Nutrition 58 (2019) 149–155

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Dietary patterns and abdominal obesity in middle-aged and elderly Japanese adults: Waseda Alumni's Sports, Exercise, Daily Activity, Sedentariness and Health Study (WASEDA'S Health Study)

Tomoko Ito M.Sc. [a], Ryoko Kawakami Ph.D. [b], Kumpei Tanisawa Ph.D. [c,d,e], Rina Miyawaki Ph.D. [b,f], Kaori Ishii Ph.D. [b], Suguru Torii M.D., Ph.D. [b,e], Katsuhiko Suzuki M.D., Ph.D. [b,e], Shizuo Sakamoto M.D., Ph.D. [b,e], Isao Muraoka Ph.D. [b,e], Koichiro Oka Ph.D. [b,e], Mitsuru Higuchi Ph.D. [b,e,*], WASEDA'S Health Study Group

[a] *Graduate School of Sport Sciences, Waseda University, Saitama, Japan*
[b] *Faculty of Sport Sciences, Waseda University, Saitama, Japan*
[c] *Department of Health Promotion and Exercise, National Institutes of Biomedical Innovation, Health and Nutrition, Tokyo, Japan*
[d] *Japan Society for the Promotion of Science, Tokyo, Japan*
[e] *Institute of Advanced Active Aging Research, Waseda University, Saitama, Japan*
[f] *School of Arts and Letters, Meiji University, Tokyo, Japan*

ARTICLE INFO

Article History:
Received 29 July 2017
Received in revised form 17 May 2018
Accepted 22 May 2018

Keywords:
Waist circumference
Visceral fat
Diet
Principal component analysis
Cross-sectional study

ABSTRACT

Objective: The aim of this study was to investigate the associations between dietary patterns and abdominal obesity among middle-aged and elderly Japanese people, using both waist circumference (WC) and visceral fat (VF) as indices.

Methods: A cross-sectional study was conducted with 829 adults (534 men and 295 women), 40 to 79 y of age, who participated in the Waseda Alumni's Sports, Exercise, Daily Activity, Sedentariness and Health Study (WASEDA'S Health Study). Dietary patterns were derived from principal component analysis. VF was measured using magnetic resonance imaging. To examine the associations of each dietary pattern with WC and VF, we calculated multivariate-adjusted means and 95% confidence intervals (CIs) of WC and VF for the tertile of each dietary pattern score.

Results: Two main dietary patterns were identified: "healthy Japanese" and "seafood and alcohol." The healthy Japanese dietary pattern score was inversely associated with WC and VF in men only. WC measurements were 84.9 cm (95% CI, 83.7–86.1), 83.9 cm (95% CI, 82.7–85.1), and 82.4 cm (95% CI, 81.2–83.6); $P_{trend} = 0.006$, and VF measurements were 94.0 cm^2 (95% CI, 85.6–102.4), 89.4 cm^2 (95% CI, 81.1–97.7), and 80.4 cm^2 (95% CI, 72.5–88.4); $P_{trend} = 0.027$ for the lowest through the highest tertile of healthy Japanese dietary pattern scores in men. The seafood and alcohol dietary pattern was not associated with WC and VF.

Conclusion: The healthy Japanese dietary pattern was negatively associated with WC and VF in middle-aged and elderly Japanese men.

Introduction

The prevalence of obesity is increasing worldwide [1,2]. Abdominal obesity is a primary risk factor for type 2 diabetes and cardiovascular disease [3,4] and has been shown to be associated with impaired physical functions and lower quality of life [5]. From a public health standpoint, it is important to reduce the prevalence of abdominal obesity.

Recent nutritional epidemiologic studies worldwide have shown associations between dietary patterns and several diseases

This study was financially supported by the Scientific Research from the Japan Society for the Promotion of Science (no. 26242070), MEXT-Supported Program for the Strategic Research Foundation at Private Universities, Ministry of Education, Culture, Sports, Science and Technology (S1511017), part of a collaborative research project with Institute of Stress Science, Public Health Research Foundation, and Nonprofit Organization WASEDA Health Promotion.

