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Dietary intake in Japanese patients with type 2 diabetes: Analysis from Japan Diabetes Complications Study

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ABSTRACT

Aims/Introduction: Though there are many differences in dietary habits and in the metabolic basis between Western and Asian people, the actual dietary intake in Asian patients with diabetes has not been investigated in a nationwide setting, unlike in Western countries. We aimed to clarify dietary intake among Japanese individuals with type 2 diabetes, and identify differences in dietary intake between Japanese and Western diabetic patients.

Materials and Methods: Nutritional and food intakes were surveyed and analyzed in 1,516 patients with type 2 diabetes aged 40–70 years from outpatient clinics in 59 university and general hospitals using the food frequency questionnaire based on food groups (FFQg).

Results: Mean energy intake for all participants was 1737 ± 412 kcal/day, and mean proportions of total protein, fat, and carbohydrate comprising total energy intake were 15.7, 27.6 and 53.6%, respectively. They consumed a 'low-fat energy-restricted diet' compared with Western diabetic patients, and the proportion of fat consumption was within the suggested range that has been traditionally recommended in Western countries. As a protein source, consumption of fish (100 g) and soybean products (71 g) was larger than that of meat (50 g) and eggs (29 g). These results imply that dietary content and food patterns among Japanese patients with type 2 diabetes are quite close to those reported as suitable for prevention of obesity, type 2 diabetes, cardiovascular disease, and total mortality in Europe and America.

Conclusions: A large difference was shown between dietary intake by Japanese and Western patients. These differences are important to establish ethnic-specific medical nutrition therapy for diabetes.

INTRODUCTION

Medical nutritional therapy is an essential constituent in managing existing diabetes and preventing, or at least slowing, the development of diabetes complications[1]. Thus, it is necessary to determine and assess dietary patterns in diabetes patients. However, there have been no large-scale studies of dietary patterns in nationwide settings from Asian regions except a recent study of elderly diabetic patients[2], although there have been many such studies among populations with diabetes in Western countries, such as the Diabetes Nutrition and Complications Trial, Strong Heart Study, National Health and Nutrition

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Examination Survey, and European Diabetes Centers Study of Complications in Patients with Insulin-Dependent Diabetes Mellitus Complications Study Group[3–6].

Dietary patterns in Asia are quite different from those of Western countries because of differences in food culture, food supply, dietary consumption and nutritional intake. For example, according to a report of the Food and Agriculture Organization (FAO) of the United Nations in 2007[7], the total energy supply and the energy supply from animal products in Asia were lower than those in Western regions (2668 and 402 kcal/day in Asia, 3748 and 1028 kcal/day in the USA, and 3406 and 942 kcal/day in European regions, respectively), although the percentage of energy from vegetable products was higher than in Western regions (85% in Asia, 73% in the USA and 72% in European regions).

In addition, in their joint position statement on the treatment of hyperglycemia, the American Diabetes Association and European Association for the Study of Diabetes encourage the development of individualized treatment plans built around racial and ethnic differences[8]. We reported previously that Japanese type 2 diabetic patients had a much lower body mass index (BMI) than Western patients, even though energy intake was the same, and both groups were similar with regard to age, diabetes duration, hemoglobin A1c (HbA1c) and other clinical variables[9,10]. This suggests a different metabolic basis between East Asians and Western patients with diabetes, such as the degree and influence of insulin deficiency and resistance[11]. Furthermore, it was reported that the profiles of the incidence of complications in diabetic patients differ between Asian and Western countries, such as much lower risks of myocardial infarction, stroke and congestive heart failure in Asian patients compared with Western patients, despite a higher risk of end-stage renal disease in Asian patients[12]. It could be possible that differences in eating patterns influence, at least partly, the differences in profiles of complications between the two groups.

Thus, given the differences in dietary habits and metabolic basis between Western and Asian people, it is necessary to clarify the actual dietary intake among Asian individuals with type 2 diabetes and compare it with that of Western diabetic patients in order to rationally develop effective medical nutritional therapy for diabetes. Our aim of the present study was to elucidate the actual dietary intake among Japanese middle-aged individuals with type 2 diabetes who participated in a nationwide cohort study, and to identify differences between Japanese and Western diabetic patients' dietary intake.

METHODS

Study Population

The Japanese Diabetes Complications Study (JDCS) is a nationwide cohort study of Japanese patients with type 2 diabetes from outpatient clinics in 59 university and general hospitals. Participants were previously diagnosed patients with type 2 diabetes aged 40–70 years whose HbA1c levels were ≥6.5%. Details of the study procedure were published elsewhere[13]. The protocol for the study, which is in accordance with the Declaration of Helsinki and the Ethical Guidelines for Clinical/Epidemiological Studies of the Japanese Ministry of Health Labor and Welfare, received ethical approval from the institutional review boards of all of the participating institutes. Written informed consent was obtained from all patients enrolled. A dietary survey was carried out in the baseline year of 1996. Nutrition and food intakes were assessed by the Food Frequency Questionnaire based on food groups (FFQg). A total of 1,516 of the eligible 2,033 patients completed the FFQg, and their data were analyzed in the present study.

Dietary Assessment

Nutrition and food intakes were assessed by the FFQg. The FFQg is composed of items on 29 food groups and 10 kinds of cookery, and elicits information on the average intake per week of each food or food group in commonly used units or portion sizes. After participants completed the questionnaire, a dietician reviewed the completed questionnaire with the participant. The FFQg was externally validated by comparison with weighed dietary records for seven continuous days of 66 subjects aged 19–60 years[14].

The correlation coefficients between the FFQg and dietary records for energy, protein, fat, carbohydrate, and calcium intakes were 0.47, 0.42, 0.39, 0.49, and 0.41, respectively. Intakes of 26 of the 31 nutrients were not significantly different between the two methods by paired *t*-tests. We used standardized software for population-based surveys and nutrition counseling in Japan (EIYO-KUN v.4.5, manufactured at the site of the Shikoku University Nutrition Database)[15] to calculate nutrient and food intakes, which were based on Japan Dietary Reference Intakes in 1996.

Other Assessments

Other measurements in addition to the dietary survey included a physical examination, blood pressure measurement, neurological/ophthalmological examination, and laboratory tests that included HbA1c, fasting plasma glucose/insulin/C-peptide, serum lipids/creatinine/urea nitrogen and urine analyses[13]. HbA1c assays were standardized by the Lab Test Committee of the Japan Diabetes Society (JDS)[13]. HbA1c values were converted from JDS values into National Glycohemoglobin Standardization Program (NGSP) equivalent values. NGSP equivalent values were calculated using the following formula: NGSP equivalent value (%) = JDS value (%) + 0.4[16]. Physical activity and smoking status were determined by a detailed questionnaire.

Statistical Analysis

All data are presented as means ± standard deviation unless otherwise stated. Differences in the major characteristics between participants who completed and did not complete the FFQg were examined by *t*-tests. All *P*-values are two-sided, and the significance level is 0.05. All statistical analyses were carried out using SAS packages version 9.1 (SAS Institute, Cary, NC, USA).

