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Accumulation of Biopsychosocial Risk Factors and Cognitive Impairment: The Impact of Slower Gait, Depression, and Low Education in Community-Dwelling Older Adults

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Background: Cognitive decline in older adults, a prodromal stage of dementia, requires early preventive attention as a major public health concern. Cognitive decline in older adults involves complex interactions among physical, psychological, and social factors. This study applied the biopsychosocial model to examine how these multidimensional domains jointly influence cognitive function and to evaluate cumulative risks associated with multidimensional vulnerabilities. **Methods:** Data from 661 community-dwelling older adults aged 65 years or older who participated in a community health screening were analyzed. Cognitive function (Cognitive Impairment Screening Test), physical performance (Timed Up and Go test log-transformed [TUG_log]), depressive symptoms (Korean version of the Short Geriatric Depression Scale [SGDS-K]), and education were measured. Age-specific TUG_log cut-offs were obtained by ROC analysis. Dual- and triple-risk groups were defined based on TUG risk, low education (≤6 years), and depression (SGDS-K ≥8). Correlation, regression, and mediation analyses were performed. **Results:** Slower gait speed, lower education, and higher depressive symptoms were significantly associated with poorer cognitive function ($p<0.05$). Compared with participants with no risk factors, those with two risk factors had 5.07-fold higher odds of cognitive impairment, while those with all three risk factors had 18.13-fold higher odds. Mediation analysis showed that depression did not directly affect cognition but had a significant indirect effect through impaired physical performance (bootstrap 95% confidence interval, −0.1765 to −0.0530). **Conclusion:** Cognitive function in older adults is shaped by interacting physical, psychological, and social factors. The accumulation of multidimensional vulnerabilities markedly increases cognitive decline risk, underscoring the need for integrated, multidomain prevention strategies.

Key Words: Cognitive dysfunction, Walking speed, Depression, Education, Biopsychosocial model

INTRODUCTION

Cognitive decline is a major public health issue that accompanies aging and is widely recognized as a prodromal stage of dementia. The World Health Organization has projected that the global number of people with dementia will reach approximately 139 million by 2050, posing a substantial burden on healthcare and welfare systems worldwide.[1)] In Korea, about 10% of adults aged 65 years or older are estimated to have cognitive impairment,[2)] and this proportion is expected to continue increasing with rapid pop-

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ulation aging. Because cognitive decline progresses gradually for several years before the onset of dementia, identifying modifiable factors that influence cognitive health at an early stage is of critical importance.

Recent studies have suggested that cognitive decline should be understood as a multidimensional process in which physical, psychological, and social factors interact rather than as the result of a single determinant.[3,4] From this perspective, the biopsychosocial (BPS) model proposed by Engel[5] provides a theoretical framework for explaining how multiple domains influence cognitive health through their interactions. According to the BPS model, physical function (e.g., gait speed), psychological state (e.g., depression), and social resources (e.g., educational attainment) are intricately interrelated and collectively shape the trajectory of cognitive changes in later life.[6] These indicators have been widely used in epidemiological studies as representative measures of biological, psychological, and social vulnerability in aging populations.[7-12]

Prior research has established individual links between these factors and cognition. Gait speed has been reported as an early and sensitive indicator of cognitive decline, and deterioration in physical function has been identified as a significant predictor of cognitive impairment.[7,8] Moreover, depression negatively affects cognitive function by influencing the rate of decline in executive and memory functions[9] and is closely associated with reduced physical activity and slower gait performance.[10] Meanwhile, educational attainment serves as a key social factor constituting cognitive reserve; individuals with higher education tend to exhibit higher cut-off scores on cognitive tests,[11] and education plays a protective role in buffering against changes caused by aging or brain injury.[12] These factors rarely act in isolation. For instance, depression may reduce physical activity, leading to functional decline, while low education may limit the coping resources needed to manage these physical and psychological challenges. This suggests that the coexistence of these vulnerabilities may be associated with a higher likelihood of cognitive decline. Despite this, few studies have comprehensively examined the combined effects of biological, psychological, and social domains on cognitive decline. Therefore, this study applied the BPS model to examine how these factors are associated with cognitive impairment and whether their coexistence is related to increased cumulative risk of cognitive impairment among community-dwelling older adults.