* Corresponding author: Tel./Fax: +81 4 2947 6745.
E-mail address: mhiguchi@waseda.jp (M. Higuchi).

https://doi.org/10.1016/j.nut.2018.05.029
0899-9007/

and health-related risk factors [6–9]. Reports indicate associations between dietary patterns characterized by a high intake of vegetables, fruits, legumes, and whole grains in each country and low waist circumference (WC) [7,8,10,11]. However, to our knowledge, no research has been published regarding the associations between dietary patterns and abdominal obesity among Japanese people. The Japanese diet is known as one of the healthiest diets in the world and it is interesting to examine the associations between it and abdominal obesity. Furthermore, although WC is generally used as a simple diagnostic indicator for abdominal obesity [12], visceral fat (VF), measured by abdominal cross-sectional imaging, has been shown to be more strongly correlated with risk factors for disease, such as lipid and glucose metabolism indices [13]. It has been demonstrated that the Japanese population has more VF than the white population with the same WC [14]; therefore, it is important to investigate not only WC but also the associations between VF and dietary patterns in the Japanese population. However, to date, few studies worldwide have been published on the associations between dietary patterns and VF [15], and no studies involving the Japanese population have been conducted, to our knowledge.

The objective of this cross-sectional study was to investigate the associations between dietary patterns and abdominal obesity among middle-aged and elderly Japanese individuals, using both WC and VF as indices.

Material and methods

Study design and participants

This cross-sectional study was conducted as part of the WASEDA'S Health Study (Waseda Alumni's Sports, Exercise, Daily Activity, Sedentariness and Health Study) involving Waseda University graduates and their spouses. There were 1016 Japanese men and women >40 y of age who had undergone a health examination between March 2015 and October 2016. After enrollment, the participants completed online questionnaires on health status and physical activity before the health examination. Overall, 466 of the 1016 participants underwent anthropometric measurements and completed a questionnaire on dietary intake at the facilities in four prefectures (Hokkaido, Tokyo, Osaka, and Fukuoka); whereas 550 of the 1016 participants underwent anthropometric measurements, including VF measured by magnetic resonance imaging and a physical fitness test, and completed a questionnaire on dietary intake at Waseda University in Saitama prefecture. We excluded 187 participants from the analysis for the following reasons: age >80 y (n = 8); failure to submit the questionnaire on dietary intake (n = 10); exclusion criteria of the questionnaire on dietary intake met because of total energy intake of >4000 kcal or <600 kcal (n = 6); lack of anthropometry measurements (n = 13); medical history of cancer or heart disease (n = 68); and missing data on covariates (physical activity, smoking status, and history of diseases) on the online questionnaire (n = 82). Finally, all data were available for 829 participants (534 men, 295 women) for the analysis. Of these participants, VF data were available for 421 (276 men, 145 women). The study was conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent, and the study was approved by the Ethical Committee of Waseda University.

Anthropometry

Height was measured using a stadiometer (YL-65, YAGAMI Inc., Nagoya, Japan). Body weight and body fat percentages (assessed by bioelectrical impedance analysis) were measured using an electronic scale (MC-980 A, Tanita Corp., Tokyo, Japan). WC was measured at the umbilical region with an inelastic measuring tape at the end of normal expiration to the nearest 0.1 cm. VF was measured using magnetic resonance imaging (Signa 1.5 T, General Electric Inc., Milwaukee, WI, USA). The imaging conditions included a T1-weighted spin-echo and axial-plane sequence with a slice thickness of 10 mm, a repetition time of 480 msec, and an echo time of 8.8 msec. Cross-sectional images were scanned at the umbilical region. The cross-sectional area of the VF at the umbilical region was determined using image-analysis software (slice Omatic 4.3 for Windows, Tomo Vision, Montreal, Quebec, Canada). To minimize interobserver variation, the same investigator performed all analyses; the coefficient of variation was 5.7% for the cross-sectional areas of the VF.

Dietary intake

We used a validated brief-type self-administered diet history questionnaire (BDHQ) to assess dietary habits during the preceding month [16,17]. The BDHQ is a four-page questionnaire that takes ~15 min to administer. The BDHQ consists of the following sections:

- daily intake frequency of 46 food and nonalcoholic beverage items
- daily intake frequency of rice and miso soup
- intake frequency of five alcoholic beverages and the amount of each alcoholic beverage item consumed per typical drinking occasion
- daily intake of five seasonings (salt, oil, sugar, soy sauce, and noodle soup) used in cooking and general dietary behavior.

Dietary intake of 58 food and beverage items and energy and selected nutrients were estimated using an ad hoc computer algorithm for the BDHQ, with reference to the Standard Tables of Food Composition in Japan [18]. In previous studies, the validity of dietary intake (energy, nutrients, and food) data assessed with the BDHQ was confirmed using 16-d semi-weighted dietary records as the gold standard [16,17].

