

ORIGINAL RESEARCH

Factors affecting cognitive function in older adults: a sex-specific analysis using panel quantile regression

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Abstract

The aging population has significantly increased in South Korea because of the factors such as longer life expectancy and lower birth rate. Healthy aging requires to preserve the cognitive function. Cognitive decline can hinder daily independent living. It is imperative to understand determinants of cognitive function in older adults for formulating effective interventions and policies. This study analyzed the data of Korean Longitudinal Study of Aging (KLoSA) from 2006 to 2020. A total of 4001 participants (1695 men and 2306 women) aged 65 and older were included in the final analysis. The sex-specific differences in cognitive function were assessed using statistical analyses including panel regression and panel quantile regression. Cognitive function had significant difference between men and women. Men showed higher cognitive function scores than women. Both men and women depicted significant influence on cognitive function based on age, employment status and depression. These factors had varying effects depending on the cognitive function level. Men's age, working status, and depression were associated with dementia regardless of cognitive function, whereas women's factors were more pronounced with low cognitive function. This study emphasizes the tailored sex-specific interventions and policies to improve cognitive function in older adults by considering sex-specific differences and varying cognitive function levels.

Keywords

Cognitive function; Older adults; Sex-specific analysis; Panel quantile regression

1. Introduction

South Korea's aging population is steadily growing because of the factors like increased life expectancy and decreased birth rates. It is increasing from 17.5% in 2022 to 46.4% in 2070 which is projected to reach 20.6% by 2025. This transition is heading to a super-aged society [1]. The interest in healthy life expectancy has increased due to the rising older adult's dependency ratio and healthcare costs.

The interaction with social and physical environments is an essential component of cognitive function for daily life and survival [2]. The aging process is major risk for several diseases and cognitive impairments [3, 4]. Biological changes in the brain during aging include decrease in white matter, prefrontal cortex volumes, and neurotransmitter levels, which cause cognitive decline [4, 5]. Furthermore, vascular dysfunction because of aging may bring chronic diseases and neurodegenerative disorders [2, 6]. It is thus imperative to maintain cognitive function for healthy aging.

The cognitive function level in older adults determines their ability of independently performing daily tasks and conversely the life quality. In 8-year study of tracking cognitive function changes, 30% older people maintained cognitive function while 70% had mild to severe cognitive decline [7]. The de-

cline in cognitive function among older adults is the major predictive factor for maintaining independence in daily life [8, 9]. A minor cognitive impairment may impact the daily activities (grocery shopping, meal preparation, financial management, household chores) and hamper life quality [8–10]. Cognitive impairments are the important indicators of conditions like dementia and Parkinson's disease. Around 35.6 million people in 2010 were living with dementia worldwide. The number can get doubled every 20 years, reaching 65.7 million by 2030 and 115.4 million by 2050 [11]. Alzheimer's disease being the most common cause of dementia has increased in South Korea over the past two decades as 5th leading death cause among older adults [12]. The prevention and intervention of factors associated with cognitive decline among older adults are thus essential.

Genetics, sociodemographic factors (age, sex, living, education, income, occupation), medical adversities (hypertension, cardiovascular diseases, diabetes), psychological factors (depression), sensory deficits (vision and hearing impairments), sleep quality (insomnia), lifestyle (smoking, diet, exercise), and social relationships are the contributing factors towards cognitive decline [2, 3, 6, 7, 13, 14]. Significant differences were found between the group characteristics (age, education, dietary habits, income) based on cognitive function levels in a

study on Korean adults aged 40 and above [15]. The behavioral and lifestyle interventions related to cognitive function are extensively studied [16, 17], however, studies on individualized therapeutic interventions have been limited.

