ORIGINAL ARTICLE

Association between cognitive function and body composition in community-dwelling older women

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Abstract

In the current global aging society, attempts should be made to help limit future health problems by promoting the effective maintenance of cognitive function among the aged. Therefore, this study aimed to investigate the association between cognitive function and body composition parameters. The study participants were 296 community-dwelling older women. The Mini-Mental State Examination (MMSE) was used to evaluate cognitive function, with poor cognitive performance (cognitive impairment) defined as an MMSE score ≤26 points. A bioelectrical impedance analysis device was used to measure body composition parameters. In total, 35 (11.8%) of the participants had an MMSE score ≤26. Compared with the MMSE >26 group, the MMSE ≤26 group was significantly older, had a lower skeletal muscle mass index (SMI), lower skeletal muscle mass, lower fat-free body mass, lower fat-free trunk mass, lower fat-free arm mass, and lower fat-free leg mass. Receiver operating characteristic curve analysis of body composition parameters indicated that SMI, skeletal muscle mass, fat-free body mass, fat-free trunk mass, fat-free arm mass, and fat-free leg mass all had an area under the curve >0.6, with threshold scores of 5.00 kg/m^2, 17.60 kg, 33.60 kg, 14.00 kg, 2.75 kg, and 9.51 kg, respectively. Logistic regression analysis adjusted for age, years of education, and body mass index (BMI) showed that participants with skeletal muscle mass ≤17.60 kg had the lowest odds ratio (OR), at 0.234 (95% confidence interval [CI]: 0.095–0.573; p = 0.0015), for an MMSE score >26. Furthermore, skeletal muscle mass <17.60 kg was associated with lower scores on the working memory subscale of the MMSE (OR: 0.694; 95% CI: 0.534–0.902; p = 0.0058). These findings suggest that cognitive impairment is associated with muscle mass, especially skeletal muscle mass. A certain amount of skeletal muscle mass may therefore be beneficial to maintain cognitive function.

Key words: *cognitive function, body composition, muscle mass, working memory, older women*

INTRODUCTION

Nursing care is frequently required in Japan for patients with musculoskeletal disease and dementia (Ministry of Health, Labour and Welfare, National Life Basic Survey, 2019). Dementia damages brain cells, eventually leading to a loss of cognitive function, including the ability to think and reason, and, by adversely affecting the ability to perform self-care and activities of daily living (ADL), a reduced quality of life. In addition, an increase in the severity of the signs and symptoms of dementia can adversely affect the physical and emotional well-being of both families and caregivers (Moyle, 2015). Dementia is presently thought to affect upwards of nearly 50 million people around the world (World Alzheimer Report, 2015), including about 2.6 million Japanese over the age of 65 years, with a prevalence of about 8.4% (Ministry of Health, Labour and Welfare, Everyone's mental health, 2011). Therefore, the risk factors associated with cognitive impairment need to be identified, and early interventions in regard to primary care for the aged need to be facilitated.

Among the various changes in body composition parameters accompanying aging are increases in fat mass and decreases in height, lean body mass, and body fluids (Gallagher, 1996; Bedogni, 2001). Changes in body composition parameters with age are also known to be closely associated with a reduced ability to perform ADL (Visser, 1998a, 1998b) and worse locomotive function (Nakamura, 2016). In particular, previous studies have suggested associations between cognition and various body composition parameters; for example, sarcopenia, a progressive and generalized skeletal muscle disorder involving the accelerated loss of muscle mass and function, has been shown to be related to brain atrophy and reduced cognitive performance (Rosenberg, 1997; Hsu, 2014). In addition, fat accumulation in muscle has recently been reported to be related to sarcopenia and decreased motor function (Baker, 2017).