RESULTS

Table 1 shows the characteristics of the 1,516 type 2 diabetes patients. Their mean BMI was 22.7 kg/m^2, and 23% of the patients had a BMI ≥25 kg/m^2. Their mean age was 59 years, and mean $HbA1_C$ value was 7.9%.

Table 2 shows the nutritional intake per day and the percentage of participants who met nutritional recommendations[17–19]. The mean daily energy intake for all participants was 1737 ± 412 kcal/day, and the mean proportions of total protein, fat and carbohydrate comprising total energy intake were 15.7, 27.6, and 53.6%, respectively. Saturated fatty acid intake comprised 28.6% of total fat intake. Additionally, we evaluated energy and nutritional intakes, respectively, by patients grouped according to sex, age, intensity of physical activity during work, HbA1C level and diabetes duration. Features of energy intake and nutritional intake, and the percentage of participants who met the nutritional recommendations by Japan and major Western guidelines were similar for each comparison with the exception that the men consumed 180 kcal/day more energy than the women (1820 and 1640 g/day, respectively; Table 2). As for intake of selected food groups per day, the mean total vegetable intake for all participants was 324 g/day (Table 3). As a protein source, consumption of fish (100 g) and soybean products (71 g) was larger than that of meat (50 g) and eggs (29 g). The male patients consumed approximately eightfold more alcoholic beverages than the female patients (115 and 14 g/day, respectively), but the characteristics of food intake did not differ greatly among the patient groups.

Table 4 summarizes the dietary composition of various study populations with diabetes, including the current JDCS participants. The JDCS patients had higher carbohydrate consumption and lower fat consumption than reported among diabetic patients in Western countries (37–50% energy and 35–45% energy, respectively)[3–6]. However, it is necessary to note differences in methods for measurement of dietary intake among the studies. In contrast, the JDCS patients had lower carbohydrate consumption and higher fat consumption than reported for type 2 diabetic patients in Korea[20] and South Africa[21]. The energy intake of JDCS patients was similar to that for Western diabetic patients[3–6], although the Western diabetic patients had a higher BMI than the Japanese diabetic patients.

Table 1 | Characteristics of 1,516 diabetic patients who participated in the nutritional and food intake survey of the Japanese Diabetes Complications Study

	Men (n = 807)		Women (n = 709)		Total (n = 1,516)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	58.4	±7.0	59.0	±6.8	58.7	±6.9
Diabetes duration (years)	11.5	±7.4	10.4	±6.7	11	±7.1
Weight (kg)	62	±8.6	54.2	±8.3	58.4	±9.3
BMI (kg/m^2)	22.7	±2.6	23.2	±3.3	22.9	±3.0
<18.5 kg/m^2	4.0%		6.8%		5.3%	
≥25 kg/m^2	19.3%		28.1%		23.4%	
Waist circumference (cm)	81.9	±7.8	76.6	±9.4	79.4	±9.0
Waist-to-hip ratio	0.89	±0.06	0.83	±0.07	0.86	±0.1
Fasting plasma glucose (mmol/L)	8.9	±2.4	9.0	±2.5	8.9	±2.4
HbA1c (%)	7.7	±1.2	8.1	±1.3	7.9	±1.3
Systolic blood pressure (mmHg)	131	±15.7	131	±16.3	131.4	±16.0
Diastolic blood pressure (mmHg)	77	±9.8	76	±9.9	76.6	±9.9
Total serum cholesterol (mmol/L)	5.0	±0.9	5.4	±0.9	5.2	±0.9
Serum LDL cholesterol (mmol/L)	3.0	±0.9	3.3	±0.8	3.2	±0.8
Serum HDL cholesterol (mmol/L)	1.4	±0.4	1.5	±0.5	1.4	±0.4
Serum triacylglycerol† (mmol/L)	1.2	±0.8	1.1	±0.8	1.1	±0.8
eGFR† (mL/min per 1.73 m^2)	79.4	±33.0	81.8	±36.6	80.3	±33.7
Treated by insulin (%)	18.1%		22.1%		20.0%	
Treated by OHA without insulin (%)	64.7%		67.1%		65.8%	
Current smoker (%)	46.4%		8.7%		28.7%	

eGFR, estimated glomerular filtration rate; HbA1c, hemoglobin A1c; HDL, high-density lipoprotein; LDL, low-density lipoprotein; OHA, oral hypoglycemic agent; SD, standard deviation. †Median and interquartile range.

DISCUSSION

In the present study, we determined the actual dietary intake among Japanese with type 2 diabetes in a nationwide large-scale setting. We clarified that the JDCS patients consumed a 'high-carbohydrate low-fat' diet compared with Western diabetic patients, and that their energy intake was similar to that of Western diabetic patients. In addition, the features of energy intake, and nutritional and food intake among the JDCS patients were similar regardless the differences in sex, age, intensity of physical activity during work, HbA1C level, and diabetes duration.

According to the National Health and Nutrition Survey[22] carried out the same year as the dietary survey of JDCS, energy intake by Japanese men and women aged 40–69 years in the general population ranged from 2214 kcal/day to 2319 kcal/day and

Table 2 | Nutritional intake per day, and percentage of participants who met the nutritional recommendations of the Japan Diabetes Society, Canadian Diabetes Association and American Diabetes Association

	Men (*n* = 807)		Women (*n* = 709)		Age <60 years (*n* = 755)		Age ≥60 years (*n* = 761)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Nutritional intake								
Energy								
kcal	1819	400	1643	405	1760	420	1714	403
Carbohydrate								
% Energy	53.0	6.8	54.2	6.3	52.9	6.7	54.2	6.5
g	239.6	55.4	220.1	48.5	230.9	54.4	230.0	52.0
Protein								
% Energy	15.2	2.3	16.2	2.4	15.6	2.4	15.8	2.4
g	69.7	20.8	67.2	22.7	69.0	22.1	68.0	21.4
Fat								
% Energy	26.7	4.9	28.7	4.8	28.1	5.1	27.2	4.8
g	54.3	17.1	53.2	18.9	55.3	18.5	52.3	17.3
SFAs								
% Energy	7.6	1.7	8.3	1.6	8.0	1.7	7.9	1.6
MUFAs								
% Energy	8.8	2.0	9.3	2.0	9.3	2.1	8.8	2.0
PUFAs								
% Energy	6.4	1.5	6.9	1.5	6.8	1.6	6.5	1.5
n6								
% Energy	5.2	1.3	5.5	1.4	5.5	1.4	5.2	1.3
n3								
% Energy	1.5	0.4	1.6	0.4	1.6	0.4	1.6	0.4
Cholesterol								
mg	316.9	116.9	306.9	118.1	313.1	116.5	311.3	118.6
Ca								
mg	619.6	228.3	661.0	229.5	628.9	228.3	648.9	230.8
Fe								
mg	8.0	2.5	8.2	2.7	8.1	2.6	8.1	2.5
Dietary fiber, total								
g	14.1	5.3	15.4	5.3	14.5	5.4	14.9	5.2
Sodium								
g	4.1	1.5	4.3	1.6	4.1	1.6	4.3	1.5
Recommendation met								
Carbohydrate†								
<55% Energy	61%		55%		61%		55%	
55–60% Energy	24%		29%		25%		27%	
≥60% Energy	15%		17%		13%		18%	
Fat†								
<25% Energy	38%		21%		27%		33%	
SFAs‡								
<7% Energy	35%		17%		26%		27%	
Fiber (total)†								
≥20 g	13%		17%		14%		16%	
Sodium†								
<3.9 g	50%		45%		50%		46%	

