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RESEARCH ARTICLE

The Nutritional Characteristics of the Hypotensive WASHOKU-modified DASH Diet: A Sub-analysis of the DASH-JUMP Study

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Abstract: ***Background***: We developed a WASHOKU-modified DASH diet named DASH-JUMP. We previously reported the hypotensive effect of the DASH-JUMP diet in Japanese participants with untreated high-normal Blood Pressure (BP) or stage 1 hypertension.

Objective: We aim to introduce the DASH-JUMP diet worldwide as a new lifestyle medicine. Accordingly, we prospectively assessed the nutritional characteristics of the DASH-JUMP diet.

Methods: Participants were treated with the DASH-JUMP diet for 2 months. Then, for 4 months after the intervention, they consumed their usual diets. We conducted a nutritional survey using the FFQg nutrient questionnaire at baseline and after 1, 2, 3, and 6 months. We received completed questionnaires from 55 participants (28 men and 27 women; mean age 54.2 ± 8.0 years) and analyzed them.

Results: The DASH-JUMP diet is rich in green-yellow vegetables, seaweed, milk, and mushrooms, while it has low contents of meat, eggs, confectionery, oils and fats, pickles, shellfish boiled in sweetened soy sauce, and fruits. Nutrients significantly associated with the observed change in systolic BP were niacin (P = 0.005) and carbohydrate (P = 0.033). The results of the FFQg questionnaire revealed that participants who had an increased BP at 1 month after ceasing the intervention had eating habits that broadly imitated the DASH-JUMP diet at 4 months after ceasing the intervention. Therefore, the systolic and diastolic BP values at 4 months after ceasing the intervention decreased significantly compared to those at baseline.

Conclusion: The DASH-JUMP diet may represent a new lifestyle medicine for reducing hypertension.

Keywords: Blood pressure, Japanese, nutrient, food, WASHOKU, DASH-JUMP.

1. INTRODUCTION

In Japan, salt restriction has been recommended by the Japanese Society of Hypertension as a dietary measure for the prevention and improvement of hypertension [1-3]. A high frequency of salt-sensitive alleles was reported in the Japanese population [4] and salt restriction has been demonstrated to stabilize Blood Pressure (BP) [5]. The Guidelines for the Management of Hypertension (JSH2014) by the Japanese Society of Hypertension set a target for restricting salt intake to less than 6 g/day [6]. The Dietary Reference Intakes for Japanese (2015) recommend a salt intake of less than 7.5 g/day [7]. According to changes in the average salt intake of the Japanese population [8], it takes 10 years to achieve 1 g of salt restriction. It is increasingly important to prevent hypertension since Japan has become a super-aged society compared with other countries, and hypertension is associated with Cardiovascular Disease (CVD) that will reduce healthy life expectancy. Therefore, our collaborative investigative team recommended salt restriction. We aimed to design low-salt menu choices to help people who normally struggle to comply with a salt-free diet to receive hypertension prevention information. Traditional Japanese foods have been introduced as healthy dietary choices to

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prevent CVD in Western countries, and their effectiveness has been evaluated in scientific studies [9]. The Japanese population consumes rice as a main staple, and Japanese foods are often seasoned with a soup stock made from kombu kelp and shiitake mushrooms. Common Japanese cooking ingredients include fermented products such as miso, soy sauce, and vinegar, as well as marine products, which are readily available around the coastlines of Japan. Our collaborative investigative team studied the DASH (Dietary Approaches to Stop Hypertension) diet, which has been used as a part of hypertension prevention strategies outside of Japan and developed a revised version (the DASH-JUMP diet: DASH-Japan Ube Modified diet Program) by adapting traditional Japanese foods. We previously evaluated the effects of the DASH-JUMP diet on cardiovascular parameters as well as fat and carbohydrate metabolism [10]. In the present study, we aimed to evaluate the nutritional characteristics of the DASH-JUMP diet *via* a prospective analysis to further assess its potential as a new lifestyle medicine for reducing hypertension.

2. MATERIALS AND METHOD

2.1. Study Design

The DASH-JUMP study was designed as an open-label single-arm cohort study. The study was performed in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Yamaguchi University Faculty of Medicine and Health Sciences. The detailed protocol of the DASH-JUMP study was previously reported [10]. This study included 60 participants (31 men and 29 women) aged 36–69 years who were not taking antihypertensive medication. They had a mean systolic BP (SBP) between 130–159 mmHg, or a mean diastolic BP (DBP) between 85–99 mmHg, or both. Participants were treated with DASH-JUMP (8 g salt/day) for 2 months and consumed their usual diets for the next 4 months following cessation of the intervention [10]. To conduct the research safely and reliably, research briefing sessions were held for the participants after the recruitment phase. The nutritional components, home delivery method, cooking methods, and intake schedule of the DASH-JUMP menu items were explained. Participants were advised to eat all the foods delivered to their homes, avoid eating between meals, and not change their established habits before the study commenced.

A pamphlet was provided to the participants, which detailed the methods for cooking the ingredients delivered with photographs of the meals. In particular, the microwave oven cooking times required to produce meals with a chewy texture to promote satiety were specified. If it was a normal diet, we would provide nutritional education about the importance of controlling caloric intake for the participants, but we did not conduct special nutritional education in this study. After we explained how to perform sphygmomanometry according to the methods recommended in the Guidelines for the Management of Hypertension (JSH2009) and the Guidelines for Self-monitoring of Blood Pressure at Home Second Edition by the Japanese Society of Hypertension [11], all participants demonstrated an ability to measure their own BP at home.

