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Association among cognitive function, physical fitness, and health status in older women

Suh-Jung Kang[1,*], Byung-Hoon Kim[2], Hyo Lee[1], Jinsung Wang[3]

[1]Department of Sports and Health Care, College of Art and Culture, Sangmyung University, Seoul, Korea
[2]Sports Science Research Center, Sangmyung University, Seoul, Korea
[3]University of Wisconsin-Milwaukee, Milwaukee, WI, USA

This study examined the association among cognitive function, physical fitness, and health status in healthy older women. Ninety-four females aged from 62 to 86 years (72.66 ± 5.38 years) from community healthcare centers and an exercise club in Seoul, South Korea. Cognitive function was assessed using the Seoul Neuropsychological Screening Battery. Physical performance comprised cardiorespiratory endurance, lower extremity strength, active balance ability, and walking speed. Health status included blood pressure and waist circumference. Multiple linear regression analyses were performed to determine the relationship among cognitive function, fitness components, and health status, with age and educational attainment as covariates. In the unadjusted model, attention was significantly associated with cardiovascular endurance (B = 0.19, $P < 0.05$). Memory was significantly associated with lower limb strength (B = 0.77, $P < 0.05$) and active balance ability (B = 2.35, $P < 0.05$). In the adjusted model, attention was significantly associated with cardiovascular endurance (B = 0.15, $P < 0.05$). Memory was significantly associated with lower limb strength (B = 0.87, $P < 0.05$). In both models, cognitive function was not significantly associated with any health status variable. Though limited by a relatively small sample of female participants, who were healthy registrants of a community exercise program with normal cognitive function, the current study demonstrates that cognitive function is significantly associated with physical fitness, but not with health status, in healthy older women.

Keywords: Cognitive function, Cardiorespiratory endurance, Lower extremity strength, Active balance ability, Walking speed, Older women

INTRODUCTION

High levels of physical activity are associated with reduced risks of cognitive impairment, and physical activity has been emphasized as a protective factor against cognitive decline and dementia (Bangsbo et al., 2019; Laurin et al., 2001). Specifically, it has been shown that cardiorespiratory fitness is strongly associated with cognitive function in older women (Brown et al., 2010), and that higher cardiorespiratory fitness is beneficial in maintaining executive function in healthy older adults by enhancing the efficiency of the global brain network (Kawagoe et al., 2017). However, it has also been demonstrated that an exercise intervention can only improve aerobic fitness, and not cognitive function (Smiley-Oyen et al., 2008). Therefore, continued research on the association between cardiorespiratory fitness and cognitive function is needed.

Cardiovascular disease (CVD) risk factors are negatively correlated with mortality rate in older adults (Loprinzi et al., 2017). For example, waist circumference is known to be an established predictor of all-cause mortality (Adegbija et al., 2017), and also to be associated with cognitive function. Previous studies have reported that abdominal obesity based on waist circumference may be related to a higher probability of dementia (Chang et al., 2012). Furthermore, body mass index is thought to be associated with a reduced risk of cognitive decline in older adults after adjusting for waist circumference (Rodríguez-Fernández et al., 2017). In contrast, other studies have reported that cognitive function is not associated with waist circumference (Liu et al., 2019), and that a larger waist circumference is associated with better attention memory (Takashi et al., 2020).

Walking capacity is a useful health index that reflects physical

*Corresponding author: Suh-Jung Kang https://orcid.org/0000-0002-8284-9299
Department of Sports and Health Care, College of Art and Culture, Sangmyung University, 20 Hongjimun 2-gil, Jongno-gu, Seoul 03016, Korea
Email: suhjkang@smu.ac.kr
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performance ability, which determines quality of life. Walking impairment is an indicator of aging, and is primarily linked to the development of dementia (Beauchet et al., 2016). For instance, people with cognitive impairment display a lower walking speed (Tian et al., 2017), which is a predictor of cognitive decline and dementia (Gale et al., 2014; Quan et al., 2017). However, some studies have reported discrepant findings, which indicated that walking speed was only partially correlated with cognitive function (Atkinson et al., 2010; Callisaya et al., 2015).

