



Research paper

The association between psychological resilience and cognitive function in longitudinal data: Results from the community follow-up survey

Ji Su Yang^a, Ye Jin Jeon^a, Ga Bin Lee^a, Hyeon Chang Kim^b, Sun Jae Jung^{b,c,*}

^a Department of Public Health, Yonsei University Graduate School, Seoul, Korea

^b Department of Preventive Medicine, Yonsei University College of Medicine, Seoul, Korea

^c Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA, USA



ABSTRACT

Background: The present study aimed to investigate the association between resilience and cognitive function of middle-aged Koreans in a longitudinal setting.

Methods: We utilized the baseline and 5-year follow-up data from the Cardiovascular and Metabolic Diseases Etiology Research Center study. The final number of participants included in the analysis was 397 (108 men, 289 women, mean age 55.4 years) who had valid measurements of both baseline resilience and Mini-Mental State Examination at follow-up. The resilient people at baseline were operationally defined as the people who had at least one negative experience in the Life Experience Survey without depression, which was defined as a Beck Depressive Inventory-II score of 20 or above. Cognitive function was evaluated by the Korean version of the Mini-Mental State Examination in both surveys. A generalized linear model was applied after adjusting for confounders. The association between resilience and cognitive function was further analyzed using stratification by median age and education level.

Results: At follow-up, only in men, the resilience group showed a higher MMSE level compared to the reference group ($\beta = 1.3, p = 0.002$). Stratified by median age, both the younger group ($\beta = 1.2, SE = 0.5, p = 0.031$) and the older group among men ($\beta = 2.1, SE = 0.7, p = 0.0069$) showed a positive association between resilience and cognitive functions. However, when stratified by education level, only the low-education group presented the association ($\beta = 1.7, SE = 0.5, p = 0.002$). In women, no significant results were found.

Limitation: This study had limited number of participants.

Conclusion: Resilience at baseline was associated with more well-preserved cognitive function at follow-up in men.

1. Introduction

Most human beings experience traumatic events, such as parental death, divorce, or natural disasters, in their lifetime. There are individuals who deal with these events successfully and report no psychiatric disorder after being exposed to traumatic events. These behaviors and outcomes were interpreted as psychological resilience. (Alim et al., 2008, Collishaw et al., 2007) Additionally, psychological resilience can also be defined as a situation in which a person adapts well and maintains a high level of psychological function even after exposure to severe stress. (Bonanno et al., 2011) Comprehensively, the term resilience is used to indicate that some individuals have relatively good psychological abilities despite the risk experiences that are expected to cause serious aftereffects. In other words, it means relative resistance to environmental risk experiences or overcoming stress and adversities. (Rutter, 2006)

In recent years, a number of studies have been performed to determine whether psychological resilience is associated with an individual's cognitive function. A longitudinal study with cognitively healthy elderly

individuals in Germany found that the amyloid-related cognitive decline was stronger in individuals with lower resilience capacities. (Wolf et al., 2019) Furthermore, a study in the United States that targeted highly traumatized individuals showed that the resilience group showed better nonverbal memory than the non-resilience group. (Wingo et al., 2010)

In our previous research, we investigated the association between psychological resilience and cognitive functions using the baseline data of a cohort utilizing cross-sectional data analysis. (Jung et al., 2019) As a result, the resilience group showed higher Mini-Mental State Examination (MMSE) scores in women compared to the reference population, who were unexposed to negative events and without depressive symptoms. This indicates that psychological resilience was associated with more well-preserved cognitive function in women. However, even though significant results were obtained, it was difficult to explain the temporality of the association due to the cross-sectional design of the study. Additionally, no existing study has determined whether the association between cognitive function and psychological resilience varied according to individual characteristics. Since age and the level of education had significant impact on cognitive function, (Farmer et al., 1995,

* Corresponding author at: Department of Preventive Medicine, Yonsei University College of Medicine, 50-1 Yonsei-ro Yonsei University Medical Center Seodaemun-gu, Seoul, S. Korea.

<https://doi.org/10.1016/j.jad.2021.04.062>

Received 13 November 2020; Received in revised form 18 January 2021; Accepted 25 April 2021

Available online 1 May 2021

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Glisky, 2007) they were also expected to influence the association between psychological resilience and cognitive function.

Therefore, in the present study, we aimed to investigate the association between the psychological resilience trait and cognitive function by using longitudinal data where cognitive functions were examined a few years after confirming psychological resilience, expecting a reduction in the reverse causation effect. Additionally, we stratified the analysis by age group and educational level to investigate whether the association between psychological resilience and cognitive function depends on age or education level, both of which are known to critically impact cognitive function.