Other variables

Physical activity; smoking status (current, former, and nonsmoker); use of medication to control hypertension, diabetes mellitus, or hyperlipidemia (yes or no); residential area (35 areas); and educational status (high school, junior college and technical college, and college diploma) were assessed via the online survey questionnaire. Moderate to vigorous physical activity (MVPA) was assessed using the Global Physical Activity Questionnaire (GPAQ) [19]. The GPAQ has been assessed for validity and reliability in a nine-country study [20] and was validated with Irish, Malaysian, and Vietnamese adults [21–23]. Physical activity during work, leisure, and transport time was represented as the sum of each metabolic equivalent (MET) value multiplied by the duration of time (in hours) across different levels of physical activity [24].

Statistical analyses

To identify the dietary patterns, we conducted a principal component analysis based on the energy-adjusted intakes of 52 food and beverage items by using a density method, excluding six items (sugar added to coffee and black tea, three items usually added during cooking [salt, oil, and sugar], table salt and salt-containing seasoning at the table, and soup consumed with noodles). To determine the number of factors to retain, we considered the eigenvalues, Scree test, and interpretability of factors, which is conventional [25]. Of several factors showing eigenvalues >1, we decided to retain two factors because the scree plots decreased substantially after the second factor (from 2.68 to 2.11) and remained similar after the third factor (2.11 for the third and 2.00 for the fourth factor) and because each of these factors appeared to represent the main dietary characteristics of Japanese individuals. The dietary patterns were named according to the food items showing high loading (absolute value) based on two factors. The factor scores for each dietary pattern and for each individual were calculated by summing the intakes of the food items weighted by their factor loadings.

The factor scores were categorized into tertiles by sex and age (40–49 y, 50–59 y, and >60 y), respectively. The difference in participant characteristics among the tertile categories of each dietary pattern score were assessed by analysis of variance for normally distributed variables with the Tukey post hoc analyses, Kruskal–Wallis test for non-normally distributed variables with Bonferroni post hoc analyses, and χ^2 test for categorical variables.

To examine the association of each dietary pattern score with WC and VF, we performed analysis of covariance and calculated the multivariate-adjusted mean and its 95% confidence intervals (CIs) of WC and VF for each tertile of the dietary pattern after adjustment for the covariates. The first model was adjusted for age (year, continuous), smoking status (current, former, and nonsmoker), use of medication (yes or no), residential area (35 areas), and educational status (high school, junior college and technical college, and college diploma). The second model was further adjusted for MVPA (MET-h/wk, continuous), and the third model was further adjusted for energy intake (kcal/d, continuous) and alcohol intake (percent energy, continuous). The trend associations were assessed using polynomial contrast for ordinal numbers 1 to 3 assigned to the tertile categories of each dietary pattern score.

To assess the effect of dietary patterns and potential independent covariates on WC and VF, we performed multiple linear regression analysis. The introduced explanatory variables were each dietary pattern score, energy intake (kcal/d, continuous), alcohol intake (percent energy, continuous), MVPA (MET-h/wk, continuous), age (y, continuous), smoking status (current, former, and nonsmoker), use of medication (yes or no), residential area (35 areas), and educational status (high school, junior college and technical college, and college diploma).

All measurements and calculated values are presented as a mean ± SD for normally distributed variables, median (interquartile range [IQR]) for non-normally distributed variables, and percentage for categorical variables. The level of significance was set at two-sided $P < 0.05$. All statistical analyses were performed with SPSS, version 24.0 (SPSS, Inc., Chicago, IL, USA).

Results

The results of principal component analysis identified two dietary patterns (Supplementary Table 1). Factor loadings were equivalent to simple correlations between food items and dietary patterns. The first factor was named *healthy Japanese dietary pattern* because it was characterized by a higher intake of vegetables and fruits, soy products, mushrooms, seaweeds, and fish. The second factor was named *seafood and alcohol dietary pattern* and was characterized by seafood and shellfish and alcohol intake (beer, shochu, and sake). These two main dietary patterns accounted for 10.6% and 5.2%, respectively, of variance in food intake and together explained 15.8% of food intake variability.

Characteristics of the study participants, according to the tertile of each dietary pattern score by sex, are shown in Table 1. Men with a higher healthy Japanese dietary pattern score had a lower body mass index (BMI), body fat, WC, and VF than men with a lower score; this result was not observed in women. Participants with a higher dietary pattern score had higher protein intake and fat intake and lower carbohydrate intake than those with a lower score. Participants with a higher healthy Japanese dietary pattern score were likely to be physically active and less likely to be smokers and drink alcohol. Regarding the seafood and alcohol dietary pattern, there was no difference in BMI, body fat, WC, and VF among the different score groups in men and women. Participants with a higher seafood and alcohol dietary pattern score had a higher protein and alcohol intake than those with a lower score.

