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Salt intake is Closely Associated with Body Weight in Patients with Lifestyle-related Diseases

Yoshiaki Hashimoto[1], Azusa Futamura[1], Mami Ohgi[2]

Abstract

Objective: The aim of this study was to assess daily salt intake and associated factors in patients with lifestyle-related diseases.

Methods: The participants were 132 men and 123 women who regularly visited our center for treatment of lifestyle-related diseases. Salt intake was estimated using 24-h urine collections without adjustment for non-urinary losses.

Results: Men and women consumed an average of 13.1 and 10.2 g/day of salt per day (p<0.001), respectively. Calculation of salt intake per kg of body weight (BW) revealed that there was no difference between men and women. The correlation coefficient between salt intake and BW was higher than that between it and body mass index, body height, and standard BW. Multiple regression analyses revealed that salt intake was most closely associated with BW, followed by frequency of drinking and age. When adjusted for frequency of drinking and age, the salt intake of participants with BWs in the highest quartile was approximately 1.5 times greater than those with BWs in the lowest quartile.

Conclusion: These results suggest that restricting daily salt intake is more difficult for individuals who require a higher amount of total energy than those with lower total energy requirements.

Keywords sodium, salt intake, body weight, lifestyle-related diseases

The average daily salt intake among Japanese has gradually decreased, from 11.5 g in 2005 to 10.0 g (11.0 g in men, 9.2 g in women) in 2015[1].

However, Japanese salt intake remains high compared with countries in Europe, North and South America, and Africa[2]. In 2015, Japan's Ministry of Health, Labour and Welfare recommended a daily salt intake of <8 g in men and <7 g in women[3], while the World Health Organization reported that salt intake in adults should be <5 g[4]. For people with hypertension, the Japanese Society of Hypertension[5] recommends an intake <6 g and the American Heart Association6 recommends an intake of <3.8 g. These recommended intakes are independent of individual total energy requirements.

The Japan Diabetes Society places emphasis on a balance of nutrients and recommends that 50–60% of total energy requirements come from carbohydrates, no more than 20% from protein, and the remainder from lipids[7]. Naturally, individuals with higher energy requirements consume more food, and therefore more salt, assuming the foods they consume are seasoned to the same degree as those eaten by individuals with lower energy requirements.

In this study, we estimated daily salt intake using 24-h urine collections in patients with lifestyle-related diseases, and examined factors associated with salt intake.

Methods

Participants were patients who regularly visited our center for treatment of lifestyle-related diseases including diabetes, hypertension, and/or dyslipidemia, who participated in 24-h urine collection to assess daily salt intake. This study was approved by the ethics committee of Ageo Central General Hospital (No. 183, date of approval: 26 March, 2013). Verbal consent for the analytical use of anonymized date was obtained from all participants. Salt intake was estimated without adjustment for non-urinary losses from 24-h urine collections, which were conducted from January to March in 2014. The

[1]Center for Lifestyle-Related Diseases, Ageo Central General Hospital ; [2]Department of Medical Information Management, Ageo Central General Hospital

Contact : Yoshiaki Hashimoto, Center for Lifestyle-Related Diseases, Ageo Central General Hospital, 1–10–10, Kashiwaza, Ageo-City, Saitama 362–8588, Japan. Tel : +81–48–773–1111 ; Fax : +81–48–776–3126 ; E-mail : hashimoto.y@ach.or.jp

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amount of daily salt intake (g/day) was calculated using the following equation: urinary sodium concentration (mEq/L) × urine volume (L/day) × 58.5/1000. The expected creatinine excretion (mg/day) estimated from sex, age, body height (BH), and body weight (BW) was calculated according to the following equation: for men, BW (kg) × 15.12 + BH (cm) × 7.39 − age × 12.63 − 79.90; for women, BW (kg) × 8.58 + BH (cm) × 5.09 − age × 4.72 − 74.95[5]. If the percentage of the actual amount of urinary creatinine of the expected amount was <70% or >130%, collections were excluded from analyses. Other exclusion criteria were proteinuria ≥ 0.5 g/day and creatinine ≥ 1.3 mg/dL in men and ≥ 1.2 mg/dL in women. The final population whose urine collections were analyzed consisted of 132 men and 123 women. Participants with hypertension had been advised to reduce their daily salt intake to <6 g by a dietitian or a doctor. However, those without hypertension did not receive this advice.