Table 2 | (Continued)

	Sedentary occupation (n = 1,032)		Non-sedentary occupation (n = 366)		HbA1c <7% (n = 1,266)		HbA1c ≥7% (n = 250)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Nutritional intake								
Energy								
kcal	1,714	400	1,774	436	1,736	407	1,739	437
Carbohydrate								
% Energy	53.6	6.5	53.9	6.9	53.4	6.7	54.6	6.2
g	227.7	51.1	237.2	59.1	229.5	52.1	235.4	57.9
Protein								
% Energy	15.7	2.4	15.3	2.4	15.7	2.4	15.5	2.2
g	67.9	21.0	68.6	23.1	68.6	21.7	67.9	21.7
Fat								
% Energy	27.7	4.8	27.1	5.3	27.6	5.0	27.8	4.8
g	53.2	17.3	53.9	19.0	53.7	17.9	54.2	18.2
SFAs								
% Energy	8.0	1.6	7.7	1.8	7.9	1.7	8.2	1.7
MUFAs								
% Energy	9.0	2.0	8.8	2.1	9.0	2.1	9.1	2.0
PUFAs								
% Energy	6.6	1.5	6.6	1.6	6.7	1.5	6.5	1.4
n6								
% Energy	5.3	1.3	5.3	1.4	5.4	1.4	5.2	1.2
n3								
% Energy	1.6	0.4	1.5	0.4	1.6	0.4	1.5	0.4
Cholesterol								
mg	311.8	116.2	305.0	118.6	312.2	117.8	312.2	116.2
Ca								
mg	637.4	222.5	631.2	242.4	637.2	232.4	648.0	215.6
Fe								
mg	8.1	2.4	8.1	2.7	8.1	2.6	8.1	2.5
Dietary fiber, total								
g	14.7	5.2	14.4	5.5	14.6	5.3	15.1	5.5
Sodium								
g	4.2	1.5	4.2	1.6	4.2	1.5	4.2	1.6
Recommendation met								
Carbohydrate†								
<55% Energy	58%		57%		59%		52%	
55–60% Energy	26%		26%		26%		28%	
≥60% Energy	16%		17%		15%		20%	
Fat†								
<25% energy	28%		36%		31%		28%	
SFAs‡								
<7% Energy	26%		30%		27%		23%	
Fiber, total†								
≥20 g	16%		12%		15%		17%	
Sodium†								
<3.9 g	49%		50%		48%		48%	

Table 2 | (Continued)

	Diabetes duration <10 years (*n* = 737)		Diabetes duration ≥10 years (*n* = 779)		Total (*n* = 1516)	
	Mean	SD	Mean	SD	Mean	SD
Nutritional intake						
Energy						
kcal	1,762	425	1,708	397	1,737	412
Carbohydrate						
% Energy	53.3	6.5	53.9	6.7	53.6	6.6
g	232.8	55.2	228.0	51.0	230.5	53.2
Protein						
% Energy	15.6	2.4	15.7	2.4	15.7	2.4
g	69.5	22.6	67.3	20.7	68.5	21.7
Fat						
% Energy	27.9	4.9	27.3	5.0	27.6	5.0
g	55.1	18.3	52.4	17.5	53.8	18.0
SFAs						
% Energy	7.9	1.7	7.9	1.7	7.9	1.7
MUFAs						
% Energy	9.1	2.0	8.9	2.0	9.0	2.0
PUFAs						
% Energy	6.7	1.5	6.5	1.5	6.6	1.5
n6						
% Energy	5.4	1.4	5.2	1.3	5.3	1.4
n3						
% Energy	1.6	0.4	1.5	0.4	1.6	0.4
Cholesterol						
mg	316.1	120.2	307.2	114.1	312.2	117.5
Ca						
mg	644.5	238.8	632.3	220.2	639.0	229.7
Fe						
mg	8.3	2.6	7.9	2.5	8.1	2.6
Dietary fiber Total						
g	15.0	5.4	14.4	5.2	14.7	5.3
Sodium						
g	4.3	1.6	4.1	1.5	4.2	1.5
Recommendation met						
Carbohydrate†						
<55% Energy	59%		57%		58%	
55–60% Energy	27%		25%		26%	
≥60% Energy	13%		19%		16%	
Fat†						
<25% Energy	28%		32%		30%	
SFAs‡						
<7% Energy	27%		27%		27%	
Fiber, total†						
≥20 g	17%		13%		15%	
Sodium†						
<3.9 g	48%		49%		48%	

MUFAs, mono-unsaturated fatty acids; n3, n-3 fatty acids; n6, n-6 fatty acids; PUFAs, poly-unsaturated fatty acids; SD, standard deviation; SFAs, saturated fatty acids. †Carbohydrate intake, 50–60% of total energy; fat intake, <25% total energy; fiber, >20 g/day; and sodium, <3.9 g (<10 g as salt) were recommended by the Japan Diabetes Society[17]. ‡Saturated fat intake should be <7% of total energy as recommended by the Canadian Diabetes Association[18] and the American Diabetes Association.[19]

Table 3 | Intake of selected food groups per day

	Men (*n* = 807)		Women (*n* = 709)		Age <60 years (*n* = 755)		Age ≥60 years (*n* = 761)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grains (g)	207	58	173	40	194	54	189	52
Potato/aroid (g)	50	40	58	50	50	41	57	49
Soybeans/soy products (g)	68	49	75	54	71	51	72	52
Fruits (g)	121	101	148	108	126	107	140	103
Green-yellow vegetables (g)	130	69	147	66	136	67	140	68
Other vegetables (g)	174	103	200	99	184	100	188	104
Meat (g)	52	37	47	39	54	40	46	36
Fish (g)	103	61	97	59	101	61	100	60
Eggs (g)	30	18	28	16	29	16	29	17
Milk/dairy products (g)	165	109	177	94	168	108	173	97
Sweets/snacks (g)	16	20	20	21	18	21	17	20
Oil (g)	17	9	17	9	18	9	16	8
Alcoholic beverages (g)	155	195	14	48	99	180	80	142
Other beverages (g)	44	85	28	67	41	84	33	70