Lower extremity muscular strength and balance ability both can affect walking capacity and are key neuromuscular components for identifying older adults at risk (Muehlbauer et al., 2015), and thus, improvement in the two components should be the target of interventions for fall prevention (Clemson et al., 2012). Improvement in cognitive function is also important for fall prevention, given that cognitive impairment is a fall risk factor (Muir et al., 2012). Furthermore, dementia elevates fall risk (Horikawa et al., 2005), which can increase by up to 20% with each one-point decline in the Mini-Mental State Examination (MMSE) score (Gleason et al., 2009). These findings suggest that fall-related fitness, falls, and cognitive function are mutually associated.

The aforementioned findings indicate a potentially meaningful association between cognitive function and a number of factors (e.g., cardiorespiratory fitness, waist circumference, walking ability, lower extremity muscular strength) in older adults; and yet, the association between them are inconclusive due to the discrepant findings. In addition, the association has been studied between cognition and physical fitness and also between cognition and health status, but only in separate studies. In this study, thus, we aimed to investigate in a single study the association among cognitive function, physical fitness (cardiorespiratory endurance, lower extremity muscular strength, active balance ability, walking speed), and health status (blood pressure, waist circumference) systematically in healthy older women.

MATERIALS AND METHODS

Participants

Potential participants of exercise classes were recruited from four community healthcare centers and one private education center for senior in Seoul, South Korea from 2017 to 2019. The inclusion criteria were: (1) neurologically intact women aged 62 years and older, and (2) normal cognitive function, as assessed via the Korean MMSE ($\geq$24) (Kukull et al., 1994). To ensure that the participants could perform the tasks employed in the current study, and also to minimize potential risks, the following exclusion criteria were used: a history of severe CVD, neurological disease, peripheral disorder, significant orthopedic conditions, or visual impairment. Final data from a total of 94 women aged from 62 to 86 years (72.66±5.38 years) were used in statistical analyses; and four samples with missing values were excluded from the analysis (listwise deletion).

All participants participated in the study voluntarily, and informed consent was obtained from them prior to their inclusion in the study. This study was approved by Institutional Review Board of the Sangmyung University (# BE2017-26).

Measurements

Cognitive function was assessed using the Seoul Neuropsychological Screening Battery (SNSB-II) (Kim et al., 2021) by certified clinical psychologists. Scores for attention, visuospatial function, memory, and frontal/executive function were calculated, and the T-score of each variable was used for analysis.

To determine the participant's physical fitness level, we included the following measures: cardiorespiratory endurance, lower extremity muscle strength, active balance ability, and walking speed. Cardiorespiratory endurance was measured by the number of times the participant could walk in place for 2 min, with the knee lifted to 70°. Lower extremity muscle strength was measured by the number of sit-to-stand repetitions for 30 sec. Active balance ability was measured as the time taken to stand up from a chair, reach a target 3 m ahead and return to the chair as quickly as possible. All measurements were performed in accordance with the guidelines for older adults. Walking speed was measured based on the time taken to walk 8 m at one's usual pace (Hackett et al., 2018; Jerome et al., 2015). However, we extended the distance by 2 m at the start and finish, creating a total of 12 m. This was done because walking speed may decrease at the start and finish. Walking speed was calculated as distance/time (m/sec).

To determine the participant's general health status, we included the following measures: blood pressure and waist circumference. Blood pressure was measured twice using a mercury sphygmomanometer, and the average of the two measurements was used in the analysis. Waist circumference was measured using a tape measure around the umbilicus on bare skin after the participant exhaled and did not hold their breath. The tape measure was placed flat and parallel to the skin, without applying excessive pressure.

