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CALORIE INTAKE AND COGNITIVE FUNCTION IN THE ELDERLY: DATA FROM THE KOREAN FRAILTY AND AGING COHORT STUDY (KFACS)

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Abstract: This study aimed to clarify the association between calorie intake and cognitive function in community-dwelling older adults. A cross-sectional analysis was performed on the first-year baseline data of 1559 adults aged 70–84 years using population data from the Korean Frailty and Aging Cohort Study. We included 543 participants who participated in nutritional surveys and accurately responded regarding their daily calorie intake. Daily ingestion was measured using the 24-hour dietary recall method, and neuropsychological tests evaluated cognitive characteristics. Logistic regression models were utilized to calculate odds ratios (ORs) with 95% confidence intervals (CIs). The prevalence rate of cognitive impairment was 8%. Subjects with cognitive impairment mainly showed memory loss. After adjusting the confounding factors, participants who had less than the recommended intake were susceptible to cognitive impairment compared to those who that had the proposed intake (adjusted OR: 7.70, 95% CI: 1.01-58.45). We showed that lesser calorie intake than the recommended intake increases the ORs of cognitive impairment. We suggest that an adequate calorie intake protects against cognitive decline, and further studies are essential to investigate the influence of calorie intake reduction on the elderly before widespread application.

Key words: Calorie intake, cognition, aging, cohort study.

Introduction

With an increasing aged population, cognitive decline has emerged as the main issue in health-related fields. According to prevalence data, 46.8 million people lived with dementia in 2015, and the number of people with dementia is anticipated to increase to 74.7 million by 2030 and 131.5 million by 2050 (1). The increasing burden of care to their family and the growing socio-economic costs are a severe social problem (2). Many researchers have been working to develop a cure for dementia; however, presently, there is no effective treatment. The importance of prevention at an early stage of cognitive decline is strongly emphasized.

Age-related cognitive decline or normal cognitive aging is an inevitable process. However, there is variability regarding cognitive function maintenance in the elderly (3). Some people have a superior cognitive function than other individuals at the same chronological age. Successful cognitive aging implies normal cognitive function until death (4). The understanding of risk factors associated with cognitive impairment is pivotal to achieve successful cognitive aging as well as to carry out timely adequate intervention to help delay the progression of dementia. To accomplish this purpose, we need to clearly establish risk factors for cognitive impairment. Although risk factors for cognitive impairment and dementia, such as age, obesity, smoking, drinking, education, social engagement, education, hypertension, diabetes mellitus, and depression, have been well documented in the literature, we need to clarify more factors (5).

One preventable risk factor is daily calorie intake. Excessive calorie intake and subsequent obesity are correlated with chronic diseases including type 2 diabetes mellitus, hyperlipidemia, stroke, ischemic heart disease, as well as cognitive decline (6). Previous studies recommended that weight loss through calorie restriction and physical activity is essential to maintain a healthy status (7, 8). Calorie restriction (CR) is defined as reduction in daily calorie intake and the ingestion of essential nutrients without causing malnutrition (9). Reduction in calorie intake has benefits such as lowering the fat body composition, proportion of cholesterol, blood pressure, and oxidative stress (10).

In the elderly, however, there is not substantial evidence that a reduced calorie intake is good for health, especially cognitive health. The relative risk of mortality associated with a higher body mass index (BMI) decreases in aged individuals (11). Being overweight and having mild obesity in older adults could protect against osteoporosis and fractures (12). A cross-sectional and longitudinal study showed that being overweight is related to better cognitive performance in the elderly (13, 14). We tried to clarify the role of calorie intake in the elderly as a risk factor for cognitive impairment. The aim of the study was to confirm the association between calorie intake and cognitive function in the elderly.

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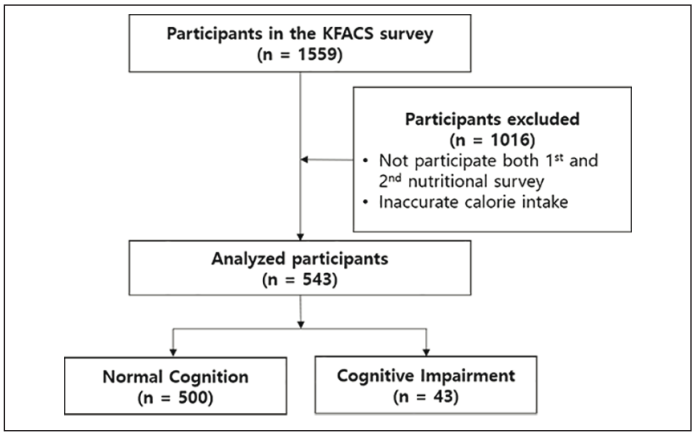
Materials and Methods