	Sedentary occupation (*n* = 1032)		Non-sedentary occupation (*n* = 366)		HbA1c <7% (*n* = 1266)		HbA1c ≥7% (*n* = 250)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grains (g)	187	50	202	62	191	53	194	54
Potato/aroid (g)	53	42	55	45	53	42	57	58
Soybeans/soy products (g)	70	49	72	57	72	53	67	44
Fruits (g)	139	105	118	109	132	104	141	112
Green-yellow vegetables (g)	139	68	132	67	137	67	143	70
Other vegetables (g)	188	102	176	100	184	102	195	103
Meat (g)	49	37	48	39	49	38	52	42
Fish (g)	99	60	100	62	102	61	93	58
Eggs (g)	29	17	28	16	29	17	30	16
Milk/dairy products (g)	170	101	169	107	168	102	184	105
Sweets/snacks (g)	18	20	19	22	17	20	20	23
Oil (g)	17	9	17	9	17	9	17	9
Alcoholic beverages (g)	83	160	103	166	96	169	54	116
Other beverages (g)	35	77	45	83	36	76	41	85

	Diabetes duration <10 years (*n* = 737)		Diabetes duration ≥10 years (*n* = 779)		Total (*n* = 1,516)	
	Mean	SD	Mean	SD	Mean	SD
Grains (g)	191	54	192	53	191	53
Potato/aroid (g)	56	45	51	45	54	45
Soybeans/soy products (g)	73	55	69	48	71	52
Fruits (g)	138	116	129	93	133	105
Green-yellow vegetables (g)	141	67	135	69	138	68
Other vegetables (g)	191	100	181	104	186	102
Meat (g)	51	39	48	37	50	38
Fish (g)	102	62	98	58	100	60
Eggs (g)	29	17	29	16	29	17
Milk/dairy products (g)	169	107	172	98	170	103
Sweets/snacks (g)	19	22	17	19	18	21
Oil (g)	18	9	16	9	17	9

Table 3 (Continued)

	Diabetes duration <10 years (*n* = 737)		Diabetes duration ≥10 years (*n* = 779)		Total (*n* = 1,516)	
	Mean	SD	Mean	SD	Mean	SD
Alcoholic beverages (g)	91	174	86	147	89	162
Other beverages (g)	38	81	35	73	37	77

HbA1c, glycated hemoglobin; SD, standard deviation.

1836 kcal/day to 1916 kcal/day, respectively. Thus, the JDCS patients consumed an energy-restricted diet reduced by 400–500 kcal/day in men and 200–300 kcal/day in women compared with Japanese men and women in the general population.

In addition, the energy intakes by the JDCS patients and Western patients with type 2 diabetes were similar. However, the mean BMI of the JDCS patients was within the normal range, and was much lower than in Western diabetic patients[3–6]. The differences in energy intake between the two groups were too small to explain the large difference in BMI. In terms of the biological aspects of ethnic differences, it is known that Asian people are more susceptible to pancreatic β-cell secretory defects and pronounced dysfunction in early insulin secretion than Western people[23]. In contrast, among Asian populations, the proportion of body fat and prevalence of prominent abdominal obesity are higher than in individuals of European origin with similar BMI values[23]. Also, ethnic differences in biological factors based on genetics, such as the basal metabolic rate, are assumed between Asian and Western people. Further studies are required to clarify the mechanism of the development of type 2 diabetes in consideration of an ethnic-specific constitution, and it should be investigated whether results of dietary assessments and actual food intake differ consistently between Asian and Western patients with diabetes.

The proportions of protein, fat and carbohydrate consumed by JDCS patients met the major current Western guidelines (American Association of Clinical Endocrinologists[24], European Association for the Study of Diabetes[25], Canadian Diabetes Association[18]), which recommend carbohydrate intake ranging from 45 to 65%, fat intake <30–35% and protein intake from 10 to 20%. Furthermore, mean carbohydrate intake as a percentage of energy intake (53.6%) met the current recommendations of the JDS (50–60%)[17], and mean fat intake (27.6%) was 2.6% higher than the recommendation (25% or less)[17]. Therefore, it was clarified that Japanese type 2 diabetic patients consumed a 'low-fat energy-restricted diet', which has been traditionally recommended in Western countries (generally 25–35% of energy from fat)[18,26,27], although the guidelines of the American Diabetes Association for 2011[19] stated the possibility of the effectiveness of both a low-carbohydrate and a low-fat calorie-restricted diet. These proportions of intake by the JDCS patients did not differ much according to sex, age, intensity of physical activity during work, HbA1C level and diabetes duration. In addition, the proportion of fat consumption by the JDCS patients met the definition of low fat intake reported in the recent systematic review by the American Diabetes Association, which might improve glycemic control, total cholesterol and low-density lipoprotein (LDL) cholesterol, but might also lower high-density lipoprotein (HDL) cholesterol[26]. However, the JDCS patients and Western type 2 diabetic patients had similar HDL cholesterol levels (1.4 mmol/L and 1.1–1.2 mmol/L, respectively)[3,4], which is probably a result of the fact that the serum level of HDL cholesterol is naturally higher in East Asians than in Western populations.

The proportions of protein, fat and carbohydrate as percentages of energy supply in the JDCS patients were similar to those reported in elderly Japanese type 2 diabetic patients (fat/carbohydrate: 25.6/59.0%)[2], the general Japanese population (25.8/59.3%)[27], and a comprehensive picture of the pattern of the country's food supply reported in the FAO Balance Sheet (27.3/59.5%)[7]. Furthermore, according to the report of the FAO in 1996[7], fat and carbohydrate as percentages of energy supply in the USA, European region, Spain, Korea, and South Africa were 34.5/53.1%, 33.5/54.4%, 39.5/47.5%, 20.0/68.9%, and 22.0/67.7%, respectively. Thus, the proportions of protein, fat and carbohydrate consumed by diabetic patients in each country were similar to those reported in the FAO Balance Sheet, which reflects dietary patterns for each country[7]. As well as in these countries, it can be estimated that Japanese type 2 diabetes patients' 'low-fat energy-restricted diet' is deeply ingrained in the ethnic-specific dietary pattern of Japan.

As a protein source, consumption of fish and soybean products was larger than that of meat and eggs, and this pattern was similar without regard to sex, age, intensity of physical activity during work, HbA1C level and diabetes duration. These results imply that dietary content and food patterns among Japanese patients with type 2 diabetes were quite close to those in Western countries that have been reported as decreasing the risk of obesity[28], type 2 diabetes[29] and mortality as a result of cardiovascular disease[29], which is known to be higher in Western countries than in Japan. Conversely, the American Diabetes Association noted that soy-derived supplements were not associated with a significant reduction in glycemic measures or risk factors for cardiovascular disease, and that there is limited evidence in relation to protein sources[26].

