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Seaweed intake and blood pressure levels in healthy pre-school Japanese children

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Abstract

Background: Few studies have examined whether dietary factors might affect blood pressure in children. We purposed to investigate whether seaweed intake is associated with blood pressure level among Japanese preschool children.

Methods: The design of the study was cross-sectional and it was conducted in autumn 2006. Subjects were healthy preschoolers aged 3-6 years in Aichi, Japan. Blood pressure and pulse were measured once by an automated sphygmomanometer, which uses oscillometric methods. Dietary data, including seaweed intake, were assessed using 3-day dietary records covering 2 consecutive weekdays and 1 weekend day. Of a total of 533 children, 459 (86.1 percent) agreed to be enrolled in our study. Finally, blood pressure measurement, complete dietary records and parent-reported height and weight were obtained for 223 boys and 194 girls.

Results: When we examined Spearman's correlation coefficients, seaweed intake was significantly negatively related to systolic blood pressure in girls (P = 0.008). In the one-way analysis of covariance for blood pressure and pulse after adjustments for age and BMI, the boys with the lowest, middle and highest tertiles of seaweed intake had diastolic blood pressure readings of 62.8, 59.3 and 59.6 mmHg, respectively (P= 0.11, trend P= 0.038). Girls with higher seaweed intake had significantly lower systolic blood pressure readings (102.4, 99.2 and 96.9 mmHg for girls with the lowest, middle and highest tertiles of seaweed intake, respectively; P= 0.037, trend P= 0.030).

Conclusion: Our study showed that seaweed intake was negatively related to diastolic blood pressure in boys and to systolic blood pressure in girls. This suggests that seaweed might have beneficial effects on blood pressure among children.

Keywords: blood pressure; child, preschool; diet records; seaweed; nutrition

Background

Hypertension, which often coexists with diabetes, dyslipidemia and obesity, promotes atherosclerosis and contributes to the development of cardiovascular disease [1]. Hypertension is generally unusual among children, but many studies have shown the tracking of blood pressure from childhood to adulthood [2], and some studies have indicated that the process of atherosclerosis starts in childhood [3, 4]. Thus, early intervention for high blood pressure is important in order to prevent cardiovascular disease later in life.

Although there is much evidence for dietary risk factors for hypertension in adults [5-13], few studies of children have been reported [14-21]. Restricted salt intake and reduced alcohol consumption are recommended for adults [6]. The Dietary Approaches to Stop Hypertension (DASH diet), which is rich in fruits, vegetables and low-fat dairy products, has beneficial effects on blood pressure among adults [5-8]. The diet is rich in potassium and calcium, which have been reported to reduce blood pressure among adults [8, 9, 13]. A negative association between magnesium and blood pressure has also been reported among adults in some papers [10, 11, 13]. However, the role of diet in blood pressure among children is not well understood.

Seaweeds are traditional Japanese foods, and are consumed as they are (nori, kombu, hijiki) or as ingredients of rice balls (nori) and salads or soups (wakame). Seaweeds contain large quantities of dietary fiber, minerals, vitamins and polysaccharides [22]. Several experimental studies in animals [23-27] have shown that feeding on seaweed or its extract lowers blood pressure, suggesting that seaweed intake might affect blood pressure in humans. However, only a few epidemiological studies have reported an association between seaweed intake and blood pressure, and the results have been inconsistent [28-31]. These studies were conducted among adults, and the relationship of seaweed intake to blood pressure has not been investigated among children.

In this study, we purposed to investigate whether dietary seaweed intake is associated

with blood pressure level among Japanese preschool children. We hypothesized that seaweed might beneficially affect blood pressure among children.

Methods

Subjects and Design

Subjects were children aged three to six years who attended one of two preschools in Aichi Prefecture, Japan. The details of the cohorts have been described elsewhere previously [32]. During October and November 2006, they underwent blood pressure measurement. Urine, which was first voided after a child waked up, was collected. Children's height, weight, health status, and lifestyles were inquired through a parent-administered questionnaire. Lifestyles included the time when they got up or went to bed, and a nap time. Physical activity was based on an outdoor playtime checklist by Burdette et al. [33].The parents were also asked to record the children's dietary intake for covering 2 consecutive weekdays and 1 weekend day. Of a total of 533 preschool children, 459 (86.1 percent) agreed to be enrolled in our study, with their parents providing written informed consent. Finally, blood pressure measurement, complete dietary records and parent-reported height and weight were obtained for 417 of the children. This study protocol and the informed consent procedure were approved by the ethical board of Gifu University Graduate School of Medicine, Gifu, Japan.