Sample

We performed cross-sectional data analysis employing first-year baseline data from the Korean Frailty and Aging Cohort Study (KFACS). The KFACS is a nationwide multicenter cohort study conducted to identify influencing factors contributing to health and frailty of the elderly living in the community (15). It began in 2016 and recruited 1559 older adults aged 70-84 years old from 10 urban and rural centers. The exclusion criteria were the inability to communicate, plans to move out in two years, incapacity of visiting the healthcare center, acute stroke or acute myocardial infarction during the past six months, and systolic blood pressure of over 180 mmHg. The survey was conducted as an in-person interview, health examination, and radiologic and laboratory tests every two years. Of the 1559 individuals recruited in the first year, we included 543 participants (284 men and 259 women) who took part in both the first and the second 24-hour dietary recall assessment accurately (Figure 1).

Figure 1
Selection flow of participants in this study. KFACS, Korean Frailty and Aging Cohort Study



Measurement

Calorie intake

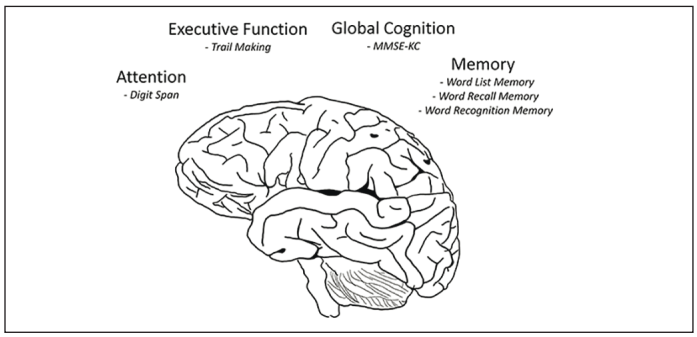
Daily calorie intake was measured using the 24-hour dietary recall method to estimate calorie intake through face-to-face interviews during home visits by trained interviewers (16). In the interview, participants recalled the amount of food and drink ingested for 24 hours during the previous day using supplementary materials such as pictures and photos. To measure a more exact amount of usual calorie intake considering the four seasons in Korea, we investigated the 24-hour dietary recall twice in the spring and fall and used the mean value for analysis. We adopted the guideline of the Ministry of Health and Welfare to set the cut-off of the recommended daily calorie intake (men: 2000 kcal, women: 1600 kcal) considering age and gender (17).

Cognitive impairment

We administered the Mini-Mental State exam in the Korean version (MMSE-KC) to all subjects to evaluate global cognition. The MMSE-KC is a screening tool used to assess cognitive impairment in older adults. Participants who had less than the fifth percentile score by age, gender, and education were regarded as having cognitive impairment, similar to what was considered in a previous study (18).

We conducted neuropsychological tests (Consortium to Establish a Registry for Alzheimer's Disease Assessment Battery, CERAD-K) to appraise the comprehensive cognitive function (Figure 2). The CERAD-K is a standardized clinical and neuropsychological assessment for the evaluation of patients with Alzheimer's disease. It initially consists of eight tests (Verbal Fluency, Modified Boston Naming, Mini-Mental State Examination, Word List Memory, Constructional Praxis, Word List Recall, Word List Recognition, and Constructional Praxis Recall), but in this study, only Word List Memory/Recall/Recognition, Digit Span (DS) (forward, backward), Trail Making, and MMSE-KC were included.

Figure 2
Schematic of global and specific neuropsychological tests



In the CERAD-K, Word List Memory is a test assessing the memory for new information learned (18). It consists of presenting 10 commonly used words at intervals of 2 sec and then reading and recalling as many words as possible for 90 sec. The total score is 30 points, 10 points per session. The Word List Recall test evaluates the ability to recall the given 10 words from the Word List Memory task (18). A maximum of 90 ses is allowed, and the maximum score is 10. The Word List Recognition test measures recognition ability (19). The target is to distinguish between 10 words presented in the Word List Memory test and 10 new words. The maximum score is 10. The Trail Making test assesses attention, ordering, executive function, time-space search, and mental motion velocity (20, 21). Patients were asked to draw a line connecting the numbers from 1 to 25 in an ascending order, and the time (sec) was recorded. We used the DS test in the standardized version of the Wechsler Adult Intelligence Scale-Revised (22, 23). The