Although some studies have reported that a higher body mass index (BMI) is a lower risk factor for developing dementia (Smith, 2014; Qizilbash, 2015; Tikhonoff, 2015; Alhurani, 2016), other studies have reported the opposite (Cui, 2013; Gallucci, 2013). Furthermore, higher fat mass and lean mass have been reported to be associated with a lower risk of cognitive impairment (Tikhonoff, 2015; Smith, 2014; Sqauwen, 2017; Yoon, 2012; Noh, 2017). However, most of these previous studies deal with only one type of component of each body composition parameter; to our knowledge, no report has covered a wide variety of types of body composition components. Therefore, the objective of this study was to examine the association between many types of body composition components and scores on the Mini-Mental State Examination (MMSE) (Tombaugh, 1992), which assesses global cognition, including orientation, registration, working, recall, language, and visuoconstruction.

METHODS

Participants

This study was conducted in Kaizuka city, Osaka Prefecture, Japan, between August 2018 and March 2020. The inclusion criteria were: 1) female gender; 2) age ≥60 years; 3) living independently at home; and 4) not having a cardiac pacemaker. All study participants initially underwent body composition measurements and had their cognitive function evaluated at a public hall, where a local government-supported “Lecture meeting and health checkup” was being held. In total, 296 participants (mean age ± standard deviation, 73.29 ± 6.44 years; range, 60–96 years) were included in the analysis. This study was approved by the Ethics Committee of Osaka Kawasaki Rehabilitation University (reference No. OKRU28-A014) and performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before the study began.

Measurement of variables

Body composition parameters were measured using a bioelectrical impedance analysis (BIA) device (InBody 270; InBody, Tokyo, Japan) at 20 and 1000 kHz while the participants were wearing normal indoor clothing without socks and shoes. All participants were instructed to grasp the handles of the BIA device and stand on electrodes contacting the bottoms of their feet. BMI was calculated as weight in kilograms divided by height in meters squared. The skeletal muscle mass index (SMI) was calculated as muscle mass in kilograms divided by height in meters squared. Calcaneus bone mineral density (BMD) was evaluated by quantitative ultrasound (i.e., the speed of sound [SOS] of the calcaneus) using an ultrasound bone densitometer (AOS-100SA; Hitachi, Tokyo, Japan) and expressed as the percent of the young adult mean of the SOS (%YAM).

Evaluation of cognitive function and questionnaire on education history

Cognitive function was assessed using the Japanese version of the MMSE. The MMSE is a 30-point scale (range, 0–30) that assesses seven different cognitive domains: i) orientation to time (range, 0–5); ii) orientation to place (range, 0–5); iii) three word registration (range, 0–3); iv) working memory (counting backwards by seven [range, 0–5]); v) delayed recall of the three words (range, 0–3); vi) language involving comprehension of a three-step command: naming, repetition, and sentence writing (range, 0–8); and vii) visuoconstruction involving the copy of intersecting pentagons (range, 0–1). Categorically defined poor performance on the MMSE was defined as a pre-specified score of ≤26 (Folstein, 1975; Oudman, 2014; Zhou, 2014). A self-administered questionnaire on education history was also implemented.

Statistical analysis

Participants were then divided into two groups based on MMSE scores: those scoring ≤26 (MMSE ≤26 group) were classified as having cognitive impairment, whereas those scoring >26 (MMSE >26 group) were classified as not having cognitive impairment. For numerical variables, the normality of distribution and homogeneity of variance were tested prior to comparison across groups. Student’s t-test was used when assumptions of normal distribution and homogeneity of variance were fulfilled in both groups, and Welch’s t-test was used when the assumption of normal distribution, but not that of homogeneity of variance, was met. The Wilcoxon signed-rank test was used when the data were not normally distributed. The receiver operating characteristic (ROC) curve was then analyzed to evaluate the ability of the body composition parameters to discriminate the MMSE >26 from the MMSE ≤26 group. The odds ratio (OR) for a threshold score of measurements on the ≤26 MMSE was calculated using logistic regression analysis adjusted for age and years of education (Model 1) or for age, years of education, and BMI (Model 2). Identically, the OR for MMSE domain scores of skeletal muscle mass >17.60 kg was calculated using logistic regression analysis adjusted for age, years of education, and BMI. All statistical analyses were conducted using JMP 11 (SAS Institute, Cary, NC). All statistical tests were two-tailed, and *p* values <0.05 were considered to indicate statistical significance. In addition to the *p* values, 95% confidence intervals (CIs) for the two-sided analysis are presented.