Dietary data

To collect nutritional data, diet including seaweed intake was assessed using 3-day dietary records covering 2 consecutive weekdays and 1 weekend day. The parents received written instructions on recording the food intakes of the children. According to the instructions, they recorded the amount and kind of foods, beverages and dishes which were consumed by their children during each of three days. When they were in trouble with recording, our stuffs

assisted them on the phone. Because our subjects usually ate a school-provided lunch, we obtained the menus from each kindergarten and our staffs, which were dieticians, checked the quantity left over after each meal. Individual nutrient intake was estimated using the Japanese Standard Table of Food Composition, 5th revised and enlarged edition [22]. We calculated energy intake in kilocalories per day and seaweed and salt intake in grams per day. Seaweed intake was converted to dry volume units.

Blood pressure and other measurements

Systolic (SBP), diastolic blood pressure (DBP) and pulse were measured once by an automated sphygmomanometer (ES-H55, Terumo Co., Japan), which uses oscillometric methods. Measurements of blood pressure were conducted in midmorning. Children were not requested to be fasting. We used the appropriate size of blood pressure cuff based on each child's arm circumference. As a rule, measurements were taken from the upper arm. The subjects were measured in a sitting position after a few minutes of rest. The height and weight of children were based on parents' reports. Body mass index (BMI) was calculated as (weight in kg) / (height in m)^2. From our subjects, we additionally obtained the measurements of the heights and weights of 103 of the children. Among them, intra-class correlation coefficients between measured and parent-reported data were 0.90, 0.96, and 0.78 in height, weight, and BMI, respectively.

Statistical analysis

All analyses were performed separately for each sex. According to the nutrient density method, we divided seaweed and salt intake by total energy intake, and presented them as grams per 1,000 kcal of total energy. The dietary intakes such as total energy, seaweed and salt were skewed and hence were logarithmic transformed in all analyses.

The characteristics by sex were calculated as mean (standard deviation: SD). The

geometric mean and 95% confidence interval were computed on the log-transformed values and converted back to the original scale of measurement. We used Spearman's correlation coefficients to detect the association of blood pressure and pulse with age, height, weight, BMI, and intakes of total energy, salt or seaweed.

We divided the subjects into three groups according to tertile category (low, middle or high) of seaweed intake. Tertiles were derived based on the distribution of seaweed consumption in the current population. In order to elucidate the relationships of seaweed intake with SBP, DBP and pulse, we used a one-way analysis of covariance (ANCOVA) after adjustments for age and BMI. Tests for linear trend were performed on multiple regression analyses using continues variables in seaweed intake.

All analyses were conducted using the SAS computer program, version 9.1 (SAS Institute). All P values were calculated by a two-sided test. A P value of less than 0.05 was considered statistically significant in all analyses.

Results

The characteristics of studied subjects are shown in Table 1. Subjects were 223 boys and 194 girls. The averages (SD) of SBP and DBP were, respectively, 98.7 (13.0) and 60.6 (11.1) mmHg among boys. Those were 99.5 (12.4) mmHg for SBP and 62.2 (11.8) mmHg for DBP among girls. The average pulse rate of girls was higher than that of boys (93.6 /min in boys and 96.5 /min in girls: P=0.047). Total energy intake was greater in boys than in girls (1446 kcal/day in boys and 1337 kcal/day in girls: P<0.001). The geometric means of seaweed intake were 0.67 and 0.76 g/day in boys and girls, respectively (P=0.096).

Age, height and weight were significantly negatively correlated with pulse in boys and girls (Table 2). BMI was positively associated with SBP in boys and girls. Total energy intake was neither associated with SBP, DBP nor pulse. Salt intake was also neither associated with SBP, DBP nor pulse. Seaweed intake was weakly, but significantly negatively related to SBP

in girls (Spearman's r = -0.190, P = 0.008). There were borderline-significant negative associations between seaweed intake and DBP in boys (Spearman's r = -0.112, P = 0.096) and girls (Spearman's r =-0.123, P = 0.089). In girls, the negative association between seaweed intake and pulse was also of borderline significance (Spearman's r = -0.137, P = 0.058).