Table 4 | Summary of literature on dietary composition of diabetic patients including the current Japanese Diabetes Complications Study results

Study name or author	Method for measurement of dietary intake	Years carried out	Study population	Type of diabetes	No. participants (No. men)	Mean age (years)†	Energy intake (kcal)†	Carbohydrate intake (% energy)†	Fat intake (% energy)†	BMI†
Present study (JDCS)	FFQg	1996	Japanese	Type 2 diabetes	1,516 (805)	M: 58.4 W: 59.0	M: 1,819 W: 1,643	M: 53.0 W: 54.2	M: 26.7 W: 28.7	M: 22.7 W: 23.2
EURODIAB IDDM Complications Study Group[6]	3-day record	NA	European	IDDM	2,868 (1458)	33	M: 2,202 W: 1,604	M: 43.1 W: 41.9	M: 37.9 W: 37.9	M: 26 W: 28
	7-day food diaries	1993–1994	Spanish	Type 1 diabetes,	144 (70)	M: 25.0 W: 27.1	M: 2,217 W: 1,623	M: 39.5 W: 40.0	M: 41.5 W: 40.5	M: 22.4 W: 23.2
DNCT[3]				Type 2 diabetes	193 (81)	M: 62.2 W: 62.5	M: 1,788 W: 1453	M: 39.0 W: 38.0	M: 38.5 W: 36.0	M: 25.8 W: 28.5
Strong Heart Study (SHS)[5]	24-h dietary recall	1997–1999	American Indians	Diabetes	1,008 (316)	M: 63.5 W: 63.5	M: 1,595 W: 1,422	M: 48.7 W: 48.7	M: 35.3 W: 35.9	M: 30.6 W: 32.8
NHANES[5]	24-h dietary recall	1999–2000	General US population	Diabetes	373 (190)	M: 64.9 W: 65.3	M: 1,852 W: 1,384	M: 48.4 W: 49.8	M: 34.7 W: 33.8	M: 30.5 W: 32.8
Diabetic Educational Eating Plan study[4]	7-day dietary recall	2005–2006	Clinical trial participants in USA White 85%, Black 5%, Asian 5%, other 5%	Type 2 diabetes	40 (19)	53.5	1,778	36.7	44.6	35.8 <25 5.0% 25–30 17.5% ≥30 77.5%
Lee *et al.*[20]	24-h dietary recall	2003–2004	Korean	Type 2 diabetes	154 (78)	61	M: 1,788 W: 1,546	M: 66.7‡ W: 68.4‡	M: 16.3‡ W: 16.2‡	M: NA W: NA
Kamada *et al.*[2]	FFQg	2001	Japan	Type 2 diabetes	912 (417)	M: 71.4 W: 72.3	M: 1,802 W: 1,661	M: 59.5 W: 58.6	M: 25.4 W: 25.8	M: 23.5 W: 24.0
Nthangeni *et al.*[21]	24-h dietary recall	1998	South African	Type 2 diabetes	290 (133)	<40§	M: 1,971¶ W: 1,712¶	M: 66.7 W: 65.8	M: 13.4 W: 14.4	M: ≥30 15.8% W: ≥30 40.8%

BMI, body mass index; DNCT, Diabetes Nutrition and Complications Trial; EURODIAB IDDM, European Diabetes Centers Study of Complications in Patients with Insulin-Dependent Diabetes Mellitus; IDDM, insulin-dependent diabetes mellitus; JDCS, Japan Diabetes Complications Study; M, men; NA, not available; NHANES, National Health and Nutrition Examination Survey; SHS, Strong Heart Study; W, women. †Maximum value and minimum value are shown if mean value was not available. ‡Estimated from mean value. §Age range was described because mean age was not reported. ¶1 kcal = 4.184 kJ.

Further studies are required to clarify whether glycemic control and risk of cardiovascular disease are affected by soy consumption and other protein sources over a long time period.

Furthermore, 73% of the JDCS patients met the recommendations for saturated fatty acid (SFA) intake (<7% of energy intake[18,19]), and their mean SFA intake was lower than those of Western type 2 diabetes participants (7.9% and 11.2–14.5%, respectively)[3–5].

Just 15% of the JDCS patients ingested 20 g or more of fiber per day, and their mean fiber intake (14.7 g/day) was similar to that of Western type 2 diabetes participants (11.4–20.5 g/day)[3–5] and the general Japanese population (15.7 g/day)[27]. More fiber consumption is recommended for JDCS patients, because it was reported that a high intake of dietary fiber improved fasting plasma glucose and HbA1c values in patients with type 2 diabetes in randomized crossover studies[26]. Increasing fiber intake is recommended to keep diabetes under good control.

The JDCS patients consumed excess sodium, and their mean sodium intake was 4.2 g/day. Thus, their mean sodium intake was lower than in the general Japanese population (4.6 g/day)[27], and higher than in the USA and UK general populations (3.6 and 3.4 g/day, respectively)[30], and a diabetic population in the USA (2.5–3.4 g/day)[5]. High sodium intake directly increases the risk of stroke, and the risk of stroke is decreased by 6% for each 1.15-g/day reduction in sodium intake[31]. Given a 1.15 g/day sodium reduction in JDCS patients, which would result in a sodium intake equal to that in Western diabetes patients, it could be expected that the morality risk of stroke in JDCS patients would be reduced from 7.5 per 1,000 patient-years[32] to 7.0 per 1,000 patient-years.

The present study had several limitations. First, the survey data were collected in 1996, 17 years ago. However, according to results of the National Health and Nutrition Survey[22] in 1996 and 2006, energy intake was slightly decreased (50–100 kcal/day) from 1996 to 2006, and the proportions of fat and carbohydrate did not differ greatly as reported in the FAO Balance Sheet (in 1996: 27.3/59.5%, 2006: 28.7/58.1%, respectively)[7]. Additionally, the characteristics of energy intake and nutritional and food intake by the JDCS patients differed very little between patients <60 years and those aged 60 years or over.

Second, inaccuracies in participants' reported dietary composition on the self-recording questionnaire are possible. Previous data show that being a woman, being obese or desiring to reduce bodyweight are factors related to the likelihood of underreporting energy intake[33]. However, the Japanese type 2 diabetic patients had a much lower BMI compared with Western patients[8]. An additional limitation is that just 74.5% of participants completed the FFQg, and their characteristics were slightly different from those who did not complete the FFQg; therefore, the differences between those who did and did not complete the questionnaire could have potentially influenced the cross-study comparisons of dietary intake. Finally, the method of dietary assessment for type 2 diabetes patients was different in each study that we examined. Establishment of a method that would allow a more direct country-by-country comparison is required.

In conclusion, we clarified that Japanese with type 2 diabetic patients had a 'high-carbohydrate low-fat' diet in comparison with Western diabetic patients, but had an energy intake similar to Western patients with diabetes. Furthermore, the proportions of protein, fat, and carbohydrate consumption and food intake were also quite close to the food pattern that has been traditionally recommended in Western countries.

The present study was a descriptive epidemiological examination to elucidate the actual dietary intake among Japanese middle-aged patients with type 2 diabetes who participated in a nationwide cohort study, and to compare findings with those of Western diabetic patients. Thus, we could not establish a cause–effect model between the risk of diabetes complications and the characteristics of food or nutritional intake, although medical nutritional therapy is an essential constituent for diabetes management.

However, the mean BMI of the JDCS patients was within normal range, whereas the BMI in the Western diabetic patients was higher, even though energy intake in both groups was similar. Additionally, the features of energy intake, and nutritional and food intake also did not differ greatly among the JDCS patients regardless of the differences in sex, age, intensity of physical activity during work, HbA1C level and diabetes duration.

It is possible that the difference in the dietary pattern and ethnic-specific characteristics, such as those related to body fat, prominent abdominal obesity and insulin deficiency and resistance, between Asian and Western people would result in different effects from medical nutritional therapy. Considering ethnic-specific dietary patterns and characteristics is important to explore effective medical nutritional therapy.