This study provides evidence on the relationships between BPS vulnerabilities and cognitive impairment and highlights the importance of multidomain approaches for community-based prevention.

MATERIALS AND METHODS

Study Participants

This cross-sectional study analyzed data from 661 community-dwelling older adults aged 65 years or older who participated in a community health screening program conducted at Pusan National University Hospital. Eligible participants were community-dwelling adults aged 65 years or older who were able to perform activities of daily living independently and who understood the purpose and procedures of the study and provided written informed consent. Individuals were excluded if they had diagnosed dementia or major neuropsychiatric disorders, had difficulty walking independently, had uncontrolled hypertension or untreated severe medical illness, or if the investigators determined that participation was inappropriate for any other reason.

Participants who completed all key assessments, including physical performance, cognitive function, depressive symptoms, and educational attainment, were included in the final analysis. Two individuals with missing data on depressive symptoms (Korean version of the Short Geriatric Depression Scale [SGDS-K]) were excluded to ensure consistency across all analyses. All participants were informed of the study purpose and procedures and provided written informed consent prior to participation. The study protocol was approved by the Institutional Review Board of Pusan National University Hospital (IRB No. 2510-016-156).

Measurements

Cognitive function

Cognitive function was assessed using the Cognitive Impairment Screening Test (CIST). The CIST evaluates multiple cognitive domains, including orientation, memory, language, attention, and executive function, with a total possible score of 30 points.[13] Lower scores indicate poorer cognitive performance. Based on previous studies using 30-point cognitive screening tools, in which cut-off scores around ≤ 23 have commonly been applied and lower cut-off ranges have been proposed to reduce potential overdiagnosis,[11,14] a single cut-off score of < 23 was applied to define cognitive impairment to ensure consistency and comparability across the total sample.

Physical function

Physical function was evaluated using the Timed Up and Go (TUG) test.[15] This test measures the time in seconds required for an individual to stand up from a chair, walk 3 meters, turn around, and sit down again. In this study, TUG values were log-transformed (TUG_log) to correct for skewness and ensure a normal distribution and were used for subsequent analyses.

Depressive symptoms

Depressive symptoms were assessed using the SGDS-K. The total score ranges from 0 to 15, with higher scores indicating more severe depressive symptoms.[16]

Clinically significant depressive symptoms were defined as a score of 8 or higher, based on previous validation studies of the SGDS-K demonstrating optimal diagnostic accuracy for major depression.[17]

Educational attainment

Educational attainment was recorded as the total number of years of formal education and categorized into three groups: low (0–6 years), medium (7–12 years), and high (≥ 13 years). This classification reflects the Korean school system, in which elementary education lasts 6 years, followed by 6 years of combined middle and high school education. Based on the cognitive reserve theory,[4] education was considered a social factor influencing cognitive function.[12]

In this study, considering the constraints of the available dataset, a single representative indicator was selected for each domain of the BPS framework to operationalize biological, psychological, and social vulnerability in older adults. These indicators were chosen based on previous epidemiological studies demonstrating consistent associations with cognitive outcomes. Specifically, gait performance measured by the TUG test was used as the physical indicator because it reflects overall mobility and functional decline and has been widely used as a screening marker for cognitive vulnerability in aging populations.[7,8] Depressive symptoms measured by the SGDS-K were included as the psychological indicator because depression is one of the most prevalent emotional conditions in later life and has been consistently associated with cognitive impairment.[9] Educational attainment was used as the social indicator because it represents cognitive reserve and lifelong socioeconomic resources that influence resilience to cognitive aging.[12] Although the BPS framework encompasses a wide range of determinants, this study focused on representative indicators from each domain—gait performance (biological), depressive symptoms (psychological), and educational attainment (social)—based on previous epidemiological studies reporting consistent associations with cognitive impairment in older adults.