Table 1
Demographic characteristics of the group

Variables	Categories	Normal Cognition (n = 500)	Cognitive Impairment (n = 43)	t or $\chi 2$	p
Age (year)		76.1 ± 3.9	77.9 ± 3.9	2.90	0.004
Gender				4.98	0.026
	Male	254 (50.8%)	30 (69.8%)		
	Female	246 (49.2%)	13 (30.2%)		
Body mass index (kg/m^2)				0.01	0.987
	<25	307 (61.4%)	27 (62.8%)		
	≥25	193 (38.6%)	16 (37.2%)		
Smoking				0.01	0.927
	Never	289 (57.8%)	24 (55.8%)		
	Ever	211 (42.2%)	19 (44.2%)		
Alcohol consumption				0.86	0.353
	Never	146 (29.2%)	16 (37.2%)		
	Ever	354 (70.8%)	27 (62.8%)		
Education (year)		8.4 ± 6.6	9.2 ± 3.9	0.74	0.458
Marital status				0.70	0.403
	Married	334 (66.9%)	32 (74.4%)		
	Divorced & widowed	165 (33.1%)	11 (25.6%)		
Living status				0.61	0.436
	Alone	126 (25.2%)	8 (18.6%)		
	With others	374 (74.8%)	35 (81.4%)		
Homeownership				0.02	0.885
	Owner-occupied	396 (79.2%)	35 (81.4%)		
	Rented	104 (20.8%)	8 (18.6%)		
Vigorous physical activity (week)				0.01	0.931
	<3 days	473 (94.6%)	40 (93.0%)		
	≥3 days	27 (5.4%)	3 (7.0%)		
Moderate physical activity (week)				2.54	0.111
	<3 days	256 (51.2%)	28 (65.1%)		
	≥3 days	244 (48.8%)	15 (34.9%)		
Hypertension				0.17	0.679
	No	210 (42.0%)	20 (46.5%)		
	Yes	290 (58.0%)	23 (53.5%)		
Hyperlipidemia				0.01	1.000
	No	353 (70.6%)	30 (69.8%)		
	Yes	147 (29.4%)	13 (30.2%)		
Diabetes mellitus				0.01	1.000
	No	393 (78.6%)	34 (79.1%)		
	Yes	107 (21.4%)	9 (20.9%)		
Depression				0.02	0.893
	No	480 (96.0%)	42 (97.7%)		
	Yes	20 (4.0%)	1 (2.3%)		
Calorie intake				4.91	0.027
	<Recommended	419 (83.8%)	42 (97.7%)		
	≥Recommended	81 (16.2%)	1 (2.3%)		

Note: Cognitive impairment is defined as a lower than the fifth percentile of the MMSE-KC score by gender and education (17.0, male, and 0-3 years of education; 21.2, male, and 4-6 years of education; 24.0, male, and ≥ 7 years of education; 14.9, female, and 0-3 years of education; 20.0, female, and 4-6 years of education; 23.0, female, and ≥7 years of education). Recommended daily calorie intake using the cut off (male, 2000 kcal; female, 1600 kcal).

Table 2
Cognitive characteristics of the group

Tests	Categories	Normal Cognition (n = 500)	Cognitive Impairment (n = 43)	t	p
Word List Memory	Memory score	16.8 ± 4.3	13.4 ± 3.9	-5.14	<0.001
Word Recall Memory	Recall score	5.6 ± 2.1	3.9 ± 1.8	-5.17	<0.001
Word Recognition Memory	Recognition score	8.7 ± 1.8	7.1 ± 2.4	-5.56	<0.001
Trail Making	Completion time	82.4 ± 59.5	97.8 ± 58.5	1.63	0.103
Digit Span	Forward score	6.7 ± 2.7	5.9 ± 2.5	-1.91	0.057
	Backward score	4.0 ± 1.9	3.4 ± 1.7	-2.06	0.040

Note: The higher score represents a higher level of cognitive function (memory score, recall score, recognition score, forward score, backward score). A higher score of completion time in the Trail Making test represents a lower level of cognitive function. Cognitive impairment is defined as lower than the fifth percentile of the MMSE-KC score by gender and education (17.0, male, and 0-3 years of education; 21.2, male, and 4-6 years of education; 24.0, male, and ≥7 years of education; 14.9, female, and 0-3 years of education; 20.0, female, and 4-6 years of education; 23.0, female, and ≥7 years of education).