Data analysis

Multiple linear regression analyses were performed to estimate

Table 1. Characteristics of the participants

Characteristic	Value
Age (yr)	72.66±5.38
Education	
Elementary or less	28 (29.79)
Middle school	23 (24.27)
High school	19 (20.21)
College or more	24 (25.53)
Cognitive function	
Attention	51.80±11.11
Visuospatial	50.13±14.66
Memory	52.16±9.08
Frontal/executive function	55.07±13.50
Physical fitness	
Cardiorespiratory endurance (reps)	108.39±15.95
Lower extremity muscle strength (reps)	16.45±3.61
Active balance ability (sec)	7.52±1.13
Walking speed (m/sec)	0.64±0.12
Health status	
Waist circumference (cm)	85.80±11.09
Systolic blood pressure (mmHg)	134.38±16.10
Diastolic blood pressure (mmHg)	77.0±11.09
Normal blood pressure	21 (22.35)
Prehypertension	38 (40.42)
Hypertension	35 (37.23)

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

the association among the aforementioned variables related to cognitive function, physical fitness, and health status (Table 1). Sociodemographic measures included age and educational attainment (calculated as years of education), which were controlled as covariates (Best et al., 2016; Dumurgier et al., 2017). Educational attainment was included because it has been suggested to influence cognitive function in older adults (Stern et al., 1994; Wilson et al., 2009; Yaffe et al., 2009).

RESULTS

Table 1 shows the means of all study parameters. To analyze the relationship among cognitive function, physical fitness, and health status, we performed analyses with and without adjusting for age and educational attainment (Tables 2, 3). According to the unadjusted model, attention was significantly associated with cardiovascular endurance (B=0.19, $P<0.05$). Memory was significantly associated with lower limb strength (B=0.77, $P<0.05$) and active balance ability (B=2.35, $P<0.05$). Visuospatial and executive functions were not significantly associated with any of the tested

Table 2. Multiple regression association between cognitive function and physical fitness, health status with age and education attainment- unadjusted model

Variable	Attention ($R^2=0.13$)				Visuospatial ($R^2=0.06$)				Memory ($R^2=0.12$)				Frontal/executive function ($R^2=0.09$)			
	B	Beta	SE	*P*-value	B	Beta	SE	*P*-value	B	Beta	SE	*P*-value	B	Beta	SE	*P*-value
Age	0.02	0.01	0.24	0.924	-0.21	-0.08	0.32	0.514	0.03	0.18	0.19	0.124	-0.27	-0.11	0.29	0.352
Cardiorespiratory endurance	0.19	0.28	0.08	0.013*	0.08	0.09	0.10	0.451	-0.61	-0.09	0.73	0.402	0.14	0.01	1.09	0.897
Lower extremity muscle strength	-0.55	-0.18	0.38	0.157	0.03	0.01	0.53	0.948	0.77	0.31	0.32	0.018*	0.11	0.03	0.48	0.821
Active balance ability	0.41	0.04	1.29	0.754	0.54	0.04	1.77	0.760	2.35	0.29	1.07	0.031*	-0.05	0	1.60	0.977
Walking speed	-0.24	-0.03	0.88	0.783	0.58	0.05	1.21	0.634	-0.61	-0.09	0.73	0.402	0.14	0.01	1.09	0.897
Waist circumference	0	0	0.11	0.992	-0.25	-0.19	0.15	0.096	-0.06	-0.07	0.09	0.535	-0.08	-0.07	0.14	0.539
Blood pressure																
Normal	Reference															
Prehypertension	-3.55	-0.16	2.95	0.233	1.24	0.04	4.06	0.760	-1.35	-0.07	2.45	0.583	-5.39	-0.20	3.67	0.146
Hypertension	-4.12	-0.18	3.01	0.175	0.10	0	4.14	0.980	0.31	0.02	2.50	0.900	-3.08	-0.11	3.75	0.414

B, unstandardized regression coefficient; beta, standardized regression coefficient; SE, standard error.
*$P\leq0.05$.