Previous studies on Korean older adults had found different cognitive functions and related risk factors based on sex [18]. The average cognitive function of women was lower compared to men, however the percentage of cognitively impaired men was higher [18]. The risk factors for cognitive function decline differed based on sex, education, nutrition, and social interaction [18]. More risk factors were identified in older women. These results could be attributed to the fact that older adult based studies included more healthy men as the women lived longer with more deteriorated health conditions [16]. Moreover, sex hormones and sociocultural factors like education and occupation might contribute to sex differences [19, 20]. Better sex-specific treatments could be developed by understanding the differences of risk factors and mechanisms of cognitive function between the sexes [20].

The cognitive function differs between sexes, and participants' characteristics vary according to cognitive function levels [15, 18, 21]. However, previous studies lack in depth analysis [18]. Multiple regression analyses have been made to analyze the factors of cognitive function. They only estimate the average relationship between predictor and dependent variables. Aging-related cognitive changes vary among the individuals [13, 15]. The cognitive function impact on these changes differs based on cognitive function levels. This study aims to examine relationships between predictor and dependent variables based on the dependent variable distribution via panel quantile regression analysis [22]. The sex-specific cognitive function levels of older adults are considered when identifying risk factors affecting cognitive function. This study can assist in developing individualized interventions.

2. Materials and methods

2.1 Data

Korean Longitudinal Study of Aging (KLoSA) was analyzed from 1st to 8th wave in the period of 2006 to 2020 to investigate the factors affecting cognitive function based on sex. KLoSA survey measured and understood variety of aspects of social, economic, psychological, demographic, and health conditions of the aging population in South Korea to formulate effective socio-economic policies.

Individuals aged 65 and older were considered during the 1st wave of study with cognitive functions estimated from 2006 (1st wave) to 2020 (8th wave). The cases of missing data regarding major variables were excluded. A total of 4001 participants (1695 men and 2306 women) were included in the final analysis.

2.2 Variables

2.2.1 Independent variables: demographic, economic, and health characteristics

Demographic, economic, and health characteristics were categorized as the independent variables of this study. Age

(continuous variable), residential area (urban = 0, rural = 1), and education (elementary school or below = 0, middle school or above = 1) were included in the demographic characteristics. Household annual income (continuous variable) and employment status (unemployed = 0, employed = 1) were included in the economic characteristics. Health characteristics included chronic illness (absent = 0, present = 1) and depression (1 = rare, 2 = sometimes, 3 = often, 4 = always). The income per household member had been equalized and log-transformed to reflect normal distribution of household income (income per household member/ $\sqrt{\text{number of household members}}$). The depression was assessed by using The Center for Epidemiological Studies-Depression Scale (CES-D10). According to the KLoSA, depression was measured with the Korean version of CES-D-10 which had 10 short questions. The CES-D was developed by Radloff (1977) [23]. The reliability of depression scale was 0.838 in 2006, 0.870 in 2008, 0.875 in 2010, 0.869 in 2012, 0.853 in 2014, 0.855 in 2016, 0.870 in 2018, and 0.850 in 2020 based on this study.

2.2.2 Dependent variable: cognitive function

The Korean Mini-mental State Examination (K-MMSE) originally developed by Folstein, Folstein and McHugh (1975) was used in general [24]. However, this study measured the cognitive function by K-MMSE as adopted by Kang, Na & Hahn (1997) [25]. The clinical and research settings widely used MMSE to assess cognitive function [26]. Better cognitive function was indicated by the higher K-MMSE scores. K-MMSE total score of 24 to 30 indicated no cognitive impairment, 18 to 23 as mild, and 0 to 17 as severe [27].

2.3 Statistical analysis

Stata version 15.0 (Stata Corp., College Station, TX, USA) was used in this study. The analysis methods and procedures were as follows: First, descriptive statistical analysis was conducted to understand the characteristics of study population. Second, independent sample *t*-tests were employed to examine the sex differences in cognitive function. Panel Regression Analysis was made before the Panel Quantile Regression Analysis to identify the factors affecting cognitive function in older men and women. A Hausman Test determined whether Fixed Effect (FE) Model or Random Effect (RE) Model should be used in panel regression analysis. Panel Quantile Regression Analysis was applied for the quantitative verification of major factors that influenced cognitive function in older women and men, which might differ depending on their cognitive function. The quantitative regression analysis was appropriate when there was heterogeneity among the sample groups or when factors were estimated based on the quantile distributions. This estimated the coefficients to explain specific quantiles within the distribution of dependent variable [28]. Most traditional regression analyses focused on the average effects which might under- or over-estimate the impact of independent variables on dependent variable, as well as fail to identify relationships between the variables [29, 30]. This study thus used Panel Quantile Regression Analysis to examine the factors affecting cognitive function by considering the distribution of dependent variable, and the high and low levels of cognitive function.