2.2. Physicochemical Analysis of DASH-JUMP Menu Items

The nutritional contents of each menu item were evaluated during the menu design phase of the DASH-JUMP diet. After cooking the various DASH-JUMP menu items, they were frozen for 1 month and then pulverized with a mixer, and a physicochemical analysis was performed. Dietary fiber content was analyzed at the Japan Food Research Laboratories (Tokyo, Japan), while all other nutritional components were analyzed by Maruha Nichiro Co., Ltd. (Tokyo, Japan). Energy content was calculated based on the Atwater coefficient [12]. Carbohydrate content was calculated using a subtraction method. An atmospheric pressure heat-drying method (105 °C) was used for moisture analysis [13]. Protein content was determined using the Kjeldahl method [14]. Lipid content was analyzed using an acid decomposition method, as the foods contained moisture or lipids bonded to other ingredients. Ash content was analyzed using a dry ashing method [15]. Fatty acid and cholesterol contents were analyzed using a gas chromatographic method. For the analysis of sodium, potassium, and magnesium contents, atomic absorption photometry was performed [16].

2.3. Assessment of Dietary Intake

The Food Frequency Questionnaire (FFQ) developed by Willett *et al*. (1985) is a semi-quantitative dietary survey that is the most widely used method to assess food or nutrient intakes in dietary studies [17]. In Japan, some simple nutrient questionnaires have been developed and their reproducibility and validity have been evaluated [18]. In this study, we used the FFQg (the FFQ modified for use in Japan) to obtain daily records for evaluating the food groups and individual nutrients in the DASH-JUMP diet. The FFQg includes questions about 29 food groups and 10 cooking methods and assesses the daily intake frequency and total intake per week for each food group and cooking method [19]. FFQg data were analyzed to calculate the participants' average nutritional intake during the DASH-JUMP study at baseline, after 1 and 2 months of the intervention, and then 1 and 4 months after ceasing the intervention.

2.4. Statistical Analyses

Analyses were performed using SPSS version 21.0 for Windows (IBM, Armonk, NY, USA). Data were expressed as mean values ± SD. The changes in the nutritional profiles of the DASH-JUMP menu items before and after cooking and freezing for 1 month were compared using a two-group paired *t*-test, and P values < 0.05 were taken as significant. The intakes of individual food groups (grains, potatoes, green/yellow vegetables, light-colored vegetables, seaweed, beans, fishery products, meat, eggs, milk and other dairy products, fruit, confectionery, flavored drinks, sugar, nuts and seeds, oils and fats, seasonings/spices, mushrooms, pickles, shellfish boiled in sweetened soy sauces, alcoholic beverages, and non-alcoholic flavored beverages) and individual nutrients (energy, protein, lipid, carbohydrate, sodium, potassium, calcium, magnesium, phosphorus, iron, zinc, copper, manganese, retinol, alpha-carotene, beta-carotene, cryptoxanthin, vitamin D, tocopherol, vitamin K, vitamin B1, vitamin B2, niacin, vitamin B6, vitamin B12, folic acid, pantothenic acid, vitamin C, saturated fatty acid, monounsaturated fatty acid, polyunsaturated fatty acid, cholesterol, water soluble dietary fiber, insoluble dietary fiber, salt, *n*-3 polyunsaturated fatty acid, and *n*-6 polyunsaturated fatty acid) were compared by repeated-measures analysis of variance or Friedman's test as appropriate. Further, comparisons were made at each time point by post-hoc analysis using Friedman tests for multiple comparisons. The sodium/potassium ratio was calculated at each time point. The participants measured their own BP values twice per day; the first time within 1 h after getting up, after urination but before breakfast and morning dosing, and the second time before going to bed in the evening. They measured their BP in their own home while sitting on a chair with a support for the back without having the legs crossed and after 1–2 min rest. We analyzed their average BP values measured in the morning and evening at home. Participants were divided into two groups using the median baseline SBP (146.1 mmHg). The higher SBP group was denoted HSBP and the lower SBP group was denoted LSBP. The Mann–Whitney U-test was used to compare individual variables between the two groups.

The physical activity level of each participant was calculated using the "activity" score from the FFQg questionnaire. A multiple regression analysis was performed to identify whether individual nutrients and foods were related to the changes in BP during the DASH-JUMP diet. Differences were considered statistically significant at $P < 0.05$.

The changes in SBP and DBP from baseline to 2 months were used as dependent variables. The changes in individual nutritional intake parameters obtained from the results of the FFQg nutrition survey from baseline to 2 months were used as independent variables. The results of a multiple regression analysis showed that the change in body mass index was a significant independent predictor of the changes in SBP and DBP from baseline to 2 months. Therefore, a reduction in body mass index was independently associated with a decrease in BP [10]. The Guidelines for the Management of Hypertension by the Japanese Society of Hypertension (JSH2014) reported that BP was significantly decreased by a weight loss of ~ 4 kg (mean reduction of −4.5/−3.2 mmHg) or exercise [10]. Therefore, the changes in weight and physical activity from baseline to 2 months were added as independent variables, and the influences of weight loss, physical activity, and nutrient intake on BP were analyzed.