Multivariate-adjusted means with 95% CIs of WC and VF according to the tertile of categories of each dietary pattern score by sex are shown in Table 2. The healthy Japanese dietary pattern score was inversely associated with WC and VF in men only. The multivariate-adjusted (model 3) means of WC in men were 84.9 cm (95% CI, 83.7–86.1), 83.9 cm (95% CI, 82.7–85.1), and 82.4 cm (95% CI, 81.2–83.6) for the lowest through the highest tertile of healthy Japanese dietary pattern scores ($P_{trend} = 0.006$). A similar inverse association was observed between healthy Japanese dietary pattern scores and VF in men. The multivariate-adjusted (model 3) means of VF in men were 94.0 cm^2 (95% CI, 85.6–102.4), 89.4 cm^2 (95% CI, 81.1–97.7), and 80.4 cm^2 (95% CI, 72.5–88.4) for the lowest through the highest tertile of healthy Japanese dietary pattern scores ($P_{trend} = 0.027$). Seafood and alcohol dietary pattern scores were not significantly associated with WC and VF in either sex.

Other lifestyle factors are potentially associated with WC and VF; therefore, we performed multiple linear regression analysis to assess the correlation between dietary patterns and other lifestyle factors on WC and VF by sex (Table 3). Healthy Japanese dietary pattern scores had a significant inverse association to WC ($\beta = -0.106$, $P = 0.032$) and VF ($\beta = -0.177$, $P = 0.010$) in men. MVPA showed a significant negative correlation with WC ($\beta = -0.209$, $P < 0.001$) and VF ($\beta = -0.218$, $P < 0.001$) in men. However, energy and alcohol intake no longer had an independent correlation with WC and VF in men. In women, the healthy Japanese dietary pattern score was not associated with WC and VF. There was a significant positive correlation between age and VF ($\beta = 0.432$, $P < 0.001$) in women. Smoking status (0, current; 1, former; 2, nonsmoker) was negatively associated with WC ($\beta = -0.179$, $P = 0.002$) and VF ($\beta = -0.262$, $P = 0.001$) in women. Seafood and alcohol dietary pattern scores were not significantly associated with WC and VF in men and women.

Discussion

The present study aimed to determine the associations between dietary patterns and abdominal obesity among middle-aged and elderly Japanese people, using both WC and VF as indices. We identified two main dietary patterns: a healthy Japanese dietary pattern and a seafood and alcohol dietary pattern. The healthy Japanese dietary pattern was inversely associated with WC and VF in men but not in women. Conversely, the seafood and alcohol pattern was not associated with WC or VF in either group.

The healthy Japanese dietary pattern identified in this study was characterized by a high intake of vegetables, mushrooms, seaweed, soy products, fruit, and seafood, which also were observed in the first dietary pattern in earlier Japanese studies [26,27]. The seafood and alcohol pattern, identified as the second dietary pattern in this study, was similar to the animal food dietary pattern in previous studies [28,29]. Although the healthy Japanese dietary

Table 1
Study participant characteristics according to the tertile of each dietary pattern score in men and women