Table 3 shows the estimated means of SBP, DBP and pulse according to the tertile category of dietary seaweed intake after adjustments for age and BMI. Boys with low, middle and high intake of seaweed had DBP readings of 62.8, 59.3 and 59.6 mmHg, respectively (*P* = 0.11, trend *P* = 0.038). Neither SBP nor pulse was associated with seaweed intake. Girls with higher seaweed intake had significantly lower SBP than those with lower seaweed intake (*P* = 0.037, trend *P* = 0.030). The DBP of girls with low seaweed intake was higher than those of middle and high intake of seaweed.

Among seaweeds, nori (dried purple laver) was taken most common among our subjects (geometrical mean: 0.37 g/day). The association of nori intake with blood pressure was similar to that of total seaweed intake. For example, boys with low, middle and high intake of nori had DBP readings of 61.4, 61.7 and 58.6 mmHg, respectively (trend *P* = 0.057). Girls with low, middle and high intake of nori had SBP readings of 100.6, 101.1 and 97.0 mmHg, respectively (trend *P* = 0.040).

In order to see whether using parent-reported height and weight could influence the results, we assessed the association between seaweed intake and blood pressure among 53 boys and 50 girls whose measurements of height and weight were obtained. When the measured BMI was used as a confounder, boys with low, middle and high intake of seaweed had DBP readings of 64.7, 57.7 and 54.8 mmHg, respectively (trend *P* = 0.075). Girls with low, middle and high intake of seaweed had SBP readings of 99.6, 98.9 and 92.5 mmHg, respectively (trend *P* = 0.032).

We repeated the same analyses including other dietary factors as a confounder. Salt or

sodium intake did not affect the negative association between seaweed intake and DBP among boys. The negative association between seaweed intake and SBP was also unaltered among girls. Additional adjustment for other mineral intakes (potassium, calcium, magnesium) also did not change the associations observed. When vegetable, fruit or fat intake was added as a confounder, the results were not substantially altered.

In addition, we assessed the association between seaweed intake and blood pressure after additional adjustment for non-dietary lifestyle factors. Sleeping habits (sleeping time in hours or the time when they got up or went to bed) or sedentary lifestyle time (total minutes of watching television or video-gaming, and reading a book) did not affect the association observed. We got data about physical activity only among 110 boys (Mean (SD): 98.0 (13.3) mmHg for SBP and 60.4 (12.1) mmHg for DBP) and 85 girls (Mean (SD): 98.5 (13.6) mmHg for SBP and 60.7 (SD: 10.2) mmHg for DBP). Although the observed association became non- significant after additional adjustment for physical activity, the tendency in the negative association between seaweed intake and blood pressure was not altered. After additional adjustments for passive smoking or years of mother's education, the negative association between seaweed intake and blood pressure were observed.

Finally, we re-examined the association between seaweed intake and blood pressure after excluding 4 children who took medications for common cold on the day of blood pressure measurement. Along with the results among all subjects, seaweed intake was negatively related to DBP in boys (trend $P = 0.024$) and to SBP in girls (trend $P = 0.028$).

Discussion

Although there is much evidence for dietary risk factors for hypertension in adults, few studies of children have been reported [14-21]. Even the association between salt intake and blood pressure has been inconsistent among children [14, 15]. Several studies have demonstrated the negative associations of blood pressure with calcium and magnesium

among children [16-19], but very few researchers have examined whether the other dietary factors might affect blood pressure in childhood [19-21]. To our knowledge, this study is the first to demonstrate an association between seaweed intake and blood pressure in healthy children. Seaweed intake was negatively related to DBP in boys and to SBP in girls. Although we cannot prove a causal relationship because of a cross-sectional design of this study, the finding suggests that seaweed might have beneficial effects on blood pressure among children.

Our study of 3- to 6-year-old Japanese children showed that the difference between the highest and lowest tertiles was 3.5 mmHg in DBP among boys and 5.5 mmHg in SBP among girls. Decreasing blood pressure in healthy children would be potentially beneficial for blood pressure control in the future. Among Japanese adults aged 40 to 49 years, the multivariate-adjusted hazard ratio of all-cause mortality for each 10-mmHg SBP increase was reported to be 1.37 times in men and 1.19 in women during 9.8 years of follow-up.[34] That for each 10-mm Hg DBP was 1.46 times in men and 1.40 times in women.