2. Methods

2.1. Study population

This study used data from the Cardiovascular and Metabolic Diseases Etiology Research Center (CMERC) cohort study. The CMERC cohort was constructed to study the risk factors of cardiovascular and metabolic diseases; community-living individuals who were free from myocardial infarction, heart failure, and stroke were enrolled. A total of 4,060 participants aged 30–64 years were recruited between December 2013 and February 2018. All of the participants completed questionnaires and examinations according to a predefined protocol. Of the 807 participants who were enrolled in the first year (2013), 787 participants (2 died, 18 withdrew consent) were requested to join in the follow-up investigation. Finally, 500 participants underwent follow-up from January to May 2019. Among the examinations, cognitive function test was performed only on people aged 50 years and older; therefore, 100 participants who were aged under 50 at the time of investigation were excluded. Additionally, three participants whose MMSE scores were not known were excluded. Consequently, a total of 397 participants (108 men, 289 women) were included in the current study.

2.2. Measurement of psychologic resilience at baseline

In the baseline survey of CMERC, the Life Experience Survey (LES) (Sarason et al., 1978) questionnaire was used to investigate the participants' general psychological response to stressful events during the last 6 months. The LES questionnaire was translated to Korean and validated for the Korean population. (Lee, 1993) The original questionnaire listed 47 possible life events, such as marriage, divorce, death of family members or friends, lifestyle changes, and occupational successes or failures. The investigation was conducted with trained interviewers. If the participants reported experiencing the corresponding item on the list, they were asked to score the item on a 7-point-scale ranging from +3 (extremely positive experience) to -3 (extremely negative experience), and any item that received a negative impact score was regarded as a "negative event."

Moreover, depressive symptoms that occurred in the previous 2 weeks were assessed using the Beck Depression Inventory II (BDI), which was translated and validated in Korean. (Lim et al., 2011) A person showing a BDI-II score of 20 or higher was regarded as having depression. Subsequently, the participants who had at least one negative experience, but had no depression, were operationally defined as the "resilience group," and participants who did not report any negative experiences and had no depression were designated as the "reference group." The other participants who had depression regardless of having negative experiences were named as the "depression group." Self-development of the definition of "resilience group" was based on suggestions from prior studies that resilience is an interactive concept related to the combination of risk experience and relatively positive psychological outcomes despite such experiences. (Rutter, 2006)

The LES and BDI-II questionnaires were self-administered, and all answers were reviewed by researchers to check for any instances of misreading, miswriting, or missing responses.

2.3. Measurement of cognitive function

Cognitive function was evaluated using the Korean version of the MMSE questionnaire by trained interviewers. (Kim et al., 2010) The questionnaire consisted of psychometric properties, such as orientation to time, place, and person; verbal memory; concentration and calculation; and the functions of language, praxis, and visuospatial construction. For each of the 30 questions, 1 point was given when the interviewer determined that the answer was appropriate according to the standardization manual. The MMSE was conducted twice, once at the baseline and once during the follow-up, for participants aged 50 years or older at each time point. The multiple imputation method was used to handle the missing values of baseline MMSE scores for participants who were aged under 50 at baseline and aged 50 and older at follow-up (N = 46, 11.6%).

2.4. Covariates

At both baseline and follow-up assessments, the participants were asked about their demographic characteristics, medical history, and health behaviors by trained interviewers using a general questionnaire with a standardized protocol. Household income was divided into quartiles (<20.7, 20.7 to <30.0, 30.0 to <42.4, and ≥42.4 million Korean won/year). Based on the years of education attainment and the education system in Korea, participants were grouped as ≤9, 10–12, and ≥13 years. According to marital status, participants were categorized as "unmarried," "divorced/married, but living apart," "married and living with spouse," and "widowed." Comorbidities were determined from the questions that deduced whether the participants had ever been diagnosed by physicians with any of the following diseases: coronary heart disease, stroke, diabetes mellitus, chronic renal failure, chronic hepatitis B or C viral infection, and cancers of the stomach, liver, colorectum, breast, uterine cervix, lung, and thyroid. Smoking and drinking statuses were classified into "non," "past," and "current." Physical activity was assessed using the Korean version of the International Physical Activity Questionnaire-Short Version and divided into three groups according to the intensity and duration. (Chun, 2012)