	Men				Women			
	T1 (low)	T2 (middle)	T3 (high)	*P*-value	T1 (low)	T2 (middle)	T3 (high)	*P*-value
Healthy Japanese dietary pattern								
n	178	178	178		98	99	98	
Dietary pattern score	−1.04 ± 0.34	−0.35 ± 0.27**	0.58 ± 0.78** ††	<0.001	−0.54 ± 0.50	0.34 ± 0.35**	1.67 ± 0.81**,††	<0.001
Age (y)	53.4 ± 9.2	53.7 ± 9.0	53.9 ± 9.2	0.836	49.8 ± 6.9	51.1 ± 7.8	51.1 ± 7.6	0.364
BMI (kg/m^2)	24.0 ± 3.3	23.6 ± 2.7	23.1 ± 2.7**	0.011	21.4 ± 3.2	21.5 ± 2.5	21.3 ± 2.9	0.927
Body fat (%)	21.0 ± 5.4	20.1 ± 5.5	19.2 ± 5.6**	0.009	27.6 ± 6.9	28.1 ± 6	27.3 ± 6.4	0.684
WC (cm)	85.2 ± 8.9	83.8 ± 8.4	82.2 ± 7.8**	0.003	77.0 ± 9.8	76.6 ± 7.3	76.5 ± 9.1	0.902
Energy intake (kcal/d)	2120 ± 589	2111 ± 556	2054 ± 555	0.497	1708 ± 444	1734 ± 478	1654 ± 412	0.446
Protein intake (% energy)	13.3 ± 1.9	15.1 ± 1.7**	17.2 ± 2.7**,††	<0.001	14.2 ± 2.2	16.3 ± 2**	18.6 ± 3**,††	<0.001
Fat intake (% energy)	24.1 ± 5.5	26.6 ± 4.8**	29.2 ± 5.5**,††	<0.001	27.2 ± 5.5	29.3 ± 4.6*	30.0 ± 5.9**	0.001
Carbohydrate intake (% energy)	51.2 ± 9.5	51.9 ± 7.8	49.0 ± 7.9*,††	0.002	52.9 ± 8.4	52.3 ± 5.9	49.0 ± 8.2**,††	0.002
Alcohol intake (% energy)	10.1 (3.7–17.1)	5.1 (1–9.9)**	2.8 (0.2–7.5)**,†	<0.001	1.5 (0.0–7.5)	0.4 (0.0–2.0) *	0.2 (0.0–3.5) *	0.008
MVPA (MET-h/wk)	18.0 (8.0 –34.0)	20.0 (10.0–34.0)	24.0 (11.8–37.3)	0.082	12.0 (3.8–26.8)	14.0 (6.0–24.0)	20.0 (9.6–40.3)**,†	0.003
Smoking status								
Current smoker (%)	18.0	10.1	3.9	<0.001	6.1	0.0	1.0	0.029
Former smoker (%)	49.4	43.3	42.7		13.3	11.1	17.3	
Nonsmoker (%)	32.6	46.6	53.4		80.6	88.9	81.6	
Use of medication (%)‖	28.7	23.0	21.3	0.243	12.2	11.1	14.3	0.793
Educational status								
High school (%)	0.6	0.0	0.6	0.733	9.2	7.1	2.0	0.090
Junior college and technical college (%)	1.7	1.1	0.6		9.2	16.2	19.4	
College diploma (%)	97.8	98.9	98.5		81.6	76.8	78.6	
N	93	85	98		54	46	45	
VF (cm^2)	97.7 ± 40.2	89.5 ± 43.5	76.9 ± 38.7**	0.002	50.9 ± 28.3	58.0 ± 32.9	46.2 ± 22.5	0.140
Seafood and alcohol dietary pattern								
N	178	178	178		98	99	98	
Dietary pattern score	−0.79 ± 0.54	0.20 ± 0.24**	1.15 ± 0.54**,††	<0.001	−1.40 ± 0.50	−0.42 ± 0.27**	0.79 ± 0.79**,††	<0.001
Age (y)	54.1 ± 9.3	53.3 ± 8.9	53.6 ± 9.1	0.683	50.5 ± 7.4	50.7 ± 7.4	50.8 ± 7.6	0.959
BMI (kg/m^2)	23.4 ± 2.9	23.7 ± 3.1	23.6 ± 2.8	0.533	21.3 ± 3.2	21.3 ± 2.6	21.6 ± 2.9	0.828
Body fat (%)	19.8 ± 5.2	20.4 ± 5.9	20.1 ± 5.4	0.624	27.6 ± 6.8	27.6 ± 5.8	27.8 ± 6.7	0.986
WC (cm)	83.3 ± 8.1	83.7 ± 8.5	84.2 ± 8.8	0.599	77.0 ± 10.0	75.9 ± 7.3	77.2 ± 8.9	0.533
Energy intake (kcal/d)	2008 ± 565	2091 ± 534	2187 ± 589**	0.012	1627 ± 448	1716 ± 450	1753 ± 433	0.128
Protein intake (% energy)	14.5 ± 2.2	15.2 ± 2.5*	15.8 ± 3.1**	<0.001	14.9 ± 1.9	16.2 ± 2.3**	17.9 ± 3.7**,††	<0.001
Fat intake (% energy)	28.4 ± 5.6	26.4 ± 5.2**	25.2 ± 5.8**	<0.001	30.3 ± 4.7	28.9 ± 5.1	27.3 ± 6.2**	0.001
Carbohydrate intake (% energy)	53.8 ± 7.0	52.1 ± 7.2	46.2 ± 9.2**,††	<0.001	53.9 ± 5.8	52.3 ± 6.9	47.9 ± 9**,††	<0.001
Alcohol intake (% energy)	1.8 (0.2–5.3)	5.4 (1.3–9.2)**	12.5 (5.9–17.9)**,††	<0.001	0.1 (0.0–0.9)	0.6 (0–4.5)**	2.3 (0.0–10.9)**	<0.001
MVPA (MET-h/wk)	20 (11.8–34)	19.2 (8.2–32.3)	23.0 (10–38.8)	0.245	14.0 (4.0–28.0)	15.0 (8.0–26.7)	17.0 (8.0–31.0)	0.250
Smoking status								
Current smoker (%)	7.3	12.4	12.4	0.215	3.1	2.0	2.0	0.746
Former smoker (%)	43.8	42.7	48.9		13.3	11.1	17.3	
Nonsmoker (%)	48.9	44.9	38.8		83.7	86.9	80.6	
Use of medication (%)‖	24.7	19.7	28.7	0.141	11.2	9.1	17.3	0.193
Educational status								
High school (%)	0.6	0.6	0.0	0.731	6.1	7.1	5.1	0.017
Junior college and technical college (%)	1.7	1.1	0.6		5.1	21.2	18.4	
College diploma (%)	97.8	98.3	99.4		88.8	71.7	76.5	
N	91	80	105		48	46	51	
VF (cm^2)	84.4 ± 41.5	88.7 ± 40.3	90.0 ± 42.7	0.628	54.4 ± 27.6	46.7 ± 22.2	53.7 ± 33.8	0.354