RESULTS

Characteristics of the study participants

The participants' age, height, total body weight, BMI, SMI, skeletal muscle mass, fat-free body mass, fat-free trunk mass, fat-free arm mass, fat-free leg mass, body fat mass, trunk fat mass, arm fat mass, leg fat mass, BMD, MMSE score, and years of education are shown in Table 1. A total of 35 participants (11.8%) had an MMSE score ≤26 (Table 2).

Comparison of characteristics between the MMSE >26 and ≤26 groups

Compared with the MMSE >26 group, the MMSE ≤26 group was older, had a higher BMI, a lower SMI, lower skeletal muscle mass, lower fat-free body mass, lower fat-free trunk mass, lower fat-free arm mass, lower fat-free leg mass, higher body fat mass, lower trunk fat mass, higher arm fat mass, higher leg fat mass, lower BMD, and fewer years of education ($p < 0.0001$). Significant differences were seen between the two groups in age ($p < 0.0001$), SMI ($p = 0.0210$), skeletal muscle mass ($p < 0.01$), fat-free body mass ($p < 0.01$), fat-free trunk mass ($p < 0.01$), fat-free arm mass ($p = 0.018$), fat-free leg mass ($p < 0.0001$), and years of education ($p < 0.001$) (Table 2).

Threshold body composition parameters and ORs for the MMSE >26 group

The threshold body composition parameters for discriminating the MMSE >26 from the MMSE ≤26 group were calculated using ROC analysis (Table 3). The SMI, skeletal muscle mass, fat-free mass, fat-free

Table 1. Characteristics of the study participants

Variables	mean value (SD)
Age (years)	73.29 (6.44)
Height (cm)	151.62 (5.74)
Weight (kg)	51.34 (7.67)
BMI (kg/m^2)	22.31 (3.11)
SMI (kg/m^2)	5.68 (0.65)
Skeletal muscle mass (kg)	18.51 (2.21)
Fat-free body mass (kg)	35.00 (3.72)
Fat-free trunk mass (kg)	14.44 (1.79)
Fat-free arm mass (kg)	2.93 (0.55)
Fat-free leg mass (kg)	10.19 (1.56)
Body fat mass (kg)	16.34 (5.43)
Trunk fat mass (kg)	7.64 (2.84)
Arm fat mass (kg)	3.98 (1.36)
Leg fat mass (kg)	2.81 (0.53)
BMD (%YAM)	78.83 (14.56)
MMSE score (points)	28.55 (1.98)
Years of education (years)	11.92 (2.14)

Abbreviations: BMI, body mass index; SMI, skeletal muscle mass index; BMD, body mineral density; MMSE, Mini-Mental State Examination; SD, standard deviation

Table 2. Comparison of body composition between MMSE group

Variables	MMSE ≤26 (n=35)	MMSE >26 (n=261)	*p* value
Age (years)	78.77 (6.17)	72.55 (6.13)	**<0.0001**
BMI (kg/m^2)	22.67 (3.71)	22.27 (3.03)	0.4752
SMI (kg/m^2)	5.45 (0.71)	5.72 (064)	**0.0210**
Skeletal muscle mass (kg)	17.20 (2.25)	18.69 (2.15)	**<0.001**
Fat-free body mass (kg)	32.86 (3.81)	35.29 (3.63)	**<0.001**
Fat-free trunk mass (kg)	13.39 (1.76)	14.59 (1.75)	**<0.001**
Fat-free arm mass (kg)	2.66 (0.52)	2.91 (0.55)	**0.0018**
Fat-free leg mass (kg)	9.25 (1.66)	10.32 (1.52)	**0.0001**
Body fat mass (kg)	16.46 (5.88)	16.32 (5.38)	0.1903
Trunk fat mass (kg)	7.63 (3.09)	7.64 (2.81)	0.9836
Arm fat mass (kg)	2.36 (0.95)	2.31 (0.85)	0.7522
Leg fat mass (kg)	5.49 (1.80)	5.42 (1.69)	0.8053
BMD (%YAM)	77.83 (14.15)	78.96 (14.63)	0.4786
MMSE score (points)	24.26 (2.20)	29.13 (0.99)	**<0.0001**
Years of education (y)	10.17 (2.01)	12.15 (2.05)	**<0.0001**