3. Statistical analysis

The chi-square test and analysis of variance (F-test) were used to compare the baseline differences in covariates among the reference, resilience, and depression groups. Continuous variables were shown as mean and standard deviation, whereas categorical variables were shown as frequency and percentage. The t-test and analysis of variance (F-test) were used to compare the LES results of the resilience group and the depression group. To compare the baseline MMSE scores and follow-up MMSE scores of the reference, resilience, and depression groups, paired t-test was conducted for each group. A generalized linear model was applied to examine the association between baseline resilience and follow-up MMSE scores. The final model was adjusted for age, marital status, household income, comorbidities, smoking, drinking, physical activity, number of people living together, and the MMSE score; and these variables were investigated in the baseline survey. Overall, data were analyzed separately for men and women. Stratified analyses by age and education were conducted with the same covariates. To confirm the results of analysis, sensitivity analysis was performed, in which the "resilience group" was defined by counting the only negative events given a score of -2 or less. All data analyses were performed using SAS version 9.4 (SAS Institute, NC, USA) and R version 4.0.2 (R Foundation).

3.1. Ethics

The study protocol was approved by the institutional review board of the hospital at Yonsei University College of Medicine (4-2013-0661), and written informed consent was obtained from all participants. All

procedures in this work complied with the ethical standards of the relevant national and institutional committees on human experimentation, and were carried out in accordance with the Ethical Principles for Medical Research from the Helsinki Declaration of 1975 revised in 2008.

4. Results

The reference, resilience, and depression groups, which were divided according to the resilience characteristics at baseline, did not show statistically significant differences in most of the descriptive characteristics at baseline. Compared to the reference and depression groups, the resilience group presented a higher proportion of people with long periods of education and high income level. However, there was no statistically significant difference between the groups. The proportion of people with no comorbid diseases was highest in the resilience group, and this result was statistically significant. Also, the proportion of people with low activity was lowest in the resilience group. The MMSE scores examined 5 years after the baseline were higher in the resilience group than in the other two groups; however, these results were marginally

significant (Table 1).

To compare the baseline LES results of the resilience group and the depression group, the number of negative life events and the total score of negative life events were analyzed. The variables (the number of negative life events and the total score of negative life events) were analyzed as a continuous variable and also as a categorical variable. For both men and women, there was no statistically significant difference between the resilience group and the depression group in terms of the characteristics associated with negative life events (Supplementary table 1).

The distribution of follow-up MMSE scores in reference, resilience, and depression groups was plotted. A correction was made to double the bandwidth to draw a smooth graph. In men, the distribution of MMSE scores in the resilience group was significantly different from the reference group and depression group, and relatively higher MMSE scores were distributed in the resilience group. In women, there was little difference between the distribution of MMSE scores in the reference group and the resilience group. Rather, the depression group showed a relatively low MMSE score distribution, unlike the other two

Table 1
Descriptive characteristics of participants classified by resilience (N = 397).

Variables	Reference group		Resilience group		Depression group		p value
	N = 146	36.8%	N = 206	51.9%	N = 45	11.3%	
Age, years	55.3	± 4.6	55.5	± 4.6	55.6	± 4.5	0.912
Age (groups)							
<52	9	(6.2)	6	(2.9)	3	(6.7)	0.467
52-55	50	(34.3)	76	(36.9)	13	(28.9)	
56-58	64	(43.8)	98	(47.6)	25	(55.6)	
≥59	23	(15.8)	26	(12.6)	4	(8.9)	
Sex							
Men	46	(31.5)	51	(24.8)	11	(24.4)	0.340
Women	100	(68.5)	155	(75.2)	34	(75.6)	
Education, years							
≤9	46	(31.5)	46	(22.3)	15	(33.3)	0.300
10-12	59	(40.4)	97	(47.1)	19	(42.2)	
≥13	41	(28.1)	63	(30.6)	11	(24.4)	
Marital status							
Unmarried	1	(0.7)	2	(1.0)	1	(2.2)	0.674
Divorced or living apart	4	(2.7)	12	(5.8)	3	(6.7)	
Living together	130	(89.0)	182	(88.4)	38	(84.4)	
Widowed	11	(7.5)	10	(4.9)	3	(6.7)	
Number of people living together							
1	6	(4.1)	10	(4.9)	3	(6.7)	0.832
2	31	(21.2)	51	(24.8)	10	(22.2)	
3	41	(28.1)	66	(32.0)	13	(28.9)	
≥4	68	(46.6)	79	(38.4)	19	(11.3)	
Income							
<2078 won/year	38	(26.0)	56	(27.2)	20	(44.4)	0.118
2078-3000 won/year	27	(18.5)	44	(21.4)	5	(11.1)	
3000-4242 won/year	47	(32.2)	51	(24.8)	13	(28.9)	
≥4242 won/year	34	(23.3)	55	(26.7)	7	(15.6)	
Number of comorbid disease							
0	65	(44.5)	93	(45.2)	19	(42.2)	0.001
1	61	(41.8)	53	(25.7)	11	(24.4)	
≥2	20	(13.7)	60	(29.1)	15	(33.3)	
Smoking							
Non-smoker	117	(80.1)	162	(78.6)	31	(68.9)	0.207
Past smoker	21	(14.4)	31	(15.1)	7	(15.6)	
Current smoker	8	(5.5)	13	(6.3)	7	(15.6)	
Alcohol							
Non-drinker	55	(37.7)	82	(39.8)	16	(35.6)	0.906
Past drinker	7	(4.8)	9	(4.4)	1	(2.2)	
Current drinker	84	(57.5)	115	(55.8)	28	(62.2)	
Physical activity							
Low activity	67	(45.9)	70	(34.0)	27	(60.0)	0.012
Middle activity	13	(8.9)	28	(13.6)	4	(8.9)	
High activity	66	(45.2)	108	(52.4)	14	(31.1)	
MMSE	27.6	± 2.0	27.9	± 1.7	27.4	± 2.0	0.066