BMI, body mass index; MET, metabolic equivalent; MVPA, moderate to vigorous physical activity; VF, visceral fat; WC, waist circumference
Data are mean ± SD, median (interquartile range) values, and percentage
Data analyzed using one-way analysis of variance (for distributed variables), Kruskal–Wallis test (for non-normally distributed variables), or χ^2 test (for categorical variables)
*$P < 0.05$ vs the low tertile group.
**$P < 0.01$ vs the low tertile group.
†$P < 0.05$ vs the middle tertile group. †† $P < 0.01$ vs the middle tertile group.
‖Use of medication to control hypertension, diabetes mellitus, or hyperlipidemia.

pattern resembles the healthy Western pattern regarding a high intake of fruits and vegetables [7], it was also shown in this study to include a high intake of foods unique to the Japanese diet, such as tofu, natto, other soy products, seafood, mushrooms, and seaweed. Furthermore, the Japanese diet of recent years has seen a decrease in the intake of rice as a staple food [30] and differs in that respect from the traditional Japanese diet described in previous studies [31]. The healthy Japanese dietary pattern identified in this study was characterized by a moderate intake of rice and a high intake of seafood, soy products, and vegetables, and it seemed to be the typical dietary pattern of the current middle-aged and elderly Japanese population.

In this study, the healthy Japanese dietary pattern was shown to be inversely associated with WC and VF in middle-aged and elderly Japanese men (Table 2). The healthy pattern often was shown to exhibit a negative association with WC. Dietary patterns, such as the Mediterranean diet, characterized by vegetables, fruits, whole grains, olive oil, and oily fish [10], and the healthy pattern in the United States, characterized by vegetables, fruits, whole grains, high-fiber cereals, and low-fat dairy products [7] exhibited a negative association with WC in both men and women. A negative association between healthy patterns and WC was observed in Asian populations, including Chinese [32] and South Korean [33] populations. These studies suggest that healthy dietary patterns are

Table 2
Multivariate-adjusted means with 95% confidence intervals of WC and VF according to the tertile of categories of each dietary pattern score in men and women