3. RESULTS

Fifty-eight participants returned FFQg questionnaires. Three participants did not answer all the questions and the missing answers were an obstacle to analysis; therefore, those participants were excluded. Completed FFQg nutrient questionnaires from 55 participants were analyzed. Table **1** shows the baseline characteristics of the study participants grouped by their BP values. The mean age of the participants was 54.2 ± 8.0 years. The results for the average nutritional intakes during the DASH-JUMP diet intervention period according to participants' daily records were as follows: energy: 1534 ± 96 kcal, protein: 77.5 ± 5.8 g, total fat: 29.5 ± 3.3 g, carbohydrate: 241 ± 17 g, fiber: 25 ± 2 g, sodium: 2718 ± 237 mg, salt: 6.9 ± 0.6 g, potassium: 3801 ± 255 mg, calcium: 1092 ± 115 mg, magnesium: 414 ± 26 mg, saturated fatty acid 5.8 ± 0.7 g, and cholesterol: 129 ± 24 mg.

3.1. Changes in the Nutrient Compositions of the DASH-JUMP Menu Items after Cooking

This study focused on analyzing the nutritional components of each DASH-JUMP diet menu item both during menu design and after cooking then freezing for 1 month.

Table 1. Baseline characteristics of the study participants grouped by their BP values.

Characteristic		HSBP	LSBP	*P*-value
n	-	28	27	-
Sex (male/female)	(male/female)	13/15	15/12	0.502**
Age	(years)	57.0 ± 7.4	51.3 ± 7.7	0.008**
Systolic blood pressure	(mmHg)	154.6 ± 8.1	139.4 ± 4.6	0.000**
Diastolic blood pressure	(mmHg)	89.3 ± 7.4	86.9 ± 6.5	0.145
Weight	(kg)	65.8 ± 13.2	67.2 ± 10.8	0.561
Physical activity level	(Af)	2.07 ± 0.52	1.99 ± 0.57	0.479
Estimated glemerular filtration rate	(mL/min)	85.7 ± 17.0	81.9 ± 12.8	0.556
Salt intake	(g)	9.6 ± 3.0	9.4 ± 3.3	0.880
Alcohol	(kcal)	81.9 ± 96.7	50.2 ± 86.3	0.328
Confectionery	(kcal)	295 ± 221	208 ± 141	0.162
Family history	(%)	57.1	48.1	0.508
Current smokers	(%)	21.4	7.4	0.144

The HSBP group had a higher SBP (≥ 146.1 mmHg) than the LSBP group (< 146.1 mmHg).

Table 2. The changes in the nutrient contents of the DASH-JUMP diet after cooking and preservation.

Nutrient Content (per day)	After Cooking, Freezing, and Preserving for 1 Month	⊿-value	*P*-value
Amount (g)	1754 ± 190	-35 ± 71	0.089
Energy (kcal)	1513 ± 54	-134 ± 43	0.000**
Protein (g)	85 ± 11	-2 ± 5	0.154
Total fat (g)	26 ± 6	-7 ± 5	0.000**
Carbohydrate (g)	234 ± 17	-18 ± 5	0.000**
Fiber (g)	28 ± 4	0 ± 3	0.736
Sodium (mg)	3013 ± 273	-32 ± 262	0.656
Salt (g)	7.7 ± 0.7	-0.1 ± 0.7	0.656
Potassium (mg)	4034 ± 425	-299 ± 334	0.005**
Calcium (mg)	1177 ± 236	-65 ± 104	0.036*
Magnesium (mg)	424 ± 56	-37 ± 32	0.001**
Fatty acid			
Total amount (g)	25.4 ± 6.1	-0.9 ± 5.4	0.540
Saturated fatty acid (g)	6.6 ± 2.2	0.2 ± 2.2	0.720
Monounsaturated fatty acid (g)	10.0 ± 2.8	0.1 ± 3.0	0.893
Polyunsaturated fatty acid (g)	8.8 ± 2.4	-1.2 ± 1.0	0.000**
Cholesterol (mg)	97.4 ± 32.8	-49.6 ± 36.7	0.000**

** indicates $P < 0.01$, * indicates $P < 0.05$, *P*-values were calculated by paired t tests.
⊿-value = the estimated nutrient contents during menu design minus the measured nutrient contents after cooking, freezing, and preservation for 1 month.

The contents of energy, total fat, carbohydrates, potassium, magnesium, polyunsaturated fatty acid, cholesterol, and calcium significantly decreased after cooking and freezing (Table **2**). The nutritional value of the menu items decreased after cooking and freezing, and we concluded that it was important for participants to also consume the broth into which the nutrients leached during cooking to ensure that all nutrients were consumed. At the research briefing session, the necessity of consuming the broth produced when cooking was explained to participants.

3.2. Association of Food Group and Nutrient Intakes with Changes in BP and Body Weight

Participants' intakes of individual food groups and their SBP, DBP, body weight, and physical activity at each time point are shown in Table **3**. The intakes of some food groups significantly decreased during the DASH-JUMP intervention, including those of oils and fats, meat, eggs, fruit, confectionery, pickles, and shellfish boiled in sweetened soy sauces. Alcohol intake was not significantly different but decreased during the intervention period. The DASH-JUMP diet also resulted in significant increases in participants' mean intakes of green/yellow vegetables, seaweed, mushrooms, and milk and other dairy products. Many of the DASH-JUMP menu items included carrots, broccoli, and/or green peppers, which are all included in the category of green/yellow vegetables. The menu items also frequently included mushrooms (shimeji and shiitake), seaweed (cut seaweed, laver, hijiki, and tangle shavings), and dairy products (nonfat milk, low-fat skim milk, and yogurt). The results of the FFQg at 4 months after ceasing the DASH-JUMP intervention indicated that participants retained high intakes of many of the foods that they ingested during the intervention period. In addition, BP was similar between 1 and 4 months after ceasing the intervention. There were no significant differences in physical activity among the tested time points during the study period.