Notes: Values are presented as mean (standard deviation). Student's t-test were performed.
Abbreviations: MMSE, Mini-Mental State Examination; BMI, body mass index; SMI, skeletal muscle mass index; BMD, body mineral density.

Table 3. Threshold values of body compositions for MMSE <26

Variables	Threshold values	Area under the curve	Sensitivity (%)	Specificity (%)	*p* value
BMI (kg/m^2)	22.90	0.53	63.22	45.71	0.4740
SMI (kg/m^2)	5.00	0.62	91.57	28.57	**0.0215**
Skeletal muscle mass (kg)	17.60	0.69	70.50	71.43	**0.0002**
Fat-free body mass (kg)	33.60	0.69	70.88	68.57	**0.0004**
Fat-free trunk mass (kg)	14.00	0.70	65.90	68.57	**0.0002**
Fat-free arm mass (kg)	2.75	0.68	69.35	60.00	**0.0020**
Fat-free leg mass (kg)	9.51	0.69	67.43	71.43	**0.0002**
Body fat mass (kg)	12.30	0.49	26.44	80.00	0.8896
Trunk fat mass (kg)	6.70	0.51	62.84	48.57	0.9836
Arm fat mass (kg)	3.40	0.50	91.57	14.29	0.7513
Leg fat mass of leg (kg)	8.10	0.50	93.87	11.43	0.8045
BMD (%YAM)	80.00	0.54	56.32	57.14	0.6655

Notes: The receiver operating characteristic curve analysis were performed.
Abbreviations: MMSE, Mini-Mental State Examination; BMI, body mass index; SMI, skeletal muscle mass index; BMD, body mineral density.

Table 4. Threshold body composition parameters and odds ratios for the MMSE >26 group

		Model1			Model2		
Variables	Value of cut off	Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value
BMI (kg/m^2)	22.90 ≥ 22.90 <	0.884 1	0.400-1.950	0.7596			
SMI (kg/m^2)	5.00 ≥ 5.00 <	0.363 1	0.142-0.927	**0.0342**	0.256 1	0.086-0.768	**0.0150**
Skeletal muscle mass (kg)	17.60 ≥ 17.60 <	0.279 1	0.121-0.644	**0.0028**	0.234 1	0.095-0.573	**0.0015**
Fat-free body mass (kg)	33.60 ≥ 33.60 <	0.292 1	0.129-0.662	**0.0032**	0.246 1	0.102-0.592	**0.0018**
Fat-free trunk mass (kg)	14.00 ≥ 14.00 <	0.420 1	0.184-0.961	**0.0400**	0.357 1	0.146-0.872	**0.0238**
Fat-free arm mass (kg)	2.75 ≥ 2.75 <	0.451 1	0.204-0.997	**0.0491**	0.314 1	0.121-0.815	**0.0173**
Fat-free leg mass (kg)	9.51 ≥ 9.51 <	0.338 1	0.146-0.781	**0.0112**	0.297 1	0.122-0.722	**0.0074**
Body fat mass (kg)	12.30 ≥ 12.30 <	1.387 1	0.537-3.579	0.4989	1.563 1	0.467-5.228	0.4686
Trunk fat mass (kg)	6.70 ≥ 6.70 <	0.629 1	0.288-1.376	0.2455	0.349 1	0.112-1.094	0.0710
Arm fat mass (kg)	3.40 ≥ 3.40 <	2.383 1	0.512-11.082	0.2683	2.383 1	0.512-11.082	0.2683
Leg fat mass (kg)	8.10 ≥ 8.10 <	1.955 1	0.556-6.870	0.2959	2.553 1	0.497-13.105	0.2613
BMD (%YAM)	80.00 ≥ 80.00 <	0.795 1	0.364-1.737	0.5650	0.763 1	0.338-1.721	0.7164