The objective was to examine distribution of cognitive function variable set as dependent variable, and factors affecting cognitive function through the panel quantile regression analysis. The current panel quantile regression model did not consider unobserved heterogeneity [31]. Resultantly, this study used Machado and Silva's (2019) [32] Method of Moments Quantile Regression (MM-QR) methodology which accounted for the unobserved heterogeneous effects.

3. Results

3.1 Descriptive statistics

The demographic, economic, and health characteristics of study participants are given in Table 1. Men had an average age of 76.83 years (Standard Deviation (SD) = 6.23), while women had 78.00 years (SD = 6.72). Women and men lived in urban areas which accounted for 65.0% of both groups' residential areas. Pertaining to education, 51.2% men and 86.5% women had completed elementary school or less. Regarding household income, men had average income of \$7330.06 (Standard Deviation = USD \$8532.95), while women had \$7550.538 (SD = USD \$10,101.82). Men had unemployment rate of 75.4%, whereas women had 90.2%. The chronic illnesses prevalence was 72.9% for men, and 81.0% for women. Women had higher depression scores than men with average score of 1.91 points (SD = 0.60) and 1.76 points (SD = 0.56), respectively.

A *t*-test conducted on independent samples confirmed that the cognitive function of men was higher compared to women from 2006 to 2020. Furthermore, the cognitive function of men and women declined over time (Table 2).

3.2 Sex-specific factors affecting cognitive function in older adults

A panel regression analysis was conducted to examine the factors influencing cognitive function based on the sex of older adults (Table 3). Hausman test ($p < 0.001$) was employed to select the fixed effects model based on panel regression analysis for men and women. Age as sociodemographic, working status as economic, and depression as health characteristic affected the cognitive function in both men and women. Younger the age, lower was depression level, and greater the cognitive function. Moreover, residential area, education, household annual income, and chronic disease had no significant impact on the cognitive function in men and women.

A panel quantile regression analysis examined the factors influencing cognitive function of older adults based on sex and cognitive level. Age, working status, and depression impacted the cognitive function in men and women with 0.1 decile. Men's age, working status, and depression were correlated with cognitive function in 0.5th and 0.9th quintiles, however women's cognitive function was not significantly correlated. Thus, the age, working status, and depression had affected the cognitive function in men regardless of their cognitive function levels, whereas in women, they only impacted when cognitive function was low (Table 4).

4. Discussion

The study investigated factors affecting the changes in cognitive function of older adults based on sex. The cognitive function differed by sex. Men had higher cognitive function than women from 2006 to 2020. As per the study by American Alzheimer's Association, women over 65 years of age were more likely to develop dementia compared to men. This match between domestic and international data showed that women had higher dementia prevalence than men [33, 34]. Resultantly, the government and social sectors should provide practical assistance to improve women cognition. Accordingly, the Dementia Support Center in Korea conducted dementia prevention program for community-dwelling women at community senior center. It improved the women cognition [35]. Establishing programs to enhance women cognitive function and improve service accessibility could contribute to the reduction in dementia rates among women. Women demographics, comorbidities, and economics must be considered when developing individualized dementia management programs.