MMSE: Mini Mental State Examination.

Values are presented as mean±SD or N(%).

Resilience group: Participants who had at least one negative life experience within 6 months but without depression.

Reference group: Participants without any negative experiences and depression.

groups (Figure 2).

The association between resilience and cognitive functions was analyzed using a generalized linear model. In men, the MMSE scores of the resilience group were higher than those of the reference group in the fully adjusted model ($\beta = 1.3$, $SE = 0.4$, $p = 0.002$). Age, baseline MMSE score, socioeconomic status, comorbidities, and lifestyle were adjusted. Subsequently, the cognitive function of the depression group was estimated to be low ($\beta = -0.5$, $SE = 0.6$, $p = 0.402$); however, this result was not statistically significant. In women, no significant results were found in both the resilience and depression groups (Table 2).

The MMSE scores for each of the two time points were also specified. In the men’s resilience group, the mean MMSE scores increased from 27.56 to 28.47 ($p = 0.0002$), and in the women’s resilience group, the mean MMSE scores increased from 27.18 to 27.77 ($p < 0.0001$). There was no statistically significant difference in the other groups (Supplementary table 2).

Age and duration of education were adjusted for the model in Table 2; however, stratified analyses were performed additionally, since it is well-known that cognitive function is highly dependent on age and education level. (Farmer et al., 1995, Glisky, 2007) The male and female groups were divided again based on the median age of 56 years and 54 years, respectively. An analysis of the male groups showed that the MMSE scores of the resilience group was higher than those of the reference group, in both the younger ($\beta = 1.2$, $SE = 0.5$, $p = 0.031$) and older groups ($\beta = 2.1$, $SE = 0.7$, $p = 0.007$). The association between resilience and cognitive function was stronger in the older age group. In women, there was no statistically significant association between resilience and cognitive function in both the younger and older age groups (Table 3).

Similarly, highly educated people and less-educated people were separately analyzed in each of the male and female groups. The reference point was determined according to the Korean education system. Only the less-educated male group presented significant results; the psychologically resilience group showed higher cognitive function than the reference group ($\beta = 1.7$, $SE = 0.5$, $p = 0.002$). In the highly educated male group as well as both female groups—highly educated and less-educated—there were no statistically significant associations between resilience and cognitive function (Table 4).

Sensitivity analysis was performed by defining the resilience group differently. Negative life events were counted only if they were scored -2 or less. Therefore, the participants who experienced at least one negative

life event, which was scored -2 or less but had no depression were defined as the resilience group. As a result, despite smaller coefficient, there were similar results to those of previous analysis. In men, the MMSE scores of the resilience group were higher than those of the reference group in the fully adjusted model ($\beta = 0.9$, $SE = 0.4$, $p = 0.002$). In women, however, no significant results were found in both the resilience and depression groups (Supplementary table 3).

5. Discussion

We observed more well-preserved cognitive function in the psychologically resilience group, and the association was stronger in men with lower levels of education and older age. Additionally, in men, the depression group showed less-preserved cognitive function than the reference group; however, it was not statistically significant. Given that the present study based on longitudinal data, one could interpret from the results that psychological resilience precedes more well-preserved cognitive function.