The negative association between seaweed and blood pressure in our study is supported by the results of several experimental studies [23-27]. A diet containing powdered brown seaweed lowered blood pressure and reduced the incidence of stroke in salt-loaded, stroke-prone spontaneously hypertensive rats [SHRs] [23]. Hydrolysates of wakame (Undaria pinnatifida), a kind of seaweed, were reported to decrease systolic blood pressure after oral administration in SHRs [24]. Peptides isolated from wakame also had inhibitory activity for angiotensin 1-conversing enzyme, causing an antihypertensive effect [25-27]. In addition, Ikeda et al. found that the administration of wakame delayed the development of stroke signs and improved the survival rate of salt-loaded, stroke-prone SHRs, although there was no significant difference in blood pressure changes compared with the control group [35]. These findings suggest that seaweed may have preventive effects on hypertension and cerebrovascular diseases.

However, only a few epidemiological studies have reported an association between seaweed intake and blood pressure, and the results have been inconsistent [28-31]. Among 62 middle-aged patients with mild hypertension in Sweden, Krotkiewski et al. observed a significant decrease in mean blood pressure after the patients were given 12 and 24 g/day seaweed fiber for 4 weeks [28]. In hypertensive elderly Japanese patients, systolic and diastolic blood pressure decreased after the patients received daily doses of 5 g of dried seaweed powder for 8 weeks [29]. In a cross-sectional study of 190 hypertensive elderly Japanese patients, the patients treated with a low dose of a single drug ate more fruits and seaweed than the patients treated with a high dose of a single drug or multiple drugs, which suggested that the habitual intake of these food might help the control of blood pressure [30]. However, among 7,081 Korean men 30 years of age and older, participants with metabolic syndrome, including hypertension, showed a higher intake of seaweed and oily foods than did participants without metabolic syndrome [31]. These studies were conducted among adults, and, in this study, the relationship of seaweed intake to blood pressure has been first demonstrated among children.

In our study, seaweed seemed to have greater relationships with DBP than SBP among boys. Meanwhile, it seemed to have greater relationships with SBP than DBP among girls. Although the effects of seaweed intake on blood pressure might be different in mechanism between boys and girls, the reason for the discrepancy is unclear. In the studies among adults, one study [31] included only men and the others [28-30] analyzed the association in mixed group of men and women. More reports are needed to determine the association by sex.

The underlying mechanism responsible for the association between seaweed and blood pressure remains to be clarified. Seaweed contains large quantities of minerals and alginate, which is a kind of dietary fiber. Alginate has been reported to reduce blood pressure [36], and Yamori et al. presumed that alginic acid in seaweed may cause the inhibition of intentional

sodium absorption [23]. Potassium, calcium and magnesium also have been reported to reduce blood pressure in observational studies [13, 16, 17] and intervention trials [9-11, 18].However, the results among our subjects did not show associations between dietary potassium, calcium and magnesium intake and blood pressure. Nonetheless, we cannot deny the possibility that simultaneous intake of several minerals through seaweed may be effective for blood pressure. Alternatively, other ingredients may play a role in the control of blood pressure since alginate or each mineral in seaweed is lower than the effective dose needed to lower blood pressure. The whole diet pattern including seaweed intake is also possible to be responsible for the lower blood pressure.

Although a dietary record would be more accurate or better if it had been used for a longer time or repeated over different seasons, using a dietary record was one of merits in this study. One limitation is that blood pressure was measured only once, which may have caused a large measurement error. However, it is unlikely that such a measurement error was directly dependent on seaweed intake. Nonetheless, repeated measurements are best practice and necessary in future studies. Another limitation was that height and weight were reported by the parents. However, the correlation coefficient between parents' reports and measured ones ranged from 0.90 to 0.96 for height and 0.95 to 0.99 for weight among 170 first-grade and 206 fourth-grade Japanese children [37]. In our supplementary analysis among 103 children, the intra-class correlation between parent-reported and measured height and weight was high. Furthermore, the negative associations between seaweed intake and blood pressure were observed among them after the measured BMI was used as a confounder. Therefore, these differences would not greatly change the associations observed in our study. We also must note that BMI might not be necessarily a very good maker of fatness in growing children. Finally, the generalizability of our study is limited by the fact that our subjects were ethnically homogeneous Japanese children, whose diets differ from those of Western children.

Conclusions

We have demonstrated a negative association between dietary seaweed intake and blood pressure among healthy children. Seaweed is a popular traditional foodstuff that is widely eaten among both children and adults in Japan. Not only do our results suggest that seaweed intake may have beneficial effects on blood pressure in children, but they also provide the possibility of creating a new, earlier-in-life strategy for the prevention of hypertension in adults.

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Abbreviations

BMI, Body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.