Cognitive function of older adults was higher in men and women regarding younger age in sociodemographic, working status in economic, and lower depression levels in health characteristics. It would thus be imperative to develop program tailored to the characteristics of each older individual for improving the cognitive function. Countries around the world are thus drafting practical laws and systems to solve the social problems of dementia. At the 2012 G8 Health Ministers' Meeting, eight countries including the United States, Canada, United Kingdom, Germany, France, Italy, Russia and Japan are hosting dementia summit to manage dementia at government level. Korea has expanded dementia-related policies and is currently implementing the 4th with the 1st National Dementia Plan established in 2008. The 4th National Dementia Plan aims to develop and spread cognitive health promotion programs to provide specialized dementia management and care. A few age-based systems and services are being established for older adults who are starting to age and those living alone with age over 75. However, no prevention policies on cognitive function focus employment status or depression level [36]. There is a need for prevention, diagnosis, and treatment of depression among retired older adults.

The panel quantile regression analysis revealed that age, working status, and depression were the main dementia causes in men regardless of cognitive function, however not in women. Evidence from previous studies depict that causes of dementia differ according to sex [37, 38]. There are biological differences in men and women, however they are also influenced by environmental, social, and cultural factors depending on the sex. Dementia prevention and support policies should thus be tailored according to the sex of individual. Pertaining to dementia prevention, men must consider age, working status, and depression rather than the current cognitive function level, while women should account for age, working status, and depression when cognitive function is low.

TABLE 1. Demographic characteristics of study participants.

| Variable | Categories | Men (N = 8799) | | Women (N = 12,718) | |
|---|----------------------------|--------------------|------|-----------------------|------|
| | | N | % | N | % |
| Demographic factors | | | | | |
| Age (M (SD)) | | 76.83 (6.23) | | 78.00 (6.72) | |
| Residential area | Urban | 5943 | 67.5 | 8763 | 68.9 |
| | Rural | 2856 | 32.5 | 3955 | 31.1 |
| Education | Elementary school or below | 4502 | 51.2 | 11,000 | 86.5 |
| | Middle school of above | 4295 | 48.8 | 1716 | 13.5 |
| Economic factors | | | | | |
| USD \$ Annual household income (M (SD)) | | 7330.060 (8532.95) | | 7550.538 (10,101.82) | |
| Employment | Unemployed | 6630 | 75.4 | 11,470 | 90.2 |
| | Employed | 2169 | 24.6 | 1248 | 9.8 |
| Health conditions | | | | | |
| Chronic illness | No | 2377 | 27.0 | 2412 | 19.0 |
| | Yes | 6422 | 72.9 | 10,306 | 81.0 |
| Depression (M (SD)) | | 1.76 (0.56) | | 1.91 (0.60) | |

SD: Standard Deviation.

TABLE 2. Cognitive function differences by sex.

| Variable | Total | | Men | | Women | | t |
|----------------------------|-------|------|-------|------|-------|------|-----------|
| | M | SD | M | SD | M | SD | |
| Cognitive function in 2006 | 22.63 | 6.34 | 24.84 | 5.35 | 20.98 | 6.51 | 20.386*** |
| Cognitive function in 2008 | 22.21 | 6.32 | 24.26 | 5.56 | 20.74 | 6.42 | 16.855*** |
| Cognitive function in 2010 | 22.03 | 6.53 | 24.18 | 5.63 | 20.50 | 6.69 | 15.991*** |
| Cognitive function in 2012 | 22.21 | 6.69 | 24.21 | 5.85 | 20.83 | 6.88 | 13.526*** |
| Cognitive function in 2014 | 21.65 | 6.77 | 23.86 | 5.92 | 20.14 | 6.90 | 13.842*** |
| Cognitive function in 2016 | 21.58 | 6.68 | 23.64 | 5.79 | 20.21 | 6.88 | 12.135*** |
| Cognitive function in 2018 | 20.86 | 7.15 | 22.89 | 6.50 | 19.54 | 7.25 | 10.040*** |
| Cognitive function in 2020 | 20.54 | 6.75 | 22.38 | 6.13 | 19.38 | 6.87 | 8.740*** |

SD: Standard Deviation. ***: $p < 0.001$.