Table 1. General characteristics of the participants (n=661)

Characteristic	Value
Sex	
Male	227 (34.3)
Female	434 (65.7)
Age group (y)	
65–74	185 (28.0)
75–84	425 (64.3)
≥ 85	51 (7.7)
Education (y)	
0–6	338 (51.1)
7–12	305 (46.1)
≥ 13	18 (2.8)
Smoking status	
Current	48 (7.3)
Former	130 (19.7)
Never	483 (73.0)
Alcohol use	
Yes	148 (22.4)
No	513 (77.6)
Hypertension	
Yes	372 (56.3)
No	289 (43.7)
Diabetes mellitus	
Yes	167 (25.3)
No	494 (74.7)
Cognitive status	
Normal	399 (60.4)
Impaired	262 (39.6)
Body mass index (kg/m²)	23.6 ± 2.9

Values are presented as number (%) or mean±standard deviation.

Table 2. Descriptive statistics of main study variables

Variable	n	Min	Max	Mean	SD
Cognitive function (CIST total score)	661	5	30	23.16	4.34
Physical function (TUG_log)	661	0.65	1.41	0.9177	0.0908
Depressive symptoms (SGDS-K total score)	661	0	14	1.93	2.538
Education (y)	661	0	18	7.22	3.623

CIST, Cognitive Impairment Screening Test; TUG, Timed Up and Go test; SGDS-K, Korean version of the Short Geriatric Depression Scale; SD, standard deviation.
Log-transformed values (TUG_log) were used for statistical analyses.

Statistical Analysis

All statistical analyses were performed using SPSS Statistics version 28 (IBM, Armonk, NY, USA). Descriptive statistics were used to summarize participants' demographic characteristics and the distribution of main study variables (Tables 1, 2). Relationships among the main variables were examined using Pearson correlation analysis (Table 3).

Receiver operating characteristic (ROC) analyses of TUG_log were conducted by age group (65–74, 75–84, and ≥ 85 years) to determine the optimal cut-off values for predicting cognitive impairment (Table 4).

Based on these criteria, participants were categorized according

Table 3. Pearson correlation matrix of main study variables

Variable	Cognitive function (CIST total score)	Physical function (TUG_log)	Depressive symptoms (SGDS-K total score)	Education (y)
Cognitive function (CIST total score)	1			
Physical function (TUG_log)	–0.308***	1		
Depressive symptoms (SGDS-K total score)	–0.101**	0.208***	1	
Education (y)	0.510***	–0.316***	–0.079*	1

Values are Pearson correlation coefficients (r).
CIST, Cognitive Impairment Screening Test; TUG, Timed Up and Go test; SGDS-K, Korean version of the Short Geriatric Depression Scale.
*p<0.05, **p<0.01, ***p<0.001.

Table 4. ROC analysis of TUG_log by age group for discriminating cognitive impairment

Age group (y)	Cut-off value (TUG_log)	Time (s)	Sensitivity (%)	Specificity (%)	AUC	95% CI	p-value	Youden index
65–74	0.9077	8.09	60.9	69.5	0.664	0.573, 0.755	0.001	0.304
75–84	0.9143	8.21	65.8	57.7	0.621	0.567, 0.674	0.001	0.234
≥ 85	0.9930	9.8	41.2	94.1	0.697	0.548, 0.846	0.023	0.353

TUG, Timed Up and Go test; ROC, receiver operating characteristic; AUC, area under the ROC curve; CI, confidence interval.
Cognitive impairment was defined as a Cognitive Impairment Screening Test (CIST) total score below the cut-off criterion.

to the number of coexisting BPS risk factors (0–3), including age-specific TUG_log risk, low educational attainment (≤ 6 years), and clinically significant depressive symptoms (SGDS-K ≥ 8). Binary logistic regression analyses were conducted to examine the independent association of each risk factor with cognitive impairment using individual logistic regression models, as well as the cumulative association between the number of coexisting risk factors and cognitive impairment. Adjusted analyses were additionally performed controlling for age, sex, body mass index (BMI), hypertension, and diabetes mellitus (Table 5). Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Finally, the mediating effect of physical performance in the relationship between depression and cognitive function was tested using the PROCESS macro (Model 4) (Supplementary Table S1) with 5,000 bootstrap samples, generating 95% CIs. A p-value < 0.05 was considered statistically significant.