Based on preliminary findings, more research is required to survey how food and nutritional intakes among Asian type 2 diabetes patients are associated with the risk of development of diabetic complications, and results should be compared with those in Western patients.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Relationship between chewing ability and sarcopenia in Japanese community-dwelling older adults

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Aim: It has been reported that if nutrient intake is unbalanced, muscle mass, muscle strength and physical performance declines, and therefore it is important to maintain chewing ability to keep a balanced nutrient intake. However, the relationship between chewing ability and sarcopenia has not been previously reported. Therefore, the present study investigated the relationship between chewing ability and sarcopenia in addition to known sarcopenia-related factors.

Methods: We examined 761 participants (average age 73.0 ± 5.1 years), who lived in the Itabashi city of Tokyo. Our research was designed to examine the relationship between chewing ability and sarcopenia. We carried out regression analysis to analyze the relationship with sarcopenia-related factors with consideration of the age of the participants.

Results: The 761 participants were divided into two groups in terms of the stage of sarcopenia according to whether there was a deterioration of muscle strength or physical performance. Furthermore, we carried out logistic regression analyses on the value as a dependent variable, including known sarcopenia-related factors. There were significant correlations of sarcopenia with age (odds ratio 2.37, 95% confidence interval 1.52–3.70), body mass index (odds ratio 0.75, 95% confidence interval 0.69–0.81) and chewing ability (odds ratio 2.18, 95% confidence interval 1.21–3.93).

Conclusions: The present study shows that chewing ability is related to sarcopenia, which is equal to the relationship with the known factor of age by odds ratio. **Geriatr Gerontol Int 2014; ••: ••–••.**

Keywords: chewing ability, color-changeable gum, community, elderly, sarcopenia.

Introduction

Sarcopenia, defined as the degenerative loss of skeletal muscle mass, has recently been considered to result from a decline in muscular strength.[1,2] It has been reported that the age-related loss of skeletal muscle mass leads to a decline in activities of daily living (ADL) in older adults, leading to difficulties in maintaining their quality of life (QOL). Studies have shown that if nutrient intake is unbalanced, muscle mass, muscle strength and physical performance declines,[3] and it is important to maintain chewing ability to keep a balanced nutrient intake.[4,5] Enjoying meals is one of the most important factors to support the QOL of senile older adults, and it is also important to maintain and promote their health.[6,7]

Several studies have reported on the relationship between chewing ability and grip strength/physical performance,[8,9] and on the relationship between tongue muscle thickness and sarcopenia,[10] but there have been no reports addressing the possible relationship between chewing ability and sarcopenia.

Therefore, we carried out this research on Japanese community-dwelling older adults, and investigated the relationship between chewing ability and sarcopenia in addition to known sarcopenia-related factors.

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Methods

Participants

The Tokyo Metropolitan Institute of Gerontology (TMIG) sent invitations for a comprehensive geriatric

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health examination for early detection and early care of geriatric syndrome to 7015 male and female older adults aged from 65 to 85 years who lived within nine towns in Itabashi city (Tokyo, Japan), excluding nursing home residents and those who had participated in our previous interventional research studies. Among them, 1325 people offered to attend and 835 people actually attended. Excluding withdrawals due to the terms of our research, and also exclusions of missing values due to people with heart pacemakers and/or walking difficulties, the data of 761 participants were analyzed in the present study.

This research was carried out at the TMIG from 25 September 2012 to 5 October 2012. The participants attended by walking, driving or being driven by family members, or by using public transportation, and furthermore, they were able to understand and follow our instructions. We received written informed consent from each participant individually. This research was carried out with permission of the TMIG Ethics Committee (Issue #.23–1253 in 2011).

Stages of sarcopenia

The guidelines of the European Working Group on Sarcopenia in Older People (EWGSOP) were used to classify the severity of sarcopenia (stage of sarcopenia [SSp]) according to muscle mass (skeletal muscle mass measured by bioelectrical impedance analysis [BIA]), muscle strength (grip strength) and physical performance (usual walking speed).[11] In addition, participants were classified by SSp into a healthy and presarcopenia group in which declines in muscle strength or physical performance were not observed (maintenance group [MG]), or into a sarcopenia and severe sarcopenia group in which declines in muscle strength or physical performance were significant (decline group [DG]). The cut-off value was according to the method established by the Asian Working Group for Sarcopenia (AWGS).[12]

General evaluation

Height

Each participant was advised to keep their heels, buttocks, back and head touching the stadiometer. Making sure that their neck, waist and knees were straight, their height was measured per 0.1 cm.

Weight

Each participant was advised to stand on a weight scale quietly, and the stable value of their weight was measured per 0.1 kg.

Skeletal muscle mass index

Body composition was measured with BIA using an InBody720 (Bio Space, Seoul, Korea), and extremity muscle mass (kg) was determined from the sum of the upper and lower extremities. We divided the measured extremity muscle mass by the squared height (m conversion), and the adjusted extremity muscle mass was used as the skeletal muscle mass index (SMI). We used the standard value set by the AWGS, which is less than 7.0 kg/m^2 for men and less than 5.7 kg/m^2 for women for the SMI cut-off value of sarcopenia.[12]

Nutrition evaluation

The body mass index (BMI) was measured as an indicator of the nutritional status of each participant. We divided the measured extremity height (m), and the weight was used as the BMI.

Physical function evaluation

Physical function was measured following the functional improvement manual issued by the Ministry of Health, Labor and Welfare.[13]

Grip strength

Grip strength was used as an indicator of muscle strength, and was measured using a Smedley dynamometer (As one, Osaka, Japan). Measurements were carried out twice, and the higher value was used.[14,15] The cut-off value of grip strength was set as the lowest of quartile value, according to the method of the AWGS, which is less than 26.0 kg for men and less than 18.0 kg for women.[12]

Usual walking speed (walking ability)

Participants walked along a walking path with a 3-m acceleration zone, a 5-m measurement zone and a 3-m deceleration zone, and the time each participant's feet were in the swing phase (the foot apart from the ground) was measured from the start-point of the measurement zone to the end-point of the measurement zone. Measurements were taken twice, and the faster time was used in the analysis. The cut-off value of the walking speed was set as the lowest of quartile value, according to the method of the AWGS, which is less than 1.0 m/s.[12]

Oral examination

Oral examinations were carried out by two dentists and five dental hygienists who had standardized their methods before the study.