TABLE 3. Factors affecting the cognitive function of older adults based on sex (Panel regression analysis).

| Variables | Men | | Women | |
|---|-----------|-------|-----------|-------|
| | B | S.E. | B | S.E. |
| Demographic factors | | | | |
| Age | -0.275*** | 0.013 | -0.290*** | 0.011 |
| Residential area (ref. Urban) | -0.325 | 0.420 | -0.249 | 0.101 |
| Education (ref. Elementary school or below) | 0.025 | 0.870 | 1.517 | 0.895 |
| Economic factors | | | | |
| Annual household income (log) | -0.002 | 0.041 | 0.043 | 0.034 |
| Employment (ref. Unemployed) | 0.660*** | 0.175 | 0.749*** | 0.196 |
| Health conditions | | | | |
| Chronic illness (ref. No) | -0.181 | 0.209 | -0.348 | 0.220 |
| Depression | -1.968*** | 0.116 | -1.491*** | 0.096 |
| Constant | 48.650*** | 1.035 | 45.761*** | 0.814 |

*** $p < 0.001$. S.E.: Standard Error.

TABLE 4. Mean and variance of initial score and rate of change of the unconditional model.

| Variables | Men | | | | | | Women | | | | | |
|---|--------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|
| | $\tau = 0.1$ | | $\tau = 0.5$ | | $\tau = 0.9$ | | $\tau = 0.1$ | | $\tau = 0.5$ | | $\tau = 0.9$ | |
| | B | S.E. | B | S.E. | B | S.E. | B | S.E. | B | S.E. | B | S.E. |
| Demographic factors | | | | | | | | | | | | |
| Age | -0.378*** | 0.028 | -0.266*** | 0.013 | -0.191*** | 0.020 | -0.321*** | 0.026 | -0.288 | 0.354 | -0.248 | 0.958 |
| Residential area (ref. Urban) | -0.228 | 0.954 | -0.334 | 0.439 | -0.406 | 0.698 | -0.682 | 1.058 | -0.862 | 0.431 | -1.072 | 0.080 |
| Education (ref. Elementary school or below) | 0.318 | 2.174 | -0.001 | 1.001 | -0.217 | 1.589 | 1.631 | 1.798 | 1.508 | 0.189 | 1.365 | 0.739 |
| Economic factors | | | | | | | | | | | | |
| Annual household income (log) | 0.082 | 0.100 | -0.009 | 0.046 | -0.071 | 0.073 | 0.109 | 0.085 | 0.038 | 0.427 | -0.045 | 0.671 |
| Employment (ref. Unemployed) | 0.805*** | 0.366 | 0.648*** | 0.168 | 0.541** | 0.267 | 1.090* | 0.428 | 0.722 | 0.425 | 0.293 | 0.983 |
| Health conditions | | | | | | | | | | | | |
| Chronic illness (ref. No) | 0.119 | 0.455 | -0.207 | 0.210 | -0.428 | 0.333 | -0.361 | 0.528 | -0.347 | 0.631 | -0.332 | 0.356 |
| Depression | -2.774*** | 0.309 | -1.897*** | 0.143 | -1.304*** | 0.225 | -1.632*** | 0.241 | -1.480 | 0.599 | -1.303 | 0.520 |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. S.E.: Standard Error.

It is imperative to develop accessible digital healthcare services, and engage in situations where dementia prevention is vital. As an outcome of this study, the cognitive function of older adult is gradually decreasing over time (male M 24.84 in 2006 decreased to M 22.38 in 2020, female M 20.98 in 2006 to M 18.38 in 2020). The aging population is a global phenomenon, and Korea is rapidly aging society with low birthrates. Older adult care is thus important for social indirect welfare. Resultantly, the related healthcare services are on the rise. Moreover, the healthcare service market is being digitalized and developed because of the factors like competition for medical staff and rising labor costs. The global digital healthcare market would reach \$509 billion in 2027 from \$152 billion in 2020 as per PricewaterhouseCoopers consulting data. There is thus a need to develop healthcare services for improving cognition of older adults. The related research is underway [39–41]. A study emphasized the importance of enhancing cognitive function and using digital technology via the virtual reality-based intervention programs for older adult dementia patients. Accordingly, the healthcare notification app was designed and implemented to improve cognitive function [42, 43].