RESULTS

Participants and Descriptive Statistics

A total of 661 older adults were analyzed (Table 1). The prevalence of cognitive impairment (CIST < 23) was 39.6%. Descriptive statistics for the main variables based on participants with complete data (n = 661) are presented in Table 2. The mean CIST score was 23.16 ± 4.34, and the mean TUG_log value was 0.92 ± 0.09.

Table 5. Logistic regression analysis of individual and cumulative biopsychosocial risk factors for cognitive impairment

Variable	OR	95% CI	p-value
Individual factors (adjusted)			
TUG risk	1.46	1.01, 2.11	0.046
Low education	3.75	2.60, 5.42	< 0.001
Depression	1.91	0.89, 4.13	0.099
Cumulative risk factors (unadjusted)			
2 risk factors	6.78	4.26, 10.80	< 0.001
3 risk factors	21.95	4.57, 105.36	< 0.001
Cumulative risk factors (adjusted)			
2 risk factors	5.07	3.11, 8.24	< 0.001
3 risk factors	18.13	3.73, 88.09	< 0.001

TUG, Timed Up and Go test (log-transformed); OR, odds ratio; CI, confidence interval.
Reference group: Participants with no biopsychosocial risk factors (risk count = 0).
Adjusted models were adjusted for age, sex, body mass index, hypertension, and diabetes.
Model statistics for the adjusted cumulative risk model: Nagelkerke R^2=0.233.

Correlations among Main Study Variables

As shown in Table 3, cognitive function was negatively correlated with physical function (TUG_log; r = –0.308, p < 0.001) and depressive symptoms (SGDS-K; r = –0.101, p = 0.009). Notably, lower education was significantly associated with both slower gait and higher depression, suggesting interconnected vulnerabilities. These correlations represent unadjusted associations and should be interpreted with caution, as potential confounding factors such as age were not controlled for in the correlation analysis.

Age-specific ROC Analysis of TUG_log

The optimal TUG_log cut-off values for predicting cognitive impairment increased with age, ranging from 0.9077 (ages 65–74) to 0.9930 (ages ≥ 85) (Table 4). This age-dependent increase supports the use of age-specific criteria for defining physical risk.

Associations of Individual and Cumulative Biopsychosocial Risk Factors with Cognitive Impairment

The results of logistic regression analyses examining both the independent and cumulative associations of BPS risk factors with cognitive impairment are presented in Table 5. To clarify the independent association of each BPS factor with cognitive impairment, individual logistic regression models adjusted for age, sex, BMI, hypertension, and diabetes mellitus were performed. Impaired gait performance (TUG risk) was significantly associated with cognitive impairment (OR = 1.46, 95% CI 1.01–2.11, p = 0.046), and low educational attainment also showed a significant association (OR = 3.75, 95% CI 2.60–5.42, p < 0.001). In contrast, depressive symptoms were not significantly associated with cognitive impairment after adjustment (OR = 1.91, 95% CI 0.89–4.13, p = 0.099).

To evaluate the cumulative effect of coexisting BPS vulnerabilities, a separate logistic regression analysis was conducted using the number of risk factors (0–3), with participants with no risk factors serving as the reference group (Table 5). After adjusting for age, sex, BMI, hypertension, and diabetes mellitus, the cumulative association remained significant. Compared with the reference group, participants with two and three risk factors had adjusted odds ratios of 5.07 (95% CI 3.11–8.24) and 18.13 (95% CI 3.73–88.09), respectively. Overall, these findings suggest a graded association between the accumulation of BPS risk factors and the likelihood of cognitive impairment.