Previous studies have shown the association between psychological resilience and cognitive function in women. However, the current study has found no statistically significant associations in women, but instead found a positive association between psychological resilience and cognitive functions in men. Several causes are expected for these inconsistent results.

First, since the previous study had a cross-sectional design, reverse causation was expected to have an effect. In other words, the association revealed in previous study included the effect of cognitive function on psychological resilience. However, the current study was a longitudinal study which is less affected by reverse causation and can focus more on the effect of resilience on cognitive function. Therefore, there may have been inconsistent study results.

Second, the characteristics of the participants of previous study and the current study may have been different. The previous study targeted 7535 participants who were recruited to baseline, and those people were collected from multiple centers. The people who participated in the current research were only followed up in one of the centers.

Third, the number of participants in the current study may have been too small to have sufficient statistical power to detect a difference in women. Further studies that are analyzed longitudinally with a larger number of people are needed.

The association between resilience and cognitive function was

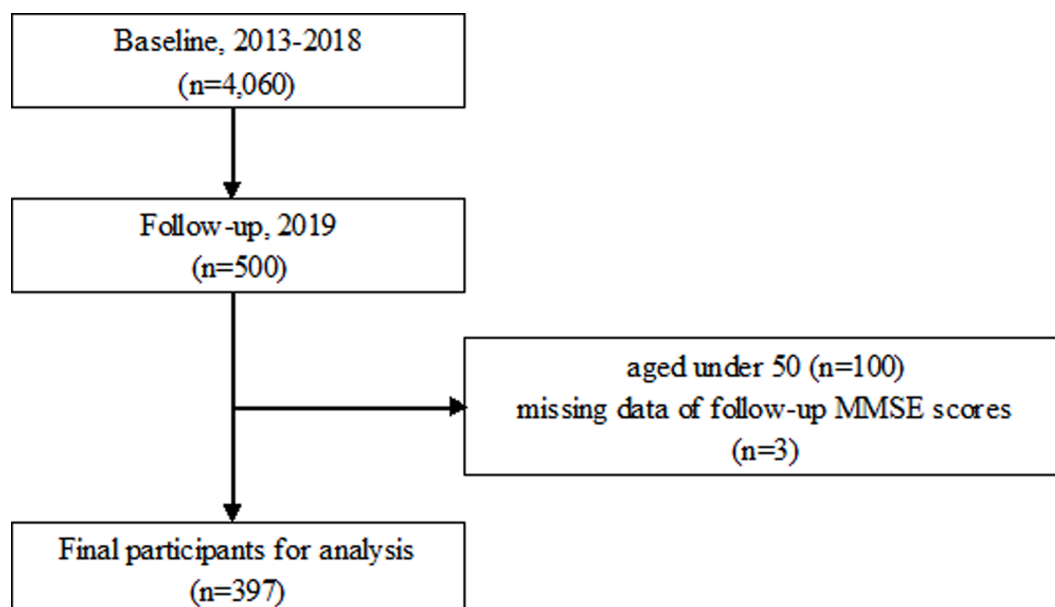


Fig. 1. Flow chart of the study participants.

