is notably impaired in dementia patients, specific inhibitory control processes may not be as severely affected in the early stages. This could imply that some cognitive functions might remain relatively preserved initially, while others deteriorate more rapidly as the disease progresses.

The mechanisms through which dual-task affects gait have been explored by Goethals et al. [8] and Scherder et al. [30], who highlighted the role of the frontal lobe in managing complex tasks that require both cognitive and motor resources. Our findings extend this work by demonstrating that the increased cognitive load associated with dual-task performance disrupts motor planning and execution in the dementia group.

Dual-task performance assessment further illustrated the impact of cognitive impairments on gait. The dementia group showed significantly slower performance times and reduced accuracy compared to the control group. This finding supports the hypothesis that cognitive load during dual-task disproportionately affects individuals with cognitive impairments. Previous research by Guarino et al. [10] and Pellecchia [26] has similarly highlighted that effective executive function and attention allocation are critical for successful dual-task performance. The observed deficits in these areas likely contribute to the poorer dual-task performance seen in individuals with dementia. These studies emphasized the need for physical training to improve gait stability; however, they did not address the cognitive aspects of dual-tasking, which are critical for real-world functionality [10, 26].

Assessments using the Berg Balance Scale (BBS) and the Timed Up and Go (TUG) test revealed that the dementia group exhibited significantly poorer balance and slower dynamic balance performance compared to the control group. These findings are consistent with previous research, which has established a link between cognitive decline, impaired gait, and an increased risk of falls. Specifically, in the TUG test, the dementia group took longer to rise, walk, turn, and return to a seated position, indicating difficulties with dynamic balance control.

Moreover, analysis using the GAITRite system highlighted significant reductions in gait velocity and step length in the dementia group under dual-task conditions. A dual-task scenario requires participants to walk while simultaneously performing a simple cognitive task, and under such conditions, the dementia group demonstrated markedly diminished gait performance. This suggests aligns with previous research that suggests cognitive load has a substantial impact on gait, making individuals with dementia particularly vulnerable in multitasking situations [31,39].

While Kim et al. [17] utilized the GAITRite system to measure spatiotemporal gait parameters, such as gait speed, stride length, and gait cycle, our study goes a step further by directly linking these gait metrics with cognitive task performance under dual-task conditions. This linkage is crucial for understanding how cognitive impairments specifically affect motor functions in environments that require multitasking. By establishing this connection, our study provides deeper insights into the complex challenges faced by individuals with dementia in their daily lives and underscores the need for targeted interventions to mitigate these deficits.

This study has several limitations. The cross-sectional design does not allow for the assessment of changes over time, and the sample size, while sufficient for the analysis, might not represent the broader elderly population. Future research should consider longitudinal studies to track changes in cognitive and gait functions over time, as well as larger, more diverse samples to enhance generalizability.

Additionally, exploring interventions that target both cognitive and motor functions could provide insights into effective strategies for mitigating fall risk and improving dual-task performance among elderly individuals. Investigating the impact of specific cognitive training or physical exercise programs on dual-task performance and gait could offer practical solutions for enhancing elderly care.

Conclusion

This study emphasizes the critical interplay between cognitive and gait functions in the elderly, particularly under dual-task conditions. The findings underscore the importance of incorporating both cognitive and physical training into interventions designed to improve gait stability and reduce fall risk in older adults. Given the observed impairments in dual-task performance and gait function, future research should explore the long-term effects of combined cognitive and physical exercise programs. Such studies could reveal the potential of these interventions to mitigate the impacts of cognitive decline on gait and mobility, ultimately enhancing the quality of life and safety for older adults, especially those with cognitive impairments.

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