It is essential to prevent or alleviate depression in older women. Panel regression analysis conducted on the study subjects revealed that depression had significant impact on cognitive function. This outcome is in line with previous studies that found correlation between depression level in elderly and cognitive abilities [44, 45]. Women had higher degree of depression than men. Depression pattern is from normal mood fluctuations to pathological conditions and appears in all age groups. However, the physical and social stress of aging in elderly brings physical vulnerability, which is difficult to control and manage. Furthermore, the depression in old age is severe than in other age groups, and may cause cognitive decline [46]. A previous study depicted that ~20% of dementia causes in elderly were reversible, and triggered by depression. Treating depression improves the cognitive function [47]. Depressive symptoms in older adults are also a cause of treatable dementia. It is important to initially screen the cognitive function level and degree of depression in older women. The role of social support for the aging population is also important who wish to prevent and alleviate depression [37, 38].

This study has certain limitations such as more independent variables (physical activity, social engagement, and dietary habits) cannot be considered because of the limitations in secondary data, and depression and cognitive functions are measured using questionnaires, which may be subjective. This study is not extended beyond the scope of this investigation. It is anticipated that investigating the interactions between variables can provide insights into the complex relationships that cannot be examined by the analysis of main effects alone in future studies. In conclusion, follow-up research should be undertaken to complement some of the study limitations. On the other hand, there are implications as the aging dilemmas are expanding. There is a need to establish system for the prevention, diagnosis, and treatment of dementia.

5. Conclusions

As the world population ages, dementia is referred to as more frightening disease than cancer. Its direct and indirect effects are significant. Korea is no exception. The number of dementia patients increase every 12 min, and die every 60 min [48]. The perspective of dementia handling has shifted from treatment to prevention and management because of the delays in developing therapies. Accordingly, the significance of this study is as follows.

It provides foundation for the academic research regarding factors affecting cognitive function among older adults. The importance of identifying dementia risk factors is increasing in current dementia research as there is no cure. It is thus important to prevent and manage dementia by knowing the factors that contribute to its development. Results of this study can be applied as a basis for future research on dementia prevention and management.

The factors affecting dementia in older adults based on the sex are analyzed and empirically verified while considering the cognitive function level. As per the findings of this study, a different approach should be followed for developing cognitive decline prevention or dementia management programs for specific groups. The obtained data can be meaningful to improve services customized for the needs of each user. According to the analysis outcomes, age, working status, and depression in men affect dementia regardless of the cognitive function, however women lower cognitive function has more significant impact. It is thus necessary to take practical measures for developing centers, education sector, and lifestyle habits to improve cognitive function in older women.

Korea is a super-aging society. Dementia being a geriatric disease is on the rise in aging population. Korea's National Responsibility for Dementia System (2017) has been announced. Country has transitioned from the policies of economic relief for older dementia adults to the care and individualized personalized services. It is speculated that results of this study can be employed as the basic data to plan differentiated programs in future.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available publicly online at: <https://survey.keis.or.kr/eng/klosa/klosa01.jsp>.

AUTHOR CONTRIBUTIONS

KHJ and SL—designed the research study; reviewed the manuscript. KHJ and SHP—performed the research and analyzed the data. JN—authored the discussion and the conclusion section of the manuscript. JJ—contributed to drafting and revising the introduction. SHP—provided administrative support for the manuscript and contributed to revise the method and conclusion section. All authors contributed to editorial changes in the manuscript, and all authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All methods were performed in accordance with the Declaration of Helsinki. This report was exempted from approval by the institutional review boards (IRB) of the Clinical Research Ethics Committee of Semyung University (IRB number: SMU-EX-2023-06-004). Every participant gave a written consent prior to their participation in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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