The intakes of individual nutrients and the sodium/potassium ratio at each time point are shown in Table **4**. The intakes of α-carotene, β-carotene, vitamin K, and folic acid significantly increased, whereas those of energy, protein, lipid, sodium, zinc, retinol, cryptoxanthin, tocopherol, vitamin B 1・2, niacin, pantothenic acid, cholesterol, water-soluble dietary fiber, insoluble dietary fiber, and ω-3/6 polyunsaturated fatty acid significantly decreased during the DASH-JUMP intervention period. The sodium/potassium ratio decreased during the DASH-JUMP intervention and the ratio at 4 months after ceasing the intervention was similar to that after 2 months.

3.3. Multiple Regression Analysis

The change in SBP from baseline to 2 months as a dependent variable was significantly associated with the changes in the intake of niacin (β −0.701, P = 0.005), carbohydrate

Table 3. Changes of the nutritional intake according to the food during the study period of DASH-JUMP.

	Category	Baseline	After 1 Month	After 2 Months	1 Month after Ceasing Intervention	4 Months after Ceasing Intervention	*P* -value
1	Grains (kcal)	599 ± 206	643 ± 143	638 ± 115	608 ± 179	326 ± 130 †† ‡‡ §§ ¶¶	0.000
2	Potatoes (kcal)	18 ± 15	24 ± 20	21 ± 25	20 ± 15	27 ± 25	0.021
3	Green/yellow vegetables (kcal)	18 ± 10	33 ± 17 ††	26 ± 15	20 ± 10 ‡‡	84 ± 48 †† ‡‡ §§ ¶¶	0.000
4	Light-colored vegetables (kcal)	30 ± 15	34 ± 22	30 ± 17	29 ± 15	122 ± 72 †† ‡‡ §§ ¶¶	0.000
5	Seaweed (kcal)	1.5 ± 1.5	3.4 ± 2.4 ††	3.2 ± 2.9 ††	2.5 ± 2.1	6.0 ± 5.5 †† ‡‡ §§ ¶¶	0.000
6	Beans (kcal)	74 ± 48	106 ± 93	84 ± 58	94 ± 60	63 ± 45 ¶¶	0.009
7	Fishery products (kcal)	111 ± 70	105 ± 97	83 ± 58	112 ± 65	79 ± 46 † ¶¶	0.002
8	Meat (kcal)	186 ± 118	142 ± 162 ††	83 ± 71 ††	182 ± 140 ‡‡ §§	69 ± 44 †† ¶¶	0.000
9	Eggs (kcal)	47 ± 29	7 ± 11 ††	7 ± 14 ††	36 ± 25 ‡‡ §§	27 ± 23 †† ‡‡ §§	0.000
10	Milk and other dairy products (kcal)	102 ± 83	128 ± 61 †	119 ± 48	116 ± 62	156 ± 109 ††	0.000
10(1)	Milk (kcal)	49 ± 54	90 ± 50 ††	79 ± 49 ††	56 ± 42 ‡	93 ± 95 ††	0.000
10(2)	Other dairy products (kcal)	53 ± 45	39 ± 22	40 ± 27	60 ± 38 ‡§	63 ± 39 ‡ §	0.001
11	Fruit (kcal)	37 ± 32	16 ± 20 †	15 ± 14 †	34 ± 30	80 ± 62 †† ‡‡ §§ ¶¶	0.000
12	Confectionery (kcal)	253 ± 190	64 ± 115 ††	75 ± 92 ††	195 ± 132 ‡‡ §§	64 ± 48 †† ¶¶	0.000
13	Flavored drinks (kcal)	87 ± 109	44 ± 69 †	60 ± 83	83 ± 95 ‡‡	183 ± 178 †† ‡‡ §§ ¶¶	0.000
13(1)	Alcoholic beverages (kcal)	66 ± 92	42 ± 69	52 ± 76	70 ± 91 ‡‡	122 ± 138 †† ‡‡ §§ ¶¶	0.000
13(2)	Non-alcoholic flavored beverages (kcal)	21 ± 59	2 ± 8	8 ± 26	13 ± 29 ‡	60 ± 114 ‡‡ §§	0.000
14	Sugar (kcal)	26 ± 18	39 ± 43	22 ± 16 ‡	25 ± 16	8 ± 5 †† ‡‡ §§ ¶¶	0.000
15	Nuts and seeds (kcal)	8.0 ± 9.9	4.3 ± 5.7	4.3 ± 6.8	7.9 ± 7.6 ‡‡ §	3.2 ± 4.9 †† ¶¶	0.000
16	Oils and fats (kcal)	93 ± 52	32 ± 34 ††	34 ± 37 ††	85 ± 49 ‡‡ §§	11 ± 6 †† ¶¶	0.000
17	Seasonings/spices (kcal)	50 ± 29	50 ± 34	53 ± 40	53 ± 28	28 ± 19 †† ‡‡ §§ ¶¶	0.000
18	Mushrooms (kcal)	22 ± 14	32 ± 22 †	29 ± 17	25 ± 14	112 ± 69 †† ‡‡ §§ ¶¶	0.000
19	Pickles (kcal)	3.8 ± 3.7	0.5 ± 1.3 ††	0.4 ± 1.2 ††	1.9 ± 2.8 † ‡ §	7.6 ± 9.6 ‡‡ §§ ¶¶	0.000
20	Shellfish boiled in sweetened soy sauces (kcal)	3.8 ± 3.6	0.8 ± 2.0 ††	0.7 ± 1.4 ††	2.3 ± 2.9 ‡‡ §§	2.1 ± 2.2 † ‡‡ §§	0.000
	HSBP group Systolic blood pressure (mmHg)	155 ± 8	137 ± 10 ††	132 ± 10 †† ‡‡	136 ± 10 †† §	138 ± 13 †† §§	0.000
	LSBP group Systolic blood pressure (mmHg)	139 ± 5	127 ± 7 ††	123 ± 8 †† ‡‡	126 ± 8 †† §	128 ± 7 †† §§	0.000
	HSBP group Diastolic blood pressure (mmHg)	89 ± 7	82 ± 9 ††	80 ± 8 †† ‡‡	82 ± 8 ††	82 ± 11 ††	0.000
	LSBP group Diastolic blood pressure (mmHg)	87 ± 7	80 ± 7 ††	78 ± 8 †† ‡‡	79 ± 7 ††	80 ± 7 ††	0.000
	Weight (kg)	66.5 ± 12.0	64.1 ± 11.4 ††	62.6 ± 11.2 ††	63.0 ± 11.4 †† ‡‡ §	63.7 ± 11.6 †† ‡‡ §§	0.000
	Physical activity level (Af)	2.03 ± 0.54	1.94 ± 0.48	2.05 ± 0.64	2.06 ± 0.56	2.10 ± 0.55	0.563