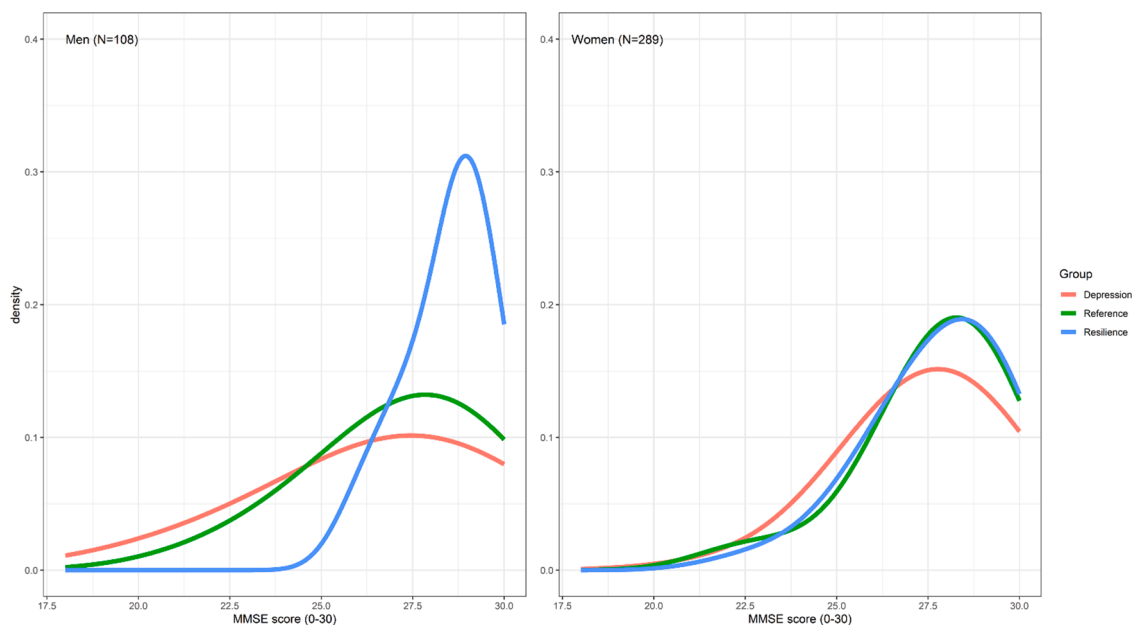


Fig. 2. Distribution of MMSE scores (follow-up) in men and women grouped by psychological resilience (correction was made to double the bandwidth to draw a smooth graph).

Table 2
MMSE scores(follow up) of participants classified by resilience(baseline).

		N	Model 1			Model 2			Model 3			Model 4		
			β	(SE)	<i>p</i> value	β	(SE)	<i>p</i> value	β	(SE)	<i>p</i> value	β	(SE)	<i>p</i> value
Men	Reference group	46	ref			ref			ref			ref		
	Resilience group	51	1.12	(0.36)	0.0024	1.21	(0.35)	0.0008	1.21	(0.37)	0.0015	1.29	(0.40)	0.002
	Depression group	11	-0.24	(0.60)	0.6847	-0.41	(0.58)	0.4818	-0.41	(0.58)	0.4831	-0.49	(0.61)	0.420
Women	Reference group	100	ref			ref			ref			ref		
	Resilience group	155	0.22	(0.22)	0.3184	0.02	(0.21)	0.9167	0.01	(0.21)	0.9739	0.01	(0.22)	0.963
	Depression group	34	0.08	(0.33)	0.8035	0.07	(0.32)	0.8204	0.05	(0.33)	0.8735	-0.03	(0.34)	0.939

Model 1: Age, baseline MMSE adjusted.

Model 2: Model 1 + education, marital status, income adjusted.

Model 3: Model 2 + comorbidity adjusted.

Model 4: Model 3 + smoking, drinking, physical activity, number of people living together adjusted.

Table 3
MMSE scores(follow-up) of participants classified by sex, age, and resilience(baseline).

Sex	Age	Resilience	N	Model 1			Model 2			
				β	(SE)	<i>p</i> value	β	(SE)	<i>p</i> value	
Men	<56	Reference group	26	ref			ref			
		Resilience group	20	0.72	(0.52)	0.172	1.22	(0.54)	0.031	
		Depression group	5	0.52	(0.87)	0.550	0.92	(0.79)	0.254	
Men	≥56	Reference group	20	ref			ref			
		Resilience group	31	1.51	(0.52)	0.006	2.07	(0.72)	0.007	
		Depression group	6	-1.05	(0.95)	0.273	-0.79	(1.16)	0.497	
Women	<54	Reference group	44	ref			ref			
		Resilience group	67	0.69	(0.35)	0.049	0.42	(0.36)	0.245	
		Depression group	13	0.31	(0.57)	0.585	-0.25	(0.61)	0.678	
	Women	≥54	Reference group	56	ref			ref		
			Resilience group	88	-0.15	(0.27)	0.577	-0.38	(0.30)	0.213
			Depression group	21	-0.11	(0.41)	0.780	-0.03	(0.43)	0.942

Model 1: Age, baseline MMSE adjusted.

Model 2: Model 1 + education, marital status, income, comorbidity, smoking, drinking, physical activity, number of people living together adjusted.

shown to be clearly different depending on gender. Several hypotheses were made to elaborate on the results.

First, men and women could have different biological mechanisms regarding the process in which the psychological resilience affect the cognitive function. Previous studies have found sex-dependent stress

effects on the neural circuitry underlying emotion, motivation, and cognition. (Wellman et al., 2018) Also, it has been known that testosterone in males promotes resilience in MDD and PTSD; as a result, women are significantly more vulnerable to developing these disorders than men. (Russo et al., 2012) Therefore, it can be inferred that domains

Table 4
MMSE(follow-up) scores of participants classified by sex, education, and resilience(baseline).