numbers are composed of 3 to 9 digits in the DS-forward test and 2 to 8 digits in the DS-backward test. Both tests have a maximum score of 14. DS-forward is regarded to be more related to attention. We gave participants a sequence number of 2 to 9 digits at a rate of one digit per sec and made them repeat it immediately. The score was calculated by the total number of items correctly repeated forward. We performed the DS-backward test to evaluate working memory. Participants had to repeat numbers in the reverse order. The score is the total number of correct items.

Other variables

Age, gender, smoking, alcohol consumption, marital status, living status, and homeownership data were obtained by a self-reported questionnaire. BMI was calculated by an equation (kg/m^2). Obesity was defined as a BMI of ≥25 kg/m^2 in the Asian population (24). Vigorous physical activities refer to activities that require a considerable physical effort and make breathing much harder than normal at least for 10 min at a time. Moderate physical activities refer to activities that require an extended physical effort and make breathing somewhat harder than usual at least for 10 min at a time. Data were self-reported using a questionnaire. Vigorous physical activities refer to activities that require laborious physical effort and make breathing much harder than normal for at least 10 min at a time (25). We also surveyed morbidities that are well known as risk factors for cognitive impairment including hypertension, hyperlipidemia, diabetes mellitus, and depression.

Ethical consideration

This study was approved by the institutional review board (IRB) at the Kyung Hee Medical Center, Seoul, South Korea (KHUH 2019-03-019). Researchers obtained informed consent after an extensive explanation of the purpose and procedures of this study prior to data collection.

Statistical analysis

We divided the participants into two groups based on the MMSE-KC score for analysis. All data were presented as mean ± standard deviation (SD), and categorical variables were expressed numbers and percentages. Demographic and cognitive characteristics were analyzed using the chi-square test or independent t-test. The association between calorie intake and cognitive function was analyzed using a logistic regression test. All statistical analyses and graphical work were produced using R statistical software (26). Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated, and a p-value of ≤ 0.05 (for 95% CI) was statistically significant.

Results

Demographic characteristics

Table 1 shows the demographic characteristics of the groups according to cognitive function. About 8% (n = 43) of the total participants (n = 543) had less than the cut-off score of MMSE-KC. Age, gender, and calorie intake were significantly different between the groups. Participants in the cognitive impairment group were older than those in the normal cognition group (p = 0.004). Male participants accounted for a higher proportion in the cognitive impairment group (p = 0.026). Participants who had less than the suggested intake made up a higher proportion in the cognitive impairment group (p = 0.027). Other variables were not significantly different.

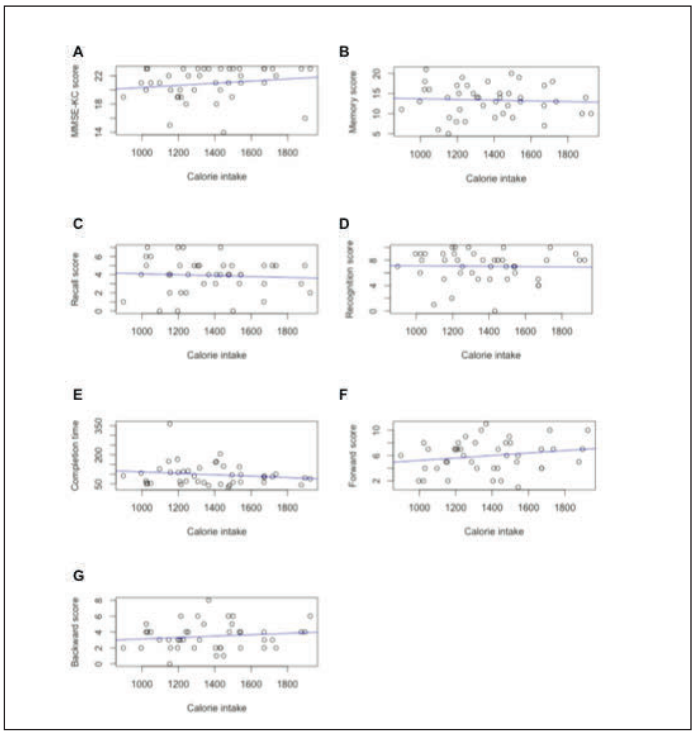
Cognitive characteristics

Neuropsychological tests evaluated various aspects of cognitive function. Data are shown in Table 2. All memory test scores including Word List Memory (p < 0.001), Word Recall Memory (p < 0.001), Word Recognition Memory (p < 0.001), and DS-backward (p = 0.040) were significantly decreased in the cognitive impairment group. These results indicated that only memory ability was impaired among numerous aspects of cognitive function in the study population.