Categories 10 (1) and 10 (2) are subcategories of category 10. Categories 13 (1) and 13 (2) are subcategories of category 13. Data are means ± SD. *P*-values were derived from Friedman's test among 5 examinations. [a,b,c,d] adjusted *P*-values derived from post-hoc analysis with Friedman's test for multiple comparisons. † indicates [a] adjusted $P < 0.05$ vs. baseline; †† indicates [a] adjusted $P < 0.01$ vs. baseline. ‡ indicates [b] adjusted $P < 0.05$ vs. after 1 month; ‡‡ indicates [b] adjusted $P < 0.01$ vs. after 1 month. § indicates [c] adjusted $P < 0.05$ vs. after 2 months; §§ indicates [c] adjusted $P < 0.01$ vs. after 2 months. ¶ indicates [d] adjusted $P < 0.05$ vs. 1 month after ceasing intervention; ¶¶ indicates [d] adjusted $P < 0.01$ vs. 1 month after ceasing intervention. The physical activity level was calculated based on the "activity" factor of the FFQg nutrient questionnaire.

Table 4. Changes of the nutritional intake according to the Nutrients during the study period of DASH-JUMP.

	Category		Baseline	After 1 Month	After 2 Months	1 Month after Ceasing Intervention	4 Months after Ceasing Intervention	*P*-Value
	Energy	(kcal)	1740 ± 472	1477 ± 420	1356 ± 330 ††	1703 ± 381 ‡ §§	1807 ± 371 ‡‡ §§	0.000
	Carbohydrate	(%E)	225 ± 65	208 ± 40	201 ± 40	219 ± 51	231 ± 59 §§	0.011
	Protein	(g)	62.1 ± 20.3	57.0 ± 28.1	47.7 ± 15.9 ††	62.4 ± 17.2 §§	66.0 ± 18.6 ‡‡ §§	0.000
	Lipid	(mg)	57.7 ± 19.5	40.5 ± 22.4 ††	33.5 ± 14.7 ††	55.7 ± 19.5 ‡‡ §§	59.8 ± 17.5 ‡‡ §§	0.000
	Cholesterol	(mg)	307 ± 125	167 ± 111 ††	135 ± 88 ††	275 ± 109 ‡‡ §§	309 ± 139 ‡‡ §§	0.000
Fatty acid	Saturated fatty acid	(g)	17.2 ± 6.3	13.1 ± 6.9 ††	10.8 ± 4.2 ††	16.9 ± 6.1 §§	18.6 ± 5.7 ‡‡ §§	0.000
	Monounsaturated fatty acid	(g)	20.0 ± 7.3	13.1 ± 8.2 ††	10.5 ± 5.4 ††	19.1 ± 7.7 ‡‡ §§	20.3 ± 6.8 ‡‡ §§	0.000
	Polyunsaturated fatty acid	(g)	12.0 ± 3.9	8.6 ± 5.0 ††	7.3 ± 3.7 ††	11.8 ± 4.3 ‡‡ §§	12.1 ± 3.8 ‡‡ §§	0.000
	n - 3 polyunsaturated	(g)	2.3 ± 0.8	1.8 ± 1.2 ††	1.5 ± 0.8 ††	2.2 ± 0.9 ‡ §§	2.4 ± 0.9 ‡‡ §§	0.000
	n - 6 polyunsaturated	(g)	9.7 ± 3.2	6.8 ± 3.9 ††	5.8 ± 3.0 ††	9.5 ± 3.4 ‡‡ §§	9.7 ± 3.0 ‡‡ §§	0.000
Vitamins	Retinol (Vitamin A)	(μg)	188 ± 73	140 ± 77 ††	114 ± 52 ††	180 ± 64 ‡‡ §§	197 ± 79 ‡‡ §§	0.000
	Vitamin B 1	(mg)	0.8 ± 0.3	0.7 ± 0.4	0.6 ± 0.2 ††	0.8 ± 0.3 §§	0.9 ± 0.3 ‡‡ §§	0.000
	Vitamin B 2	(mg)	1.0 ± 0.4	0.9 ± 0.3	0.8 ± 0.3 ††	1.0 ± 0.3 §	1.1 ± 0.4 ‡‡ §§	0.000
	Niacin (Vitamin B3)	(mgNE)	13.7 ± 5.7	12.0 ± 7.5 †	9.6 ± 4.1 ††	13.5 ± 5.1 §§	15.1 ± 5.0 ‡‡ §§	0.000
	Pantothenic acid (Vitamin B5)	(mg)	4.7 ± 1.4	4.5 ± 1.6	3.9 ± 1.1 ††	4.7 ± 1.2 §§	5.1 ± 1.3 ‡ §§	0.000