Mediation Analysis of Depression, Physical Performance, and Cognitive Function

Depression (SGDS-K score) was significantly associated with physical performance (TUG_log) (B = 0.0074, p < 0.001). Physical performance was, in turn, significantly associated with cognitive function (CIST) (B = −14.5417, p < 0.001), whereas the direct effect of depression on cognitive function was not significant (Fig. 1).

The indirect effect of depression on cognitive function through physical performance was significant (B = −0.1080), and the 95% bootstrap CI (−0.1765, −0.0530) did not include zero, supporting a mediating role of physical performance (see Supplementary Table S1).

DISCUSSION

This study investigated the associations of BPS factors with cognitive impairment among community-dwelling older adults and examined the cumulative pattern of risk when these factors coexisted. The analysis showed that slower gait performance (TUG_log) and lower educational attainment were associated with a higher likelihood of cognitive impairment, whereas depressive symptoms (SGDS-K) were not significantly associated with cognitive impairment in the adjusted logistic regression model.

Gait speed has been widely recognized as an early indicator of cognitive impairment,[18,19] and a similar pattern was observed in the present study. While the TUG test provides valuable information on gait, it also encompasses essential components such as attention, lower-extremity muscular strength, and dynamic balance. Consequently, it offers more comprehensive clinical insights than a simple straight-line walking test, serving as a representative measure of overall physical function. This finding aligns with previous research[3] that emphasizes the importance of a BPS approach to understanding cognitive impairment. Physical frailty and impaired gait performance are critical components of the aging process that

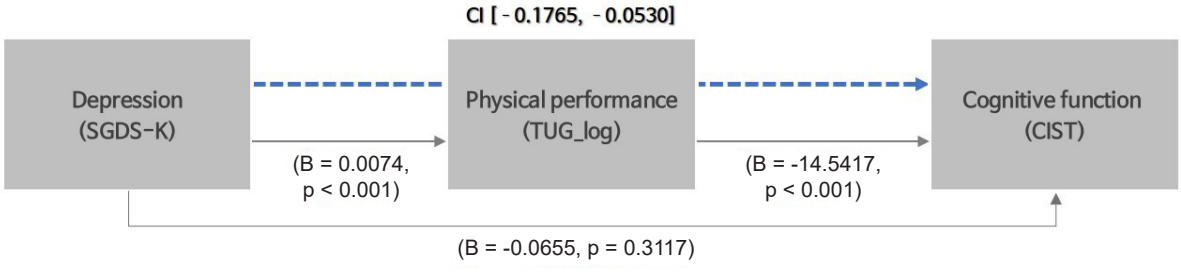


Fig. 1. Conceptual mediation model of the relationship between depression, physical performance, and cognitive function. Solid arrows indicate significant direct paths within the mediation process, while the direct path from depression to cognitive function was not significant (p>0.05). Blue dashed arrows represent the significant indirect effect (95% CIs do not include zero). SGDS-K, Korean version of the Short Geriatric Depression Scale; TUG_log, Timed Up and Go test (log-transformed); CIST, Cognitive Impairment Screening Test; CI, confidence interval.

may precede or accompany cognitive vulnerability.[20] Taken together, these findings suggest that physical performance may represent an important component of cognitive health in later life.

Education was identified as the strongest social factor associated with cognitive impairment. This finding can be interpreted based on the cognitive reserve theory.[21] Higher educational attainment provides cognitive resilience that compensates for brain damage or age-related neural changes,[12,21] whereas lower education may reduce this protective effect, thereby increasing susceptibility to other risk factors such as physical decline or depressive symptoms. These findings suggest the need for differentiated screening and intervention strategies according to educational level to prevent or delay cognitive impairment in older adults.

In this study, depressive symptoms were not directly associated with cognitive impairment in the adjusted logistic regression model but showed a significant indirect association through physical performance (Fig. 1).