We also assessed the association between the results of neuropsychological tests and calorie intake among participants with cognitive impairment, and there was no correlation (Figure 3). This result indicated that cognitive function was independent with calorie intake less than the recommended intake.

Figure 3

Results of the association between the results of neuropsychological tests and calorie intake. (A) MMSE-KC and calorie intake. (B) Word List Memory and calorie intake. (C) Word Recall Memory and calorie intake. (D) Word Recognition Memory and calorie intake. (E) Trail Making and calorie intake. (F, G) Digit Span and calorie intake. The Y-axis represents cognitive function (Memory score, learning memory; Recall score, ability to recall; Recognition score, ability of recognition; Completion time, executive function; Forward score, attention; Backward score, working memory)

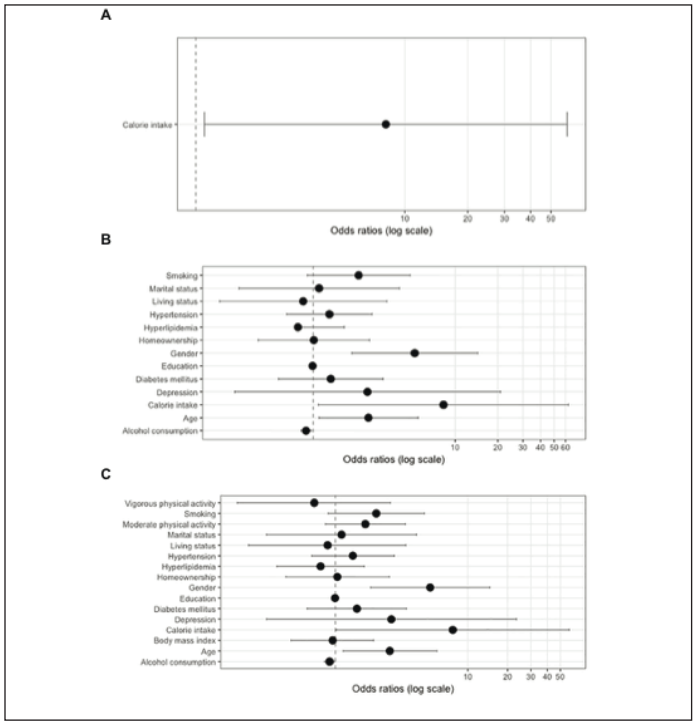


Association between calorie intake and cognitive impairment

In our study samples, regardless of gender, the mean of daily calorie intake was lower than the recommended intake (men: 1582.2 ± 406.4 kcal, women: 1254.8 ± 335.5 kcal) according to the guideline of the Ministry of Health and Welfare. Logistic regression tests were performed to examine whether calorie intake was associated with cognitive function. Data are shown in Table 3 and Figure 4. We adjusted potential risk factors including age, gender, BMI, smoking, alcohol consumption, education, marital status, living status, homeownership, vigorous physical activity, moderate physical activity, hypertension, hyperlipidemia, diabetes mellitus, and depression (Model 2). After adjusting confounding factors, participants who had less than the recommended daily intake were susceptible to cognitive impairment compared to those who had more than the recommended intake (adjusted OR: 7.70, 95% CI: 1.01-58.45).

Figure 4

Plots for odds ratios with 95% confidence interval. (A) Plot of unadjusted. (B) Plot of model 1. (C) Plot of model 2



Discussion

The study highlights that the elderly who have less than the recommended intake might be more vulnerable to cognitive impairment. We demonstrated that an adequate calorie intake is crucial for maintaining cognitive health. To our knowledge, this study is the first to investigate the association between calorie intake and cognitive function in a nationally representative sample of the elderly who live in the Korean community. Our findings suggest that intervention which reduces the calorie intake needs to be considered before its widespread application in aged individuals.