	Vitamin B 6	(mg)	1.0 ± 0.3	1.0 ± 0.5	0.8 ± 0.3 †	1.0 ± 0.3 §	1.1 ± 0.3 ‡ §§	0.000
	Vitamin B 12	(μg)	6.9 ± 3.7	6.5 ± 5.0	5.2 ± 3.0	7.0 ± 3.3 §	7.7 ± 3.8 ‡ §§	0.000
	Vitamin C	(mg)	71.3 ± 37.4	77.6 ± 35.3	65.7 ± 30.7	70.6 ± 31.3	85.9 ± 39.3 §	0.013
	Vitamin D	(μg)	7.5 ± 4.6	6.7 ± 5.5	5.3 ± 3.8	7.3 ± 3.8	8.2 ± 4.8 ‡ §§	0.001
	Tocopherol (Vitamin E)	(mg)	7.1 ± 2.1	5.7 ± 2.4	4.9 ± 2.2 ††	6.8 ± 2.2 §§	7.5 ± 2.0 ‡‡ §§	0.000
	Vitamin K	(μg)	173 ± 66	234 ± 107 ††	191 ± 98 ‡‡	187 ± 70 ‡	205 ± 82	0.001
	Folic acid (Vitamin M)	(μg)	228 ± 77	275 ± 110 †	235 ± 101 ‡‡	236 ± 77 ‡	264 ± 90	0.001
	Alpha-carotene	(μg)	434 ± 231	782 ± 375 ††	621 ± 361 ††	473 ± 221 ‡‡	584 ± 327 †† ¶	0.000
	Beta-carotene	(μg)	2642 ± 1375	4656 ± 2190 ††	3718 ± 2136 †	2880 ± 1318 ‡‡	3533 ± 1927 †† ¶	0.000
	Cryptoxanthin	(μg)	436 ± 354	207 ± 219 ††	193 ± 154 ††	394 ± 332 §§	512 ± 368 ‡‡ §§	0.000
Fiber	Water soluble dietary	(g)	2.5 ± 0.8	2.6 ± 1.0	2.2 ± 0.9 ‡	2.4 ± 0.8	2.8 ± 0.8 §§	0.002
	Insoluble dietary fiber	(g)	7.8 ± 2.5	8.5 ± 3.1	7.4 ± 2.8 ‡	7.9 ± 2.4	8.6 ± 2.5 §	0.014
Minerals	Calcium	(mg)	491 ± 237	554 ± 220	487 ± 175	517 ± 182	580 ± 237 †	0.013
	Magnesium	(mg)	213 ± 71	224 ± 90	195 ± 70	220 ± 65	238 ± 67 §§	0.007
	Phosphorus	(mg)	915 ± 310	882 ± 376	761 ± 244	929 ± 249 §	997 ± 285 ‡‡ §§	0.000
	Iron	(mg)	6.7 ± 2.5	6.4 ± 2.9	5.4 ± 2.2 †	6.7 ± 2.1	7.2 ± 2.9 ‡ §§	0.000
	Zinc	(mg)	7.2 ± 2.2	6.9 ± 2.9	6.0 ± 1.6 ††	7.3 ± 1.9 §§	7.5 ± 1.9 ‡ §§	0.000
	Copper	(mg)	0.9 ± 0.3	1.0 ± 0.3	0.9 ± 0.2	1.0 ± 0.2	1.0 ± 0.2 §	0.017
	Manganese	(mg)	2.2 ± 0.6	2.3 ± 0.6	2.2 ± 0.5	2.2 ± 0.5	2.3 ± 0.6	0.170
	Sodium	(mg)	3733 ± 1239	3680 ± 2258	2987 ± 1484 ††	3429 ± 1262	3702 ± 1384 §§	0.003
	Potassium	(mg)	1938 ± 670	2074 ± 828	1775 ± 655	1960 ± 588	2217 ± 618 §§	0.001
	Sodium/potassium ratio		1.93	1.77	1.68	1.75	1.67	
	Salt	(g)	9.5 ± 3.2	9.3 ± 5.7	7.5 ± 3.8 ††	8.7 ± 3.2	9.4 ± 3.6 §§	0.004

n= 55, Data are means ± standard deviation. *P*-values were derived from Friedman's test among five examinations. a,b,c,d indicate adjusted *P*-values derived from post-hoc analysis with Friedman's test for multiple comparisons.

† indicates adjusted $P < 0.05$ vs. baseline; †† indicates adjusted $P < 0.01$ vs. baseline. ‡ indicates adjusted $P < 0.05$ vs. after 1 month; ‡‡ indicates adjusted $P < 0.01$ vs. after 1 month. § indicates adjusted $P < 0.05$ vs. after 2 months;

§§ indicates adjusted $P < 0.01$ vs. after 2 months. ¶ indicates adjusted $P < 0.05$ vs. 1 month after ceasing intervention; ¶¶ indicates adjusted $P < 0.01$ vs. 1 month after ceasing intervention.

Table 5. Nutrients and foods significantly associated with changes in BP.