Notes: Multiple logistic regression analysis adjusted for age and education period (Model 1) and for age, education period, and BMI (Model 2), were performed.
Abbreviations: MMSE, Mini-Mental State Examination; BMI, body mass index; SMI, skeletal muscle mass index; BMD, body mineral density; CI, confidence interval.

Table 5. Odds ratios of MMSE domain scores for skeletal muscle mass <17.60 kg

Variables	Odds ratio	95% CI	*p* value
Orientation-Time	0.741	0.441-1.245	0.2536
Orientation-Place	0.757	0.681-0.841	0.2366
Registration	0.539	0.125-2.328	0.3758
Working memory	0.694	0.534-0.902	**0.0058**
Recall	0.824	0.566-1.199	0.3096
Language	1.020	0.597-1.743	0.9421
Visuoconstruction	1.087	0.159-7.436	0.9322

Notes: Multiple logistic regression analysis adjusted for age, education periods, and BMI were performed.
Abbreviations: MMSE, Mini-Mental State Examination; CI, confidence interval.

trunk mass, fat-free arm mass, and fat-free leg mass showed an area under the curve >0.6, with threshold scores of 5.00 kg/m^2, 17.60 kg, 33.60 kg, 14.00 kg, 2.75 kg, and 9.51 kg, respectively.

Logistic regression analysis adjusted for age and years of education (Model 1) or for age, years of education, and BMI (Model 2) showed that participants with skeletal muscle mass ≤17.60 kg had the lowest OR (0.279; 95% CI: 0.120–0.644; p = 0.0028) in Model 1 and an OR of 0.234 (95% CI: 0.095–0.573; p = 0.0015) in Model 2 for an MMSE score >26 (Table 4).

ORs of MMSE domain scores for skeletal muscle mass <17.60 kg

Table 5 shows the ORs of MMSE domain scores for skeletal muscle mass <17.60 kg by multiple logistic regression analysis adjusted for age, years of education, and BMI. The results indicated that skeletal muscle mass <17.60 kg was associated with lower scores on the working memory subscale of the MMSE (OR: 0.694; 95% CI: 0.534–0.902; p = 0.0058) (Table 5).

DISCUSSION

The results of this study revealed a relationship between muscle mass, especially skeletal muscle mass, and cognitive function. Furthermore, regarding the relationship between cognitive function and fat-free arm mass, fat-free leg mass, and fat-free trunk mass, fat-free leg mass had the lowest OR. Increased thigh muscle mass has been reported to be associated with a lower likelihood of dementia, independent of weight change from middle age (Noh, 2017), which strongly supports our results. Therefore, to help prevent dementia in the aged, it appears to be more important to increase fat-free leg mass than fat-free trunk or arm mass.

Furthermore, in this study, a strong relationship was observed between the working memory MMSE domain and skeletal muscle mass. Skeletal muscle is a well-established endocrine organ that secretes physiologically active substances such as the myokine-transcription factor peroxisome proliferator-activated receptor gamma co-activator 1-alpha (PGC-α), cathepsin B, irisin, and insulin-like growth factor 1 (IGF-1). These myokines affect brain function as well as metabolism. For example, PGC-1α induces fibronectin type III domain-containing protein 5 (FNDC5), upregulates brain-derived neurotrophic factor, which is known to support hippocampal-dependent memory, and indicates muscle-brain crosstalk directly (Wrann, 2013). In a study using a mouse model of Alzheimer's disease (AD), irisin was found to be involved in synaptic plasticity and memory (Lourenco, 2019). It has also been reported that IGF-1, an endocrine hormone, is a key regulator of skeletal muscle development and promotes cell survival in the hippocampus, suppresses apoptosis, and stimulates neurogenesis (Lee, 2009). Furthermore, IGF-1 contributes to synaptic plasticity and the neural mechanisms necessary for learning and memory through blood–brain barrier transport (Reinhardt, 1994; Dyer, 2016; Llorens, 2010). In addition, in association with AD, IGF-1 has been reported to suppress the deposition of brain amyloid beta and abnormal tau phosphorylation (Hong, 1997). In studies involving disease-free middle-age and older people, high serum levels of IGF-1 were found to be associated with less cognitive decline, larger cerebral volumes, and lower risks of developing AD compared with low serum levels (Rollero, 1998; Kalmijin, 2000; Westwood, 2014).