In our study, age and gender showed a significantly higher risk of cognitive impairment. Similar to this result, an older age and male showed a higher prevalence of cognitive impairment in the Mayo Clinic Study of Aging (27). Age is a well-known risk factor for age-related cognitive decline and dementia (5). The reason why male patients are at a higher risk is not clear, but biological and psychosocial differences might explain this difference. Biological differences include chromosomal differences, gonadal differences, or hormonal differences, and psychological differences such as access to education and occupation (28).

Memory loss is highly sensitive to chronological age (29). Neuropsychological tests are related to memory function that evaluated encoding, delay retention, and recognition of new verbal information. In the normal aging process, memory loss

Table 3
Odds ratio for cognitive impairment by calorie intake

Variable	Unadjusted		Model 1		Model 2	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
More than the recommended daily calorie intake (Reference)	1.00		1.00		1.00	
Less than the recommended daily calorie intake	8.12 (1.10, 59.84)	0.040	8.28 (1.09, 62.80)	0.041	7.70 (1.01, 58.45)	0.048

Note: OR, odds ratio; CI, confidence interval. Model 1: adjusted for age, gender, smoking, alcohol consumption, education, marital status, living status, homeownership, hypertension, hyperlipidemia, diabetes mellitus, and depression. Model 2: adjusted for age, gender, body mass index, smoking, alcohol consumption, education, marital status, living status, homeownership, vigorous physical activity, moderate physical activity, hypertension, hyperlipidemia, diabetes mellitus, and depression. Cognitive impairment is defined as lower than the fifth percentile of the MMSE-KC score by gender and education (17.0, male, and 0-3 years of education; 21.2, male, and 4-6 years of education; 24.0, male, and ≥7 years of education; 14.9, female, and 0-3 years of education; 20.0, female, and 4-6 years of education; 23.0, female, and ≥7 years of education). Recommended daily calorie intake using the cut off (male, 2000 kcal; female, 1600 kcal).

is due to reduced ability of encoding and retrieval of memory from new information (30, 31). On the other hand, the retention of new information that is successfully encoded is conserved (32).

The amount of daily calorie intake of the study subjects was shown to be less than that recommended by the guideline of the Ministry of Health and Welfare. Data of energy intake among Korean elderly people from the Korea National Health and Nutrition Examination Survey in 2013-2015 presented similar trends with those in our study (33). In our samples who had less than the recommended intake showed a higher prevalence of cognitive impairment. Consistent with our result, poor cognitive performance was demonstrated in people who had less calorie intake (34). In a longitudinal study in France, elderly subjects with a BMI of ≥23 kg/m2 had a 3.6 times lower chance of presenting cognitive decline in the subsequent 5 years (13). With old age, an inadequate calorie intake might be a risk factor for cognitive impairment.

One possible explanation for this finding is that an inadequate calorie intake causes weight loss. Subsequent weight loss not only reduces fat but also accelerates muscle loss, which is essential for maintaining the functional abilities and activities of the elderly in their daily lives (35). A reduced calorie intake is a cause of sarcopenia, which refers to the age-related gradual loss of muscle mass and function characterized by a decreased size of muscle with changes in muscle metabolism, oxidative stress, and degeneration of neuromuscular junction (36–38). Regarding sarcopenia associated with cognitive impairment, the OR of the association between sarcopenia and cognitive impairment was 2.926 (95% CI, 2.30-3.73) (39). The possible biological link between sarcopenia and cognitive impairment might be a common etiology such as oxidative stress, inflammation, and insulin resistance (39). For example, skeletal muscles are responsible for glucose metabolism. A reduced size and number of muscle fibers can cause insulin resistance (40). As a result, insulin resistance may have a negative impact on cognitive health (41). In this study, subjects who had less than the recommended calorie intake were vulnerable to cognitive impairment even after adjusting BMI and physical activity (comparison between Model 1 and Model 2). However, considering only these variables might not be enough to explain the association between sarcopenia and cognitive impairment. Thus, further studies are needed. There are limitations to our study. First, as the present study had a cross-sectional design, we cannot confirm the direction of the causality. Second, recall bias, especially for those with cognitive impairment, may have caused an inaccurate retrieval of past events.

Conclusions

We showed that the recommended calorie intake increased the odds of cognitive impairment. To confirm these associations, an additional longitudinal study may be needed. Further studies will be necessary to clarify the underlying mechanism between calorie intake and cognitive function in the elderly in a preclinical level.

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Conflicts of Interest: The authors declare no conflict of interest.

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