	Dependent Variable	Independent Variable		Unstandardized Regression Coefficients		Standardized Regression Coefficients	P	Partial Correlation Coefficient	VIF
				β	Standard Error				
1	The change in SBP from baseline to 2 months	Nutrients	niacin	-0.701	0.237	-0.460	0.005	-0.379	1.482
			carbohydrate	0.048	0.022	0.341	0.033	0.291	1.482
			$P_{⊿F}$	0.015	-	-	-	-	-
			R	0.386	-	-	-	-	-
			Adjusted R-squared	0.116	-	-	-	-	-
			N	55	-	-	-	-	-
2	The change in SBP from baseline to 2 months	Foods	Shellfish boiled in sweetened soy sauces	-0.977	0.322	-0.385	0.004	-0.385	1.000
			$P_{⊿F}$	0.004	-	-	-	-	-
			R	0.385	-	-	-	-	-
			Adjusted R-squared	0.132	-	-	-	-	-
			N	55	-	-	-	-	-
3	The change in DBP from baseline to 2 months	Foods	Pickles	-0.551	0.210	-0.340	0.011	-0.340	1.000
			$P_{⊿F}$	0.011	-	-	-	-	-
			R	0.340	-	-	-	-	-
			Adjusted R-squared	0.099	-	-	-	-	-
			N	55	-	-	-	-	-

Abbreviations: Independent variables were values of the change in BP from baseline to 2 months, $P_{⊿F}$ was a *P*-value from analysis of variance.

(β 0.048, *P* = 0.033), and shellfish boiled in sweetened soy sauces (β −0.977, *P* = 0.004) as independent predictors. The change in DBP from baseline to 2 months as a dependent variable was significantly associated with the change in the intake of pickles (β −0.551, *P* = 0.011) as an independent predictor. Although the predictive accuracy of the model was low, the results indicated that the changes in SBP and DBP were significantly related to the intakes of niacin, carbohydrate, shellfish boiled in sweetened soy sauces, and pickles even after correcting for the influences of body weight and physical activity. Table **5** shows the results of the multiple regression analysis.

3.4. Difference in Nutritional Intake Between the High and Low BP Groups

There were significant differences in age (*P* = 0.008) and SBP (*P* = 0.000) between the HSBP and LSBP groups. There were no significant differences in the intakes of nutrients and foods between those groups at baseline (Table **1**). The LSBP group consumed significantly more seaweed than the HSBP group (*P* = 0.043) after 1 month.

4. DISCUSSION

In this study, we prospectively evaluated the effects of individual nutrients and food groups in the DASH-JUMP diet using participants with untreated high-normal BP or stage 1 hypertension.

Few dietary studies have measured the changes in the nutritional value of meals after cooking and freezing. A physicochemical analysis of the DASH-JUMP menu items showed that their contents of energy, total fat, carbohydrate, potassium, calcium, magnesium, polyunsaturated fatty acid, and cholesterol significantly decreased after cooking and freezing them for 1 month compared with the nutritional values calculated during the menu design stage. A previous study [20] reported that cooking various food materials resulted in a decrease in their content of minerals to about 60–70% of that in raw or uncooked foods. This decrease was particularly pronounced for vegetables and was largest when squeezing foods after boiling or soaking in water or after slicing them thinly, followed by parching, frying, and stewing. In that study, the authors indicated that measures to prevent the loss of minerals during cooking included: (a) eating boiled foods with the broth they were cooked in; (b) adding a small amount of salt (about 1% NaCl) when boiling; (c) avoiding too much boiling; and (d) selecting a cooking method causing less mineral loss (stewing, frying, or parching). From the viewpoint of preventing hypertension, the addition of salt when boiling cannot be recommended, but it is valid to select a cooking method producing less reduction of minerals. At the research briefing session for the DASH-JUMP study, we explained that participants should drink all the broth used for boiling foods because nutrients dissolve into the broth. It is important to ensure that the nutritional content of the menu items planned at the design stage matches participants' actual intakes during the intervention phase as closely as possible. Therefore, it will be necessary to refine the cooking methods and menu contents to prevent excessive losses of energy, total fat, carbohydrate, potassium, calcium, magnesium, polyunsaturated fatty acid, and cholesterol when designing dietary interventions in future.

In terms of individual food groups, participants' intakes of green/yellow vegetables, seaweed, mushrooms, and milk/dairy were significantly higher during the DASH-JUMP intervention period than at baseline. Some previous studies [21] have reported that vegetarians have a significantly lower BP than non-vegetarians. Dietary fiber, carotene, nitrate, folic acid, potassium, and vitamins C and E are components of green/yellow vegetables that may contribute to reducing CVD risk [22-26]. Spinach, carrot, green pepper, broccoli, and cabbages were frequently used as ingredients in the DASH-JUMP menu items. As a characteristic nutrient of seaweed, fucosterol was reported to reduce Angiotensin-Converting Enzyme (ACE) activity in endothelial cells by inhibiting the synthesis of glucocorticoid receptors that regulate ACE activity, and certain peptides having ACE-inhibiting activity were isolated from a peptic digest of seaweed [27]. In addition to containing dietary fiber, mushrooms also have high contents of protein and essential amino acids such as glutamic acid, aspartic acid, and arginine, as well as folic acid, minerals, vitamins, and β-carotene [28]. It was reported that certain peptides produced by mushrooms might block the active site of ACE *via* substrate-enzyme binding, thus inhibiting the conversion of angiotensin I to angiotensin II, which is a potent vasopressor [29]. In particular, it was reported that peptides derived from milk proteins have ACE inhibitory properties and have the effects of improving vascular endothelial function and lowering BP [30].