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Table 3. Multiple regression association between cognitive function and physical fitness, health status with age and education attainment- adjusted model

Variable	Attention (R^2=0.13)				Visuospatial (R^2=0.06)				Memory (R^2=0.12)				Frontal/executive function (R^2=0.09)			
	B	Beta	SE	*P*-value	B	Beta	SE	*P*-value	B	Beta	SE	*P*-value	B	Beta	SE	*P*-value
Age	0.16	0.08	0.23	0.482	-0.13	-0.05	0.33	0.702	0.29	0.17	0.20	0.145	-0.25	-0.10	0.30	0.395
Education																
Elementary or less	Reference															
Middle school	-2.85	-0.11	3.08	0.358	-4.39	-0.13	4.49	0.331	-3.58	-0.17	2.70	0.188	-2.26	-0.07	4.02	0.575
High school	2.77	0.10	3.13	0.379	-3.69	-0.10	4.56	0.421	0.65	0.03	2.74	0.812	7.03	0.21	4.09	0.089
College or more	8.97	0.35	3.13	0.005	4.65	0.14	4.55	0.310	0.60	0.03	2.73	0.827	3.35	0.11	4.08	0.414
Cardiorespiratory endurance	0.15	0.22	0.08	0.051*	0.04	0.04	0.11	0.727	0.13	0.22	0.07	0.064	0.15	0.17	0.10	0.142
Lower extremity muscle strength	-0.44	-0.14	0.37	0.231	0.09	0.02	0.53	0.868	0.87	0.34	0.32	0.008*	0.20	0.05	0.48	0.681
Active balance ability	-0.64	-0.07	1.33	0.629	-0.41	-0.03	1.93	0.833	2.13	0.26	1.16	0.070	0.59	0.05	1.73	0.732
Walking speed	0.04	0.004	0.84	0.966	0.73	0.07	1.22	0.550	-0.31	-0.05	0.73	0.673	0.18	0.02	1.09	0.871
Waist circumference	-0.003	-0.003	0.11	0.975	-0.28	-0.21	0.15	0.073	-0.05	-0.06	0.09	0.618	-0.13	-0.11	0.14	0.341
Blood pressure																
Normal	Reference															
Prehypertension	-3.11	-0.14	2.86	0.281	2.27	0.08	4.16	0.588	-1.72	-0.09	2.50	0.494	-4.09	-0.15	3.73	0.277
Hypertension	-3.3	-0.14	2.98	0.272	1.30	0.04	4.34	0.765	-0.28	-0.02	2.61	0.914	-0.94	0.03	3.89	0.810

B, unstandardized regression coefficient; beta, standardized regression coefficient; SE, standard error.
*$P \leq 0.05$.

variables. Similar results were observed for the adjusted model. Attention was significantly associated with cardiovascular endurance (B = 0.15, $P < 0.05$). Memory was significantly associated with lower limb strength (B = 0.87, $P < 0.05$). Visuospatial and frontal/executive functions were not significantly associated with any of the tested variables.

DISCUSSION

This study aimed to investigate the relationship among cognitive function, physical fitness, and health status in healthy older women. We found that cognitive function was significantly associated with certain physical fitness parameters, but not with walking speed and any health status parameters.

Among the various factors of physical fitness, cardiorespiratory fitness is an independent predictor of cognitive function that is associated with all-cause mortality (Brown et al., 2010; Kawagoe et al., 2017). In addition, lower extremity strength and active balance ability deteriorate with aging and are associated with fall risk (Clemson et al., 2012; Muehlbauer et al., 2015). Falls among older adults cause secondary health problems, deteriorate physical fitness, and induce cognitive decline and depression (Muir et al., 2012). Thus, both lower extremity muscle strength and balance ability are important factors that are strongly associated with both physical and brain health in older adults. Although we had a relatively small sample of 94 participants in contrast to past cross-sectional studies with larger study populations, we still observed a significant correlation between cognitive function and physical fitness, regardless of the covariates (age, education). Hence, our results strongly support and emphasize the positive relationship between physical fitness and cognitive function.