Most relationships reported between myokines and cognition involve exercise to our knowledge, no studies have been conducted on the relationship between muscle mass and myokines. However, when performing the same exercise, greater myokine secretion can be expected with higher muscle mass. Therefore, the relationship observed in this study between skeletal muscle mass and cognitive function, especially working memory, was considered to be a mechanism mediated by myokines.

In this study, no relationship was found between BMI, body fat, and cognitive function. In previous reports, associations were reported between a lower risk of dementia or better performance in cognitive tasks and a higher BMI (>32 kg/m^2) and higher body fat mass (>42 kg) (Qizilbash, 2015; Tikhonoff, 2015). In the present study, the highest BMI was 32 kg/m^2 and the highest body fat mass value was 33.5 kg; these differences seem to be primarily attributed to the average body composition parameters of the general population.

A higher amount of abdominal and thigh subcutaneous fat were reported to be associated with a lower likelihood of dementia in a study involving Icelandic women, (Spauwe, 2017). On the other hand, a longitudinal study reported finding no relationship between increases or decreases in fat mass and cognitive function (Zhou, 2014). As mentioned above, many of these studies have involved obese people or been conducted to measure visceral fat mass. The differences between the results of the present and previous studies are thought to be the result of differences in the participants' physiques and genetic backgrounds. A study conducted in Japan found that the higher the amount of abdominal visceral fat measured in autopsy cases, the lower the rate of cognitive impairment in the aged (Nishizawa, 2019). No relationship was found between body fat mass and cognitive function in our study, but a possible relationship between visceral fat mass and cognitive function remains.

BMD has been shown to be regulated through the brain (Guntur, 2012; Lee, 2000), and the adipocyte-derived hormone leptin has been reported to regulate bone formation through the hypothalamus via the sympathetic nervous system (Qury, 2013; Bradburn, 2016). Cognitive impairment and dementia have been reported to be significantly associated with lower BMD and osteoporosis among postmenopausal women (Lee, 2012; Kang, 2018; Nakamura, 2020). In the present study, no relationship was found between BMD and cognitive function. Most previous studies have used dual-energy X-ray absorptiometry; however, in the present study, we used a BIA device, and this different measurement method could have led to the differences seen in the results.

LIMITATIONS AND FUTURE RESEARCH

This study had several limitations. First, the sample size (n = 296) was small, only representing about 2.0% of all women aged 60–90 years in Kaizuka city. Therefore, additional research with a larger sample is needed. Second, the participants in this study were all Japanese women because there were few male participants; thus, caution is needed when generalizing the results to other populations, including men. Third, comorbid diseases that could affect cognitive function, such as depression and hypothyroidism, were not considered in this study. Fourth, as this was a cross-sectional study, the data obtained were not sufficient to determine the existence of a causal relationship between body composition parameters and cognitive function; therefore, longitudinal studies are needed to clarify these relationships.

CONCLUSION

The results of this study indicated that cognitive function in women is deeply related to muscle mass, particularly skeletal muscle mass, as opposed to body fat mass and BMD. These findings suggest that cognitive impairment could lead to reduced dietary intake and physical activity, resulting in excessive muscle loss in the aged. Conversely, low muscle mass might reduce myokine production and cognitive function.

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