	Men				Women			
	T1 (low)	T2 (middle)	T3 (high)	P_{trend}*	T1 (low)	T2 (middle)	T3 (high)	P_{trend}*
Healthy Japanese dietary pattern								
WC (cm)								
n	178	178	178		98	99	98	
Model 1†	84.9 (83.7–86.1)	83.9 (82.7–85.1)	82.4 (81.2–83.6)	0.006	76.9 (75.2–78.6)	76.9 (75.2–78.6)	76.3 (74.6–78.0)	0.625
Model 2‡	84.9 (83.7–86.1)	83.8 (82.6–85.0)	82.6 (81.4–83.8)	0.008	76.9 (75.2–78.6)	76.9 (75.2–78.6)	76.3 (74.6–78.0)	0.645
Model 3§	84.9 (83.7–86.1)	83.9 (82.7–85.1)	82.4 (81.2–83.6)	0.006	76.9 (75.2–78.6)	76.9 (75.2–78.6)	76.3 (74.6–78.0)	0.625
VF (cm^2)								
n	93	85	98		54	46	45	
Model 1†	95.0 (86.8–103.1)	89.6 (81.2–97.9)	79.4 (71.5–87.3)	0.008	51.7 (45.2–58.3)	58.1 (51.0–65.2)	45 (38.0–52.2)	0.177
Model 2‡	94.7 (86.7–102.6)	89.3 (81.1–97.5)	80.0 (72.2–87.7)	0.011	51.3 (44.7–57.9)	58.1 (51.0–65.2)	45.6 (38.4–52.7)	0.249
Model 3§	94.0 (85.6–102.4)	89.4 (81.1–97.7)	80.4 (72.5–88.4)	0.027	51.1 (44.4–57.9)	58.4 (51.2–65.6)	45.5 (38.2–52.7)	0.270
Seafood and alcohol dietary pattern								
WC (cm)								
n	178	178	178		98	99	98	
Model 1†	83.4 (82.1–84.6)	83.9 (82.6–85.1)	84 (82.8–85.2)	0.474	77.0 (75.3–78.7)	76.3 (74.6–77.9)	76.9 (75.2–78.6)	0.909
Model 2‡	83.3 (82.1–84.5)	83.8 (82.6–84.9)	84.1 (82.9–85.3)	0.343	77.0 (75.3–78.7)	76.2 (74.5–77.9)	76.9 (75.2–78.6)	0.934
Model 3§	83.7 (82.5–85.0)	83.8 (82.6–85.0)	83.7 (82.3–85.0)	0.945	77.0 (75.2–78.7)	76.2 (74.5–77.9)	77.0 (75.2–78.8)	0.994
VF (cm^2)								
N	91	80	105		48	46	51	
Model 1†	85.7 (77.5–94.0)	87.7 (78.9–96.5)	89.5 (81.9–97.2)	0.502	56.9 (49.8–63.9)	46.9 (39.7–54.2)	51.1 (44.3–57.9)	0.245
Model 2‡	85.2 (77.2–93.3)	86.7 (78.1–95.3)	90.8 (83.3–98.3)	0.326	56.5 (49.4–63.6)	46.7 (39.4–53.9)	51.7 (44.8–58.6)	0.343
Model 3§	86.5 (78.0–95.0)	87.2 (78.5–95.9)	89.3 (81.2–97.4)	0.660	56.7 (49.2–64.3)	46.8 (39.5–54.1)	51.3 (44.0–58.7)	0.337

WC, waist circumference; VF, visceral fat
Data are multivariate-adjusted mean (95% CI)
*P-values for linear trend were obtained using polynomial contrast for ordinal numbers 1–3 assigned to the tertile categories of each dietary pattern.
†Model 1: Adjusted for age (y, continuous), smoking status (0 current; 1 former; 2 nonsmoker), use of medication (0 no; 1 yes), residential area (1–35 areas), and educational status (1 high school; 2 junior college and technical college; 3 college diploma).
‡Model 2: Model 1 plus moderate to vigorous physical activity (metabolic equivalent h/wk, continuous).
§Model 3: Model 2 plus energy intake (kcal/d, continuous) and alcohol (% energy, continuous).

associated with a decrease in WC regardless of race or region. Healthy dietary patterns involve a high intake of antioxidant vitamins, minerals, dietary fiber, and ω-3 fatty acids. Indeed, both a previous study [34] and the present study (data not shown) showed that the healthy Japanese dietary pattern was significantly positively associated with the intake of these nutrients. A population-based study involving Swedish men and women found negative associations between serum β-carotene concentrations and both general and central adiposity [35]. Interestingly, a study of Australian men and women reported that plasma ω-3 polyunsaturated fatty acids (PUFAs) were negatively associated with BMI, WC, and hip circumference [36], suggesting that ω-3 PUFAs may play an important role in preventing abdominal obesity. Furthermore, a meta-analysis demonstrated that fish oil intake helps reduce the waist-to-hip ratio, especially when combined with lifestyle-modifying interventions [37]. The interaction of these complex nutrients from the healthy dietary pattern may suppress the accumulation of VF. According to a study comparing middle-aged Japanese and white men, Japanese men were shown to have more VF than white men with the same WC [14]. The negative correlation between the healthy Japanese dietary pattern score and VF among men in this study, even after adjusting for the main covariates, suggests that

Table 3
Multiple linear regression analysis evaluating the association between dietary patterns and other lifestyle factors on WC and VF in men and women