Table 1 Basic attributes of Japanese community-dwelling older adults

		Total (n = 761) Mean ± SD	Male (n = 314) Mean ± SD	Female (n = 447) Mean ± SD	P-value
Age (years)		73.0 ± 5.1	73.7 ± 5.5	72.6 ± 4.9	0.011 (u)
BMI (kg/m^2)		22.9 ± 3.3	23.7 ± 3.1	22.4 ± 3.3	<0.001 (u)
SMI (kg/m^2)		6.5 ± 1.0	7.3 ± 0.9	5.9 ± 0.6	<0.001 (u)
Grip strength (kg)		24.3 ± 8.2	31.2 ± 7.1	19.4 ± 4.7	<0.001 (u)
Usual walking speed (m/s)		1.4 ± 0.2	1.4 ± 0.2	1.4 ± 0.3	0.689 (u)
No. existing teeth		19.9 ± 8.9	19.0 ± 9.4	20.5 ± 8.6	0.040 (u)
No. functional teeth		27.0 ± 3.0	26.8 ± 3.5	27.1 ± 2.6	0.386 (u)
Occlusal force (N)		529 ± 342	576 ± 383	497 ± 305	0.011 (u)
Chewing ability	Good	85.8 = 653/761	87.6 = 275/314	84.6 = 378/447	0.241 (χ^2)
	Poor	14.2 = 108/761	12.4 = 39/314	15.4 = 69/447	
Stages of sarcopenia	MG	84.8 = 645/761	86.0 = 270/314	83.9 = 375/447	0.429 (χ^2)
	DG	15.2 = 116/761	14.0 = 44/314	16.1 = 72/447	

Values are mean ± standard deviation. Chewing ability (divided the color changes of color-changeable gum into 5 stages, 1 and 2 with less color change into "Poor," and 3, 4 and 5 with more color change into "Good"). χ^2, χ^2-test; BMI, body mass index; DG, decline group; MG, maintenance group; SD, standard deviation; SMI, skeletal muscle mass index; u, Mann–Whitney U-test.

Chewing ability

A color-changeable chewing gum (masticatory performance evaluating gum Xylitol; Lotte, Saitama, Japan) was used to examine chewing ability. After chewing the gum for 1 min, the participant spat the gum on a piece of white paper, and the gum was analyzed with a color chart into five levels by testers.[16] Levels 1 and 2, which were approximately the lowest of quartile value, were classified as "poor," and levels 3, 4 and 5 were classified as "good".

Number of existing teeth

The number of existing intraoral erupted teeth was counted, excluding the residual roots.

Number of functional teeth

The number of prosthetic treatment bridges, plate dentures (removal dentures), implants (artificial roots) of defect sites and the number of existing teeth were counted.

Occlusal force

An occlusal force measurement system film was used, Dental Prescale 50H Type R (Fuji Photo Film, Tokyo, Japan) and an Occuluser (Fuji Photo Film). Following the method of Matsui *et al.*,[17] each participant sat on a chair, making sure that the Frankfurt horizontal plane and the floor were as parallel as possible, and then was asked to bite down on the prescale at the intercuspal position as hard as possible.[17] Occlusal force was measured in newtons (N).

Statistical analysis

The Mann–Whitney U-test was carried out to assess differences between continuous variables in the two groups. For the categorical variable, the χ^2-test was used. Logistic regression analysis was used for the purpose of researching factors related to DG. All statistical analyses were carried out using SPSS20.0J for Windows (IBM, Armonk, NY, USA), and a risk ratio of less than 5% was considered a significant difference.

Results

Basic attributes of the participants

The basic attributes of the participants in the present study are shown in Table 1. There were 761 participants (mean age 73.0 ± 5.1 years), 314 men (mean age 73.7 ± 5.5 years) and 447 women (mean age 72.6 ± 4.9 years). Women had higher values for the number of existing teeth (P = 0.040). Men had higher values for age (P = 0.011), BMI (P < 0.001), SMI (P < 0.001), grip strength (P < 0.001) and occlusal force (P = 0.011).

The rate of MG and DG of SSp was: men 14.0% and women 16.1%. However, the percentage of DG was not significantly different between men and women.

SSp comparisons

Comparisons of each variable between MG and DG of SSp are shown in Table 2. The ages of the participants were higher with DG (P < 0.001). BMI (P < 0.001), SMI (P < 0.001), grip strength (P < 0.001), usual walking speed (P < 0.001), number of existing teeth (P < 0.001), occlusal force (P < 0.001) and chewing ability

Table 2 Comparison between stage of sarcopenia and each factor

$n = 761$		MG Total (645) Mean ± SD	Men (270) Mean ± SD	Women (375) Mean ± SD	DG Total (116) Mean ± SD	Men (44) Mean ± SD	Women (72) Mean ± SD	*P*-value
Age (years)		72.6 ± 5.0	73.0 ± 5.2	72.3 ± 4.8	75.7 ± 5.2	77.9 ± 4.9	74.4 ± 4.9	<0.001 (u)
Early elderly		64.2 = 414/645	61.1 = 165/270	66.4 = 249/375	42.2 = 49/116	20.5 = 9/44	55.6 = 40/72	<0.001 (χ^2)
Late elderly		35.8 = 231/645	38.9 = 105/270	33.6 = 126/375	57.8 = 67/116	79.5 = 35/44	44.4 = 32/72	
BMI (kg/m^2)		23.3 ± 3.2	24.0 ± 3.1	22.8 ± 3.3	20.9 ± 2.7	21.6 ± 2.1	20.4 ± 2.9	<0.001 (u)
SMI (kg/m^2)		6.6 ± 1.0	7.5 ± 0.9	6.0 ± 0.6	5.7 ± 0.7	6.4 ± 0.5	5.2 ± 0.4	<0.001 (u)
Grip strength (kg)		25.6 ± 8.1	32.9 ± 6.1	20.3 ± 4.4	17.1 ± 4.5	21.1 ± 3.7	14.7 ± 3.0	<0.001 (u)
Usual walking speed (m/s)		1.4 ± 0.2	1.4 ± 0.2	1.4 ± 0.2	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	<0.001 (u)
No. existing teeth		20.3 ± 8.8	19.8 ± 9.2	20.7 ± 8.5	17.5 ± 9.4	13.7 ± 9.1	19.8 ± 8.9	<0.001 (u)
No. functional teeth		27.0 ± 2.9	26.9 ± 3.5	27.1 ± 2.4	26.7 ± 3.6	26.4 ± 4.0	26.9 ± 3.4	0.693 (u)
Occlusal force (N)		551 ± 347	610 ± 388	509 ± 308	407 ± 280	368 ± 276	431 ± 282	<0.001 (u)
Chewing ability	Good	88.7 = 572/645	8.9 = 24/270	86.9 = 326/375	69.8 = 81/116	65.9 = 29/44	27.8 = 20/72	<0.001 (χ^2)
	Poor	11.3 = 73/645	91.1 = 246/270	13.1 = 49/375	30.2 = 35/116	34.1 = 15/44	72.2 = 52/72	

Value are mean ± standard deviation. Early elderly aged less than 75 years; late elderly aged more than 75 years; chewing ability (divided the color changes of color-changeable gum into 5 stages, 1 and 2 with less color change into "poor," and 3, 4 and 5 with more color change into "good"). χ^2, χ^2-test; BMI, body mass index; DG, decline group; MG, maintenance group; SD, standard deviation; SMI, skeletal muscle mass index; u, Mann–Whitney *U*-test.