High intakes of meat, eggs, fat, and oil contribute to increases in serum cholesterol [31] and participants' consumption of these food groups significantly decreased during the DASH-JUMP intervention. Participants' intakes of pickles and shellfish boiled in sweetened soy sauces also decreased, resulting in a reduction in salt intake that may have contributed to the observed decrease in BP. A decrease in participants' consumption of confectionery contributed to their decreased intakes of carbohydrate and lipid. Although it was not an intentional effect of the DASH-JUMP diet, participants' consumption of fruit declined during the research period, which contributed to their decreased carbohydrate intake. Their consumption of tea increased, which would be expected to replace some of the micronutrients lost from the decrease in fruit intake.

The SBP and DBP of the HSBP and LSBP groups rose after the intervention ended, but their BP did not change much between 1 and 4 months after ceasing the intervention. These data indicated that those participants who experienced a decrease in BP due to ingesting the DASH-JUMP diet consciously ingested a meal that imitated the DASH-JUMP diet from 1 month after ceasing the intervention. In the present study, the findings provided evidence that the participants did not continue to have low intakes of fat, alcohol and salt after ceasing the DASH-JUMP intervention. However, they continued to have high intakes of vegetables, seaweed, mushrooms, and milk. The results of the FFQg questionnaire survey also showed that the sodium/potassium ratio at 4 months after ceasing the intervention was similar to that after 2 months of the intervention [32]. Hence, it was shown that BP hardly changed due to their antihypertensive effects.

The results of a multiple regression analysis revealed the characteristics of Japanese style food. The staple food in Japan is rice, and the major nutrient of rice that is relevant to changes in BP is niacin, which is deeply involved in the metabolism of carbohydrates as an energy source. A previous study indicated that a high carbohydrate intake (70% of energy) was associated with lower intakes of energy, protein, fat, iron, thiamin, riboflavin, and niacin [33]. Furthermore, men and women with a high carbohydrate intake had higher SPB values than those with a lower carbohydrate intake [33]. In our study, the intake of carbohydrate increased at 4 months after ceasing the intervention and that of niacin also increased, but participants' BP values hardly changed. This led to the hypothesis that Japanese who consume a lot of carbohydrates tend to also consume a lot of niacin, and this high niacin intake represents a secondary means of preventing hypertension.

The DASH-JUMP study showed that a strong hypotensive effect was obtained by the synergistic effect between traditional Japanese foods and the DASH diet. The hypotensive effect could be achieved by a moderate reduction in salt intake and an increased consumption of traditional Japanese foods and low-fat milk and dairy products. In addition, it is important to ingest a sufficient amount of nutrients daily. This goal can be assisted by choosing a cooking method that results in a low loss of nutrients from foods and offering guidance to drink all the broth used in cooking. The results of this study suggest that individual food groups and nutrients in the DASH-JUMP diet affect vascular endothelial function. In a future study, it will be necessary to evaluate vascular endothelial function using flow-mediated dilatation to examine the effects not only on BP but also on the blood vessels. A challenge facing the intake of a healthy diet in modern society is that making menus and cooking meals containing a high abundance of green/yellow vegetables, seaweed, mushrooms, and dairy products is time-consuming. In the current social environment, there are many families in which couples are both working and arriving home late. Consequently, the frequency of eating at restaurants, ordering takeaways, and eating prepared foods is increasing. Additionally, in the super-aged Japanese society, there are many elderly people who have difficulty cooking because they cannot stand for a sustained period. It is difficult to cook meals such as those comprising the DASH-JUMP diet at home if the person mainly responsible for cooking in the family is doing other exhausting labor. To overcome these challenges, the DASH-JUMP diet is expected to be distributed as prepared products so that it can easily be obtained by those seeking improved health.

CONCLUSION

A strong hypotensive effect was obtained by the DASH-JUMP diet, which is based on traditional Japanese foods with a tailored nutritional composition of DASH diet including reduced salt. The DASH-JUMP diet is rich in green/yellow vegetables, seaweed, milk, and mushrooms, and it had low contents of meat, eggs, confectionery, oils and fats, pickles, shellfish boiled in sweetened soy sauces, and fruits. Taken together, the findings indicate that traditional Japanese foods support health and reduce CVD risk. The DASH-JUMP diet is suitable as a new lifestyle medicine for the prevention and improvement of hypertension for people with high-normal or stage 1 high BP.

STUDY LIMITATIONS

This study had some limitations that require consideration. First, this study was a small-scale cohort study with low statistical power. Second, the number of analyzed nutrients and food groups was limited by the scope of the FFQg questionnaire. Finally, because flow-mediated dilatation or the quantification of nitrate and nitrite were not performed, the effects of the DASH-JUMP intervention on vascular endothelial function were not measured. This was a pilot study, and we intend to conduct a randomized controlled trial in the near future to accurately evaluate the potential benefits of the DASH-JUMP diet for Japanese people with high BP.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was performed and was approved by the Ethics Committee of Yamaguchi University Faculty of Medicine and Health Sciences.

HUMAN AND ANIMAL RIGHTS

No animal were used in this research. All humans research procedures followed were in accordance with the standards set forth in the Declaration of Helsinki <https://www.wma.net/policiespost/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/> principles of 1975, as revised in 2008 (http://www.wma.net/en/20activities/10ethics/10helsinki/).

CONSENT FOR PUBLICATION

All participants gave an Informed consent for the study.

CONFLICT OF INTEREST

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