	Men				Women			
	WC		VF		WC		VF	
	β	P-value	β	P-value	β	P-value	β	P-value
N	534		276		295		145	
Healthy Japanese dietary pattern score	**−0.106**	**0.032**	**−0.177**	**0.010**	−0.044	0.508	−0.104	0.244
Seafood and alcohol dietary pattern score	0.028	0.589	0.047	0.504	0.021	0.775	−0.024	0.805
Energy intake (kcal/d)	0.056	0.181	0.011	0.845	0.062	0.288	−0.028	0.726
Alcohol intake (% energy)	0.022	0.699	−0.008	0.920	−0.049	0.502	−0.010	0.921
MVPA (MET-h/wk)	**−0.209**	**<0.001**	**−0.218**	**<0.001**	−0.020	0.732	−0.067	0.382
Age (y)	0.023	0.632	**0.194**	**0.005**	0.098	0.123	**0.432**	**<0.001**
Smoking status(0 current; 1 former; 2 nonsmoker)	−0.045	0.297	**−0.125**	**0.032**	**−0.179**	**0.002**	**−0.262**	**0.001**
Use of medication* (0 no; 1 yes)	**0.216**	**<0.001**	**0.184**	**0.002**	**0.200**	**0.001**	0.059	0.479
Educational status (1 high school; 2 junior college and technical college; 3 college diploma)	−0.070	0.090	−0.023	0.684	0.055	0.357	−0.056	0.468
Residential area (1–35 areas)	0.054	0.194	−0.067	0.240	−0.028	0.622	−0.069	0.345
Model r^2	**0.117**	**<0.001**	**0.178**	**<0.001**	**0.100**	**0.001**	**0.306**	**<0.001**

MET, metabolic equivalent; MVPA, moderate to vigorous physical activity; VF, visceral fat; WC, waist circumference
Boldface indicates significance ($P < 0.05$)
*Use of medication: To control hypertension, diabetes mellitus, or hyperlipidemia medicine.

the healthy Japanese dietary pattern is an effective dietary pattern for suppressing the accumulation of VF in Japanese men.

We did not observe clear associations between the healthy Japanese dietary pattern and WC or VF in women in this study (Table 2). The World Health Organization defines a BMI of $\geq$30 kg/m^2 as obese [38]. The women participating in this study were healthy, with an average BMI of 21.4 kg/m^2 and average build, and VF was $>$100 cm^2 in only 5.5% of these women. Furthermore, more women than men followed the healthy Japanese dietary pattern in this study (data were not shown), and women had a higher healthy dietary pattern score than men in previous studies focusing on Japanese people [26,27]. Japanese women have a habit of eating healthier meals than men, thus we postulated that their intake of various nutrients is also higher. There may be weak associations between the healthy Japanese dietary pattern score and WC or VF in Japanese women with a high healthy Japanese dietary pattern score and average build.

In studying the associations with other lifestyle factors related to WC and VF (Table 3), we found that the healthy Japanese dietary pattern score was also inversely correlated with WC and VF in men. MVPA showed a similar association independent of the healthy Japanese dietary pattern score. Therefore, the results of this study suggest that a healthy Japanese dietary pattern and physical activity are each independently associated with abdominal obesity. Conversely, in women, age was positively associated with VF, and not smoking was negatively associated with VF. Previous studies have shown that postmenopausal women [39] and women who smoke [15,40] exhibited an accumulation of VF. The results of this study suggest that factors, excluding the dietary pattern, were associated with abdominal obesity in middle-aged and elderly Japanese women.

There were some limitations to this study. First, although the cross-sectional study explored the association between diet and WC or VF, reverse causation could not be entirely ruled out. In the future, it will be necessary to conduct a longitudinal study to examine this association. Second, although we confirmed the validity of the nutrient and food intake amounts, they are taken from a BDHQ and are estimated values. Third, because the GPAQ, which was used to measure physical activity levels, is limited to physical activity in the three domains of work, leisure, and transportation and does not consider physical activity in other domains, it is possible that the GPAQ scores are underestimated. Fourth, although we adjusted for the main potential independent covariates, some unmeasured confounding factors related to fat accumulation might have remained in this study. Finally, the participants in this study were graduates of the same university and their spouses, so the representativeness of the sample may have been an issue.

Conclusions

The healthy Japanese dietary pattern, characterized by a high intake of vegetables, mushrooms, seaweed, soy products, fruit, and seafood, was negatively associated with WC and VF in middle-aged and elderly Japanese men but not in women. The healthy Japanese dietary pattern may be associated with a low incidence of abdominal obesity in men. Our observed association requires confirmation in prospective studies.

Acknowledgment

The authors acknowledge all participants of the WASEDA'S Health Study.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nut.2018.05.029.

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