Table 3 Examination of relationship between various items and Sarcopenia

	OR	95% CI	*P*-value
Age (early elderly = 0, late elderly = 1)	2.37	(1.52–3.70)	<0.001
BMI (/kg/m^2)	0.75	(0.69–0.81)	<0.001
No. existing teeth (/tooth)	1.01	(0.98–1.04)	0.523
Occlusal force (/N)	1.00	(1.00–1.00)	0.007
Chewing ability (good = 0, poor = 1)	2.18	(1.21–3.93)	0.010

Logistic regression analysis dependent variable: cut-off stage of sarcopenia at maintenance group and decline group. Independent variable: Age, BMI, number of existing teeth, Occlusal force and Chewing ability. Early elderly aged less than 75 years; late elderly aged more than 75 years. BMI, body mass index.

($P < 0.001$) declined in participants with DG. Among patients aged less than 75 years, 10.6% had DG. Among participants aged more than 75 years, 22.5% had DG ($P < 0.001$).

Logistic regression analysis

The results of the logistic regression analysis are shown in Table 3. The dependent variable was 0 for MG and 1 for DG. As a result, age, BMI, number of existing teeth, occlusal force and chewing ability were selected as independent variables. Age (OR 2.37, 95% Cl 1.52–3.70), BMI (OR 0.75, 95% Cl 0.69–0.81) and chewing ability (OR 2.18, 95% Cl 1.21–3.93) were significant factors of sarcopenia.

Discussion

There have been many reports about sarcopenia, regarding the concept of the frail model proposed by Fried *et al.*[18] It has been reported that sarcopenia decreases the ADL of older adults, makes it difficult to maintain their QOL,[1,2] and it is important to intake a good balance of nutrition to prevent a decline in muscle mass, muscle strength and physical performance.[3] It has been reported that it is essential to maintain the ability to chew to keep a good balance of nutrient intake.[4,5] From these understandings, a strong relationship between chewing ability and sarcopenia has been inferred, but this hypothesis has not been previously tested. Thus, in the present study, we examined the relationship between chewing ability and sarcopenia in addition to known sarcopenia-related factors.

The prevalence of severe sarcopenia in the present study was 5.6% (42 participants), 12.8% (96 participants) had sarcopenia and 22.5% (169 participants) had presarcopenia. Three factors of EWGSOP, muscle mass, muscle strength and physical performance, were used as a concept of sarcopenia in the present study. This EWGSOP consensus guide is used worldwide as diagnostic criteria of sarcopenia intended to unify views of the definition of sarcopenia.[11] However, the basic value of EWGSOP is targeted for white and black subjects in the USA and Europe. Therefore, it is difficult to apply that standard to physically different Japanese people.[19] We classified sarcopenia according to cut-off values, and basic values of SMI, grip strength and usual walking speed targeted for Asian people by the AWGS.[12] In addition, the BMI significantly decreased in the DG group. Several studies have reported that the BMI significantly decreases in subjects with sarcopenia, and as we obtained similar results in the present study, we believe that our research results are valid.[20]

A color-changeable chewing gum was used to evaluate chewing ability. With this evaluation method, the chewing ability of each participant can be evaluated easily and in a short amount of time, and it has been correlated with other chewing ability evaluation methods.[21] One previous study reported that results from color charts, like the one used in our study, correlated well with results using a color difference meter.[16] We used the same cut-off value for chewing ability as the lowest quartile used for the cut-off value for grip strength and walking speed established by the EWGSOP.[11] As a result, out of five stages of chewing ability, it was matched with the lowest quartile, by setting 1 and 2 as "poor," and the percentages as 14.1%. In a previous study with a color-changeable chewing gum, the percentages of "poor" were similar to the present results, and this supports the validity of our results.[22]

To make SSp the dependent variable, we set the cut-off value between presarcopenia and sarcopenia. This is because it is considered that not only a decline in muscle mass, but also declines in muscle strength and physical performance exist in the stage between presarcopenia and sarcopenia. It is considered to be a turning point of the decline in the QOL of older adults, as it has been reported that a decline in muscle strength of the knees and ankles are related to the balance ability of the extremities in daily life and a decline in walking speed.[23] It has also been reported that a decline in general function can be a predictive factor for the worsening of health status.[24]

We carried out a logistic regression analysis on sarcopenia-related factors, which confirmed that sarcopenia is related to age and BMI, similar to previous reports.[20] Depressed metabolism and depressed appetite could be caused by a decline in general function. It was considered that if daily nutritional intake is lacking, a negative cycle of decline in BMI, muscle mass and general function occurs.

The present study showed that there is a relationship between chewing ability and sarcopenia. Three factors of EWGSOP; muscle mass, muscle strength and physical performance, were used for the concept of sarcopenia in the present study. There have been many reports of the relationship between these three factors, and age and nutrition.[2,3] It has also been reported that both muscle strength and physical performance have a relationship with chewing ability. Moriya *et al.* reported the relationship between chewing ability and grip strength regardless of the number of existing teeth.[9] Takata *et al.* also reported the relationship between chewing ability and general function regardless of the number of existing teeth.[8] There has been no report about the relationship between general muscle mass and chewing ability, whereas there have been reports about the relationship between chewing ability related tongue thickness and brachial muscle mass.[10] Many muscles related to sarcopenia components, muscle strength and physical performance are antigravity muscles, and it was reported that a decline in the strength of antigravity muscles occurs all over the body.[25] As many muscles related to chewing ability are classified as antigravity muscles, it is considered that a decline in muscle strength occurs simultaneously.[26] It has been also reported that a decline in muscle mass causes a decline in muscle strength, and the decline in muscle strength then causes atrophy of muscles and a decline in function.[27] From these studies, it was considered that the reason for a notable relationship between chewing ability and sarcopenia in consideration of age and nutrition could be related to changes in general muscle mass and muscle mass related to chewing ability. In addition, it was seen that occlusal force and number of existing teeth have a relationship with occlusal function, but not directly with sarcopenia. Unlike a single evaluation index, such as occlusal force or number of teeth, occlusal function is a global evaluation index related with muscle of mastication, tongue, teeth and nerves. Similarly, sarcopenia is globally evaluated from muscle mass, muscle strength and general function, therefore, it could be considered that this is the background of why the relationship with sarcopenia was seen.[28]

The present research showed a relationship between chewing ability and sarcopenia, which will be meaningful to consider solutions to suppress sarcopenia in older adults in terms of dentistry in the future.

The present study had several limitations. First, the participants in this study actively attended a geriatric health examination, thus they are possibly highly conscious of their health, and can walk by themselves or attend the examination with assistance, and therefore they are a highly independent group. Therefore, these research findings might not apply to less independent groups. Second, the present study was cross-sectional, and did not prove a causal relationship between sarcopenia and chewing ability in consideration of time-course changes.

In the present study, we examined whether chewing ability is related to sarcopenia, but it could be considered that chewing-related muscle function declines as a result of sarcopenia, and leads to the aggravation of chewing ability. In addition, it could be considered that a lower amount or less quality of muscle of mastication leads to a decline in chewing ability. More details on the causal relationship need to be determined through longitudinal research and intervention research in the future.

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Disclosure statement

None of the authors has a conflict of interest to declare.

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