Depression may reduce self-efficacy and motivation for physical activity, which may be associated with decreased physical engagement and poorer gait performance.[10] In addition, chronic stress responses may affect neuroplasticity and prefrontal function, thereby contributing to cognitive vulnerability.[22,23]

These findings suggest that psychological vulnerability alone may not independently predict cognitive impairment but may contribute to increased vulnerability when combined with other BPS factors. Consistent with this interpretation, the cumulative-risk analysis showed that the likelihood of cognitive impairment increased as the number of coexisting BPS risk factors increased. In particular, participants with three BPS risk factors showed markedly higher odds of cognitive impairment compared with those without risk factors. However, the wide confidence interval observed for this estimate suggests limited precision, and therefore the magnitude of this association should be interpreted with caution. This finding suggests that the accumulation of vulnerabilities may play an important role in explaining cognitive vulnerability in older adults and supports the view that cognitive impairment may be better understood within a multidimensional framework that considers the combined influence of biological, psychological, and social factors.

Accordingly, the present findings provide empirical support for the BPS framework and highlight the importance of considering multidimensional vulnerabilities rather than single risk factors when evaluating cognitive health in older adults. In this context, the results contribute to the growing body of literature suggesting that cognitive vulnerability in aging populations is shaped by the combined influence of multiple BPS factors rather than isolated determinants.

The relatively modest explanatory power of the logistic regression model should also be considered. In studies examining complex health outcomes such as cognitive impairment, relatively low explanatory power is commonly observed because cognitive outcomes are influenced by multiple interacting biological, psychological, and social determinants that cannot be fully captured within a single statistical model. Nevertheless, the increasing odds ratios according to the number of coexisting BPS vulnerabilities suggest that the accumulation of risks remains relevant for understanding cognitive vulnerability in older adults. These findings highlight the potential importance of community-based screening and multidomain preventive strategies. Interventions targeting physical performance, such as gait training and mobility exercises, may represent an important component of broader strategies addressing depressive symptoms and cognitive vulnerability in older adults.

Limitations

Several limitations should be noted. First, the cross-sectional design of this study precludes causal inference regarding the relationships between BPS factors and cognitive impairment.

Second, although the BPS framework encompasses a wide range of biological, psychological, and social determinants, each domain in this study was represented by a single indicator due to data availability. Specifically, gait performance (TUG), depressive symptoms (SGDS-K), and educational attainment were used as representative indicators of the biological, psychological, and social domains based on previous epidemiological studies reporting consistent associations with cognitive impairment. However, these variables may not fully capture the multidimensional nature of the BPS framework. In particular, additional social characteristics such as residential status (e.g., living alone or living with family members) were not available in the dataset. Because such factors may reflect important aspects of social vulnerability among older adults, future studies should incorporate a broader range of social indicators to provide a more comprehensive assessment of BPS influences on cognitive aging.

Third, the relatively small number of participants with three coexisting BPS risk factors may have limited the statistical precision of the estimated odds ratios, as reflected by the relatively wide confidence interval observed in this group. Fourth, although the logistic regression models were adjusted for age, sex, BMI, hypertension, and diabetes, the possibility of residual confounding cannot be completely excluded.

Finally, this study was conducted at a single center, which may limit the generalizability of the findings to other populations.

Conclusion

This study demonstrated that physical and social vulnerabilities were independently associated with cognitive impairment among community-dwelling older adults. In contrast, psychological vulnerability may be indirectly associated with cognitive impairment through physical performance. In addition, the accumulation of BPS risk factors was associated with substantially higher odds of cognitive impairment. These findings highlight the importance of a BPS approach that integrates biological, psychological, and social factors in maintaining cognitive health in older adults.

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CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Conceptualization, HK, JHP, MJS; Data curation, HK; Funding acquisition, MJS; Investigation, HK, JHP, TSP, MJ; Methodology, HK, JHP, TSP, MJS; Project administration, HK, MJS; Supervision, MJS; Formal analysis, HK, JHP; Writing_original draft, HK; Writing_review & editing, HK, JHP, TSP, MJS.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.4235/agmr.26.0020.

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