Because of the nature of the cross-sectional design, we could not establish a causality between cognitive decline and deteriorated physical fitness. A previous longitudinal study reported that cognitive function decrements precede or co-occur with physical performance decline (Atkinson et al., 2010). Furthermore, a study examining the relationship among CVD risk factors, cognitive function, and mortality risk showed that individuals with poor cognitive function had a high mortality risk, irrespective of their CVD risk factors (Loprinzi et al., 2017). However, CVD risk factors are still associated with cognitive function, and this relationship is also influenced by physical fitness, which is a predictor of and mutually associated with cognitive function (Daimiel et al., 2020). Moreover, physical fitness mediates the effect of aging on cognitive function, suggesting physical activity as a major factor in preventing cognitive decline in older adults (Pérez-Sousa et al., 2021). Therefore, our results support previous findings and highlight the importance of physical fitness reducing or slowing cognitive decline with aging.

Walking is typically perceived as an automated motor task, although it is a complex task that involves higher levels of cognitive function (Hausdorff et al., 2005) as it requires integration of attention, planning, memory, motor, perceptual, and cognitive processes (Mulder et al., 2002). Previous studies have reported that slow walking speed is associated with cognitive decline (Rosano et al., 2005), which in turn is associated with the preclinical stage of dementia (Marquis et al., 2002; Verghese et al., 2002). Moreover, the risk of dementia is higher among those with slow walking speed or severe reductions in walking speed over time (Hackett et al., 2018). These results suggest that preventing the reduction of walking speed with aging may have health benefits. Interestingly, however, our results showed that none of the cognitive functions was significantly associated with walking speed. It has been shown that the association between walking speed and cognitive function varies depending on how walking speed is measured (e.g., walking at one's normal pace or as fast as possible) (Clouston et al., 2013): when walking at a normal pace, walking speed was not associated with one's mental state; when walking as fast as possible, however, it was (Deshpande et al., 2009). Similarly, fast walking has been shown to be associated with cognitive decline more than normal walking or walking while talking (Deshpande et al., 2009). The reason may be that compared to normal walking, fast walking is related more to the individual's physical fitness, such as lower extremity muscular strength, balance, and functional capacity. These findings may explain the lack of a statistically significant association between cognitive function and walking speed in the present study, given that we measured walking speed at a normal pace. A more thorough investigation of the relationship between varying walking speeds (especially fast walking) and cognitive function is warranted in future studies.

Moreover, the lack of a statistically significant association between cognitive function and walking speed in our study may also be attributable to the small sample size, compared to previous large population-based studies with a study population of greater than 1,000. However, a study conducted among 2,938 participants without dementia or severe walking impairment reported that low baseline walking speed was associated with the onset of dementia within 6 years although baseline walking speed and dementia were not correlated (Welmer et al., 2014). This shows that walking speed may play an important role in processing speed of dementia over time. Therefore, although our cross-sectional study did not find a significant association between walking speed and cognitive function, we believe the findings have valuable implications for the management of cognitive decline or dementia risk in the long term.

Previous findings suggest that blood pressure and waist circumference are CVD risk factors and are linked to cognitive function (Kanaya et al., 2009; Tadic et al., 2016), based on which we hypothesized that high blood pressure and a large waist circumference would be significantly associated with poor cognitive function. Liu et al. (2019) found that waist circumference was independently and significantly associated with cognitive impairment in adults aged 70 years or older. Moreover, participants with an abnormally large waist circumference were at 1.8 times greater risk for poor cognitive function. In addition, a large-scale cohort study involving 872,082 adults aged 65 years or older reported that abdominal obesity, as measured by waist circumference, significantly increased the risk of dementia (Cho et al., 2019). However, contradictory findings have also been reported, showing an association between lower abdominal fat mass and worse cognitive function in elderly women (Bagger et al., 2004). In addition, a larger waist circumference was associated with better cognitive function among women and men aged between 65 and 74 years (Takashi et al., 2020). These findings collectively suggest that the impact of increased abdominal fat on cognitive function may vary with age and sex (Takashi et al., 2020). The mean waist circumference of our participants was 85.8±11.09 cm, which is slightly above the World Health Organization criteria for obesity in the Korean population. Our current findings indicate that waist circumference is not significantly associated with cognitive function at least in Korean older women (aged over 62 years) who are slightly obese.