Authors' contributions

Author KW wrote the paper. Author CN designed the study and directed its implementation, including quality assurance and control. Author KN helped designing the study's analytic strategy. Author YT, MT, and YS conduct the literature review and prepare the Discussion sections of the text. Author KW, SO., KY and KA helped supervise the field activities. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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Table 1 Characteristics of 417 studied preschool children

	Boys		Girls	
n	223		194	
Age (years)[a]	5.14	(0.89)	5.12	(0.89)
Height (cm)[a]	106.9	(7.1)	106.6	(7.3)
Weight (kg)[a]	17.5	(2.6)	17.3	(2.6)
BMI (kg/m^2)[a]	15.2	(1.3)	15.2	(1.5)
SBP (mmHg)[a]	98.7	(13.0)	99.5	(12.4)
DBP (mmHg)[a]	60.6	(11.1)	62.2	(11.8)
Pulse (beat/min)[a]	93.6	(15.4)	96.5	(13.6)
Diet				
Total energy intake (kcal/day)[b]	1446	(1411, 1483)	1337	(1304, 1372)
Salt intake (g/day)[b]	5.98	(5.77, 6.19)	5.74	(5.53, 5.96)
Salt intake (g/1000kcal)[b]	4.13	(4.02, 4.23)	4.28	(4.17, 4.40)
Seaweed intake (g/day)[b]	0.67	(0.58, 0.78)	0.76	(0.64, 0.89)
Seaweed intake (g/1000kcal)[b]	0.49	(0.42, 0.56)	0.58	(0.49, 0.68)

[a]mean (SD); [b]geometrical mean and 95% confidence interval

SBP, systolic blood pressure; DBP, diastolic blood pressure; SD, standard deviation

Table 2 Spearman's correlation coefficients of blood pressure and pulse, with age, height, weight, BMI and diet

	Boys (n=223)			Girls (n=194)		
	SBP	DBP	pulse	SBP	DBP	pulse
Age	-0.125*	-0.016	-0.318***	-0.062	-0.045	-0.212***
Height	-0.046	-0.021	-0.275***	0.036	0.011	-0.247***
Weight	0.081	0.021	-0.261***	0.142**	0.089	-0.163**
BMI	0.155**	0.033	-0.012	0.187***	0.124*	0.120*
Total energy intake	0.090	0.001	-0.020	0.066	-0.041	-0.045
Salt intake[a]	0.018	0.005	-0.070	-0.097	-0.013	-0.058
Seaweed intake[a]	-0.071	-0.112*	-0.031	-0.190***	-0.123*	-0.137*

SBP, systolic blood pressure; DBP, diastolic blood pressure

[a]Each intake was controlled for total energy intake by the nutrient density method.

*P < 0.1. **P < 0.05. ***$P < 0.01$

Table 3 Adjusted means of blood pressure and pulse according to the tertiles of dietary seaweed intake[a]

	Tertiles of seaweed intake[b]			*P*-value	*Liner trend P*
	low	middle	high		
Boys (n=223)	75	74	74		
Median (range)	0.06 (0,0.15)	0.36 (0.16,0.68)	1.11 (0.71,3.11)		
SBP (mmHg)[c]	100.0 (97.1-103.0)	97.9 (94.9-100.8)	98.1 (95.1-101.0)	0.52	0.31
DBP (mmHg)[c]	62.8 (60.2-65.3)	59.3 (56.7-61.8)	59.6 (57.1-62.2)	0.11	0.038
Pulse (/min)[c]	93.4 (90.0-96.8)	94.2 (90.8-97.7)	93.3 (89.8-96.7)	0.91	0.89
Girls (n=194)	65	65	64		
Median (range)	0.07 (0,0.22)	0.44 (0.22,0.76)	1.30 (0.77,7.98)		
SBP (mmHg)[c]	102.4 (99.4-105.4)	99.2 (96.2-102.2)	96.9 (93.9-99.9)	0.037	0.030
DBP (mmHg)[c]	65.1 (62.2-67.9)	60.4 (57.5-63.3)	61.2 (58.4-64.1)	0.055	0.25
Pulse (/min)[c]	98.8 (95.6-102.1)	96.3 (93.1-99.6)	94.2 (90.9-97.5)	0.15	0.092

SBP, systolic blood pressure; DBP, diastolic blood pressure

[a]Adjustments for age and BMI.

[b]Seaweed intake was controlled for total energy intake by the nutrient density method.

[c]Estimated mean and 95% confidence interval