Sex	Education	Resilience	N	Model 1			Model 2		
				β	(SE)	p value	β	(SE)	p value
Men	≤12 years	Reference group	28	ref			ref		
		Resilience group	32	1.42	(0.45)	0.002	1.75	(0.54)	0.002
		Depression group	7	-0.94	(0.73)	0.206	-0.93	(0.74)	0.217
	≥13 years	Reference group	18	ref			ref		
		Resilience group	19	0.60	(0.59)	0.315	1.21	(0.71)	0.102
		Depression group	4	0.90	(0.96)	0.357	0.27	(1.28)	0.833
Women	≤12 years	Reference group	77	ref			ref		
		Resilience group	111	0.08	(0.26)	0.766	-0.22	(0.27)	0.428
		Depression group	27	-0.10	(0.39)	0.806	-0.19	(0.41)	0.640
	≥13 years	Reference group	23	ref			ref		
		Resilience group	44	0.42	(0.35)	0.235	0.64	(0.38)	0.096
		Depression group	7	0.54	(0.60)	0.368	0.21	(0.73)	0.770

Model 1: Age, baseline MMSE adjusted.

Model 2: Model 1 + marital status, income, comorbidity, smoking, drinking, physical activity, number of people living together adjusted.

of the brain affected by stress, managing the stress, and ultimately related with cognitive functions are differently working in men and women.

Second, the depressive symptoms may have obscured the association between resilience and cognitive function in women. There were participants who were not included in the depression group but showed mild depressive symptoms. It is expected that such participants were more distributed in the women resilience group than in the men resilience group. The mean BDI score of the resilience group was 5.4 in men and 10.1 in women, and the mean BDI score of the reference group was 6.3 in men and 6.4 in women. The fact that people in the resilience group exhibit depressive traits compared to those in the reference group may have caused the positive association between resilience and cognitive function to appear less than it actually is, since it is known that the cognitive function decline occurs when there are depressive symptoms. For this reason, it is possible that no statistically significant associations was found in the women’s resilience group, where the BDI scores was high.

Third, the characteristics of resilience may have been different in men’s resilience group and women’s resilience group. The items that men chose as a negative life event were mainly about social experiences. For example, there were items such as "light violation of the law," "changes in workplace conditions," and "conflict with work manager." However, women tended to select items about personal experiences such as "change in sleeping habits" and "change in eating habits" as negative life events. Therefore, depending on the definition of the current study, resilient people may show a resilient characteristic to social conflict, a resilient conflict to personal difficulties, or both. Therefore, the positive association between resilience and cognitive function may differ according to the detail field of resilience; and for this reason, different results may have been shown in men and women.

According to the results of the current study, the association between resilience and cognitive function was significant in less-educated men, but not in highly educated men and women. Since education level is an important factor influencing the social/economic status, it may be the beginning of an important discovery that that the effect of resilience on cognitive function differs according to social/economic status. Interventions that increase resilience in less-educational levels may play a role in preserving cognitive functions.

A number of previous studies support our findings. A longitudinal study conducted in Germany suggested that psychological resilience is associated with an attenuation of cognitive function decline in the elderly population. (Wolf et al., 2019) Cognitive decline was observed over time with increasing baseline amyloid- β in the 276 cognitively healthy elderly individuals. Psychological resilience was quantified by education, and cognitive decline was evaluated with Alzheimer’s Disease Neuroimaging Initiative data. The results showed that

amyloid-related cognitive decline was stronger in individuals with lower resilience capacities. Furthermore, there was a study that targeted highly traumatized civilians in the United States. (Wingo et al., 2010) Resilience was defined as having at least one trauma and no current depressive or post-traumatic stress disorder (PTSD) symptoms, and non-resilience was defined as having at least one trauma event and current moderate/severe depressive or PTSD symptoms. As a result, the resilience group showed better nonverbal memory. When comparing the above two studies to the current study, it can be seen that the characteristics of participants, the definition of psychological resilience, detailed characteristics of cognitive function, and the method of measuring the cognitive function were different from our research. However, the fact remains that psychological resilience and cognitive function appear to be somewhat related and the direction of their association was the same with that of the current study.