Regarding blood pressure, the prevalence of hypertension is 50.7% among Korean women in their 60s and 72.4% among those aged 70 years or older (Korea Centers for Disease Control and Prevention, 2020). Our study population comprised people with relatively healthy waist circumference and blood pressure according to age- and sex-specific criteria, and the composition of the study population may have influenced the study outcomes. The lack of a significant relationship between blood pressure and cognitive function in our current study may be attributable to the fact that the majority of the participants in this study had normal blood pressure or were at the stage of prehypertension (Table 1). Previous findings indicate that reduced brain circulation caused by aging decreases resting cerebral blood flow and causes functional impairment, thus causing hypertension-related cognitive

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dysfunction (Gąsecki et al., 2013). Moreover, arterial stiffness, rather than blood pressure, is a stronger predictor of cognitive function (Hajjar et al., 2016). Thus, it would have been difficult to observe a statistically significant result regarding blood pressure in this study, especially given that fewer than half of our participants had high blood pressure. Additionally, interactions among other factors, which include health behavior, health conditions, use of medication, motor ability, reduced physical fitness, and body composition changes, may have influenced the relationship between blood pressure and cognitive function (Altschul et al., 2020). Thus, subsequent studies may want to consider recruiting a larger sample consisting of participants with a wider range of blood pressure and investigating the relationship between different ranges of blood pressure and cognitive function separately.

It is worth noting that a significant correlation was observed between cognitive function and physical fitness parameters, regardless of educational attainment, which has been suggested to influence cognitive function in older adults. Stern et al. (1994) conducted a cross-sectional study in which 593 older adults were examined for 4 years, and reported that the risk of dementia was increased in subjects with low education. Yaffe et al. (2009) also argued that educational attainment needs to be taken into consideration when interpreting data regarding cognitive function in older adults. However, Wilson et al. (2009) reported, based on the data from more than 6,000 older adults who were interviewed for up to 14 years, that education is associated with level of cognitive function, but not with rate of cognitive decline. Our current findings add to the literature, by suggesting that the level of educational attainment does not play a big role in determining the association among cognition, physical fitness, and health status in Korean older women.

One strength of the present study is that we performed concurrent assessments of physical fitness, walking speed, health status, and cognitive function. In addition, we used a validated cognitive function instrument (SNSB-II) (Kim et al., 2021) instead of a simple questionnaire to assess cognitive function (Best et al., 2016; Laurin et al., 2001). This study also has several limitations. First, the sample size was relatively small, compared to some previous studies in which the number of participants exceeded 1,000 (Makizako et al., 2015; Mielke et al., 2013); and the sample included the registrants of a community exercise program who had normal cognitive function and were deemed sufficiently physically healthy to participate in an exercise program. In addition, we limited our sample to female participants (women in clinical trials are likely to be healthier than the general population, which limits confounders) (Atkinson et al., 2010). In relation to addressing these limitations, future studies should consider testing a larger sample consisting of both male and female participants to determine the association between cognitive function and physical fitness, especially by investigating the effects of additional factors that may have influence in cognitive function, such as one's physical activity level (e.g., active vs. sedentary), sedentary time, and alcohol consumption. Employing a quantitative gait analysis in such investigations would also be beneficial.

In conclusion, certain aspects of cognitive function (attention, memory) were significantly correlated with some of the physical fitness parameters (cardiovascular endurance, lower limb strength, active balance ability) measured in the current study; however, none of the cognitive functions was significantly correlated with walking speed and health status (blood pressure, waist circumference) in our participants who were healthy Korean women aged from 62 to 86 years. Our findings suggest the importance of maintaining or improving physical fitness to avoid cognitive function decline associated with aging.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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