This study had certain limitations. First, due to the limited number of participants, the study may not have sufficient statistical power to detect a difference. Research with large samples will be needed to reanalyze the results that were found to be statistically insignificant in this study. Moreover, due to the insufficient number of participants, there were only a few subjects with clinical dementia. Second, the definition of psychological resilience used in this study was self-developed; therefore, it may be difficult to compare our results with those of previous studies. Different measurements, such as using the heart rate variability test or psychometrics, including the Connor Davidson resilience scale, could be used for comparison. Third, since negative life event experiences were self-reported, there could be information bias (reporting bias). People’s life experiences are not easily shared, and questions may not be answered honestly depending on the attitude of the participants. Additionally, people with depression may also remember negative events more; in other words, people without depression may not remember negative life experiences well. Fourth, due to the limitation of the follow-up period, the time it takes for the resilient characteristics appear could not be considered. In general, post-traumatic growth shows a pattern of recovery after experiencing anxiety and depression symptoms. (Tedeschi and Calhoun, 2004, Tedeschi and Calhoun, 1996) Therefore, our depression group may include people who are in the process of overcoming trauma before displaying resilient characteristics. Further studies are required to observe the appearance and disappearance of depressive symptoms in participants through long-term follow-up. Fifth, only limited psychological symptoms were used to define resilience. Psychological reactions after stress or trauma can manifest not only as depression symptoms but also as anxiety or insomnia. Unfortunately, due to the limitation of the variables investigated, other psychological responses could not be considered. Sixth, there would be unmeasured confounders. There was a lack of information about the sleep quality and quantity. Sleep has been known to affect both

resilience and cognitive function (Cohen-Zion et al., 2001, Ferrie et al., 2011, Pedersen et al., 2015), but this could not be controlled. It is also expected that family support or social support would have worked as a confounder. (Ozbay et al., 2007, Seeman et al., 2001) More accurate results could have been obtained if the size and density of the family/-social support have been quantified and adjusted for analysis.

However, the current study exhibits several strengths. To the best of our knowledge, the present study is the first longitudinal study that investigated the association between psychological resilience and cognitive function of the middle-aged Korean population. In addition, as this study employed a longitudinal study design, it was able to reduce the reverse causation. Review papers suggested that resilience and well-preserved cognitive function occur simultaneously (Kalisch et al., 2015), whereas other studies indicated that cognitive deficits may affect the processing of adaptive emotional regulation, which is closely related to psychological resilience. (Cohen et al., 2014) In this study, the time point of defining people's resilience preceded the time point of assessing the cognitive function, and the result was significant even after adjustments for previous cognitive function. Therefore, it supports the theory that psychological resilience may lead to well-preserving cognitive function. Finally, we conducted stratified analyses by age groups and education levels, which are known to be critical factors that may modulate the association between resilience and cognitive function. The present study showed that psychological resilience had a stronger influence on the cognitive functions of less-educated people.

6. Conclusion

In summary, we found a positive association between psychological resilience and cognitive function in Korean middle-aged men; this relation is prominent in older and less-educated men. From the present study's results, it could be suggested that middle-aged men who were psychologically resilient may have more well-preserved cognitive function later compared to those who were not psychologically resilient. As a result, increasing individual psychological resilience could be a method of reducing cognitive function decline later in life. Furthermore, in the 21st century society, where dementia is the greatest challenge for health and social care, developing the psychological resilience trait of individuals may be an influential way to prevent dementia and may further reduce the burden of healthcare in the society. However, further studies with larger participation and long follow-up periods would be needed. Additionally, it is suggested that the association between psychological resilience and cognitive function be analyzed in multiple populations, including clinical populations and large female cohorts.

Funding/Support

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF), funded by the Ministry of Science and ICT (grant number 2020R1C1C1003502), and a faculty research grant of Yonsei University College of Medicine (6-2019-0114) awarded to Jung.

Role of the Funder/Sponsor

The funders of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

CRedit authorship contribution statement

Ji Su Yang: Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Writing - original draft, Writing - review & editing. **Ye Jin Jeon:** Investigation, Methodology, Project administration, Software, Validation, Writing - review & editing. **Ga Bin Lee:** Investigation, Methodology, Writing - review & editing. **Hyeon Chang Kim:** Data curation, Resources, Writing - review

& editing. **Sun Jae Jung:** Conceptualization, Data curation, Funding acquisition, Methodology, Resources, Supervision, Validation, Writing - review & editing.

Conflict of Interest

We declare no competing interests.

Acknowledgements

We would like to thank Editage (www.editage.co.kr) for English language editing.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2021.04.062.

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