Statistical analyses were performed using Dr SPSS II for Windows (IBM JAPAN, Ltd., Tokyo, Japan). Student's t-test and one-way analysis of variance were used to compare the means of two and three groups, respectively. Pearson's method was used to calculate correlation coefficients. Analysis of covariance was conducted to adjust for differences in some variables. Multiple regression analyses were performed to determine independent associated factors. Differences with a p-value <0.05 were considered significant.

Results

Participants' average ages were approximately the same for men (68.3 years old) and women (68.9 years old). Compared with women, men had a significantly higher BH and BW, but no significant difference in body mass index (BMI) was found (**Table 1**). Regarding lifestyle habits, fewer men than women had never smoked, while more men than women were current smokers. The frequencies of drinking and exercise were higher in men than women. All participants were taking at least one medication, to treat one or more of the following: diabetes (59.6%), hypertension (69.8%), and dyslipidemia (61.2%).

Daily salt intake was significantly different between men (13.1 g) and women (10.2 g) (**Table 1**). However, no difference was observed when salt intake was calculated per 1 kg of BW or standard BW. **Table 2** shows unadjusted and age-adjusted correlation coefficients between salt intake and variables related to body size. The correlation coefficient between salt intake and BW was higher than that between it and BMI, BH, and standard BW. We conducted multiple regression analyses selecting BW and BMI from body size parameters as explanatory variables (**Table 3**). Salt intake was most closely associated with BW, followed by frequency of drinking and age. No association was found between salt intake and consumption of antihypertensive drugs. When participants were stratified according to BW quartiles, salt intake was greatest in the highest quartile (**Table 4**). When adjusted for frequency of drinking and age,

Table 1. Participants' Clinical Chracteristics and Daily Salt Intake

	Men	Women	p
n	132	123	
Age	68.3 (7.7)	68.9 (9.4)	
BH (cm)	166.1 (6.0)	152.2 (6.1)	***
BW (kg)	67.2 (10.7)	55.2 (9.5)	***
BMI (kg/m^2)	24.4 (3.4)	23.8 (3.6)	
Drinking (times/week)	3.0 (3.2)	0.4 (1.5)	***
Exercise (times/week)	3.8 (2.7)	3.1 (2.8)	*
Smoking			
never (%)	12.1	87.8	***
past (%)	74.2	8.1	***
present (%)	13.6	4.1	**
Medication			
diabetes (%)	57.6	61.8	
hypertension (%)	69.7	69.9	
dyslipidemia (%)	56.1	66.7	
Salt intake /day			
g	13.1 (5.2)	10.2 (3.5)	***
g/kg BW	0.194 (0.068)	0.187 (0.056)	
g/kg SBW	0.215 (0.082)	0.201 (0.066)	

Variables are given as means ± SD. *: p < 0.05, * < 0.01, * < 0.001
BW: body weight, BH: body height, SBW: standard body weight
BMI: body mass index

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Table 2. Correlation Coefficients between Daily Sodium Intake and Participants' Body Size Variables

	Age	BW (kg)	BH (cm)	SBW (kg)	BMI (kg/m^2)
Unadjusted	-0.279	0.502	0.371	0.373	0.347
Adjusted for age	–	0.453	0.331	0.333	0.302

BW: body weight, BH: body height, SBW: standard body weight, BMI: body mass index

Table 3. Multiple Regression Analysis for Salt Intake

	Salt (g/day)	
	T value	*p*
Sex (female to male)	-0.228	0.820
Age (years)	-2.055	0.041
BMI (kg/m^2)	-0.368	0.714
BW (kg)	3.434	0.001
Smoking (present to never and past)	-1.421	0.157
Drinking (times/week)	2.209	0.028
Exercise (times/week)	-1.031	0.304
Antihypertensive drug (with to without)	-1.417	0.158

BMI: body mass index, BW: body weight

Table 4. Participants' Characteristics and Salt Intake Stratified According to Quartiles of Body Weight

BW (kg)	< 54	54–59	60–66	=/> 67	*p*
n	61	59	69	66	
Age	70.7 (8.8)	70.5 (8.1)	69.2 (7.3)	64.2 (8.5)	***
BH (cm)	151.3 (7.3)	156.3 (6.8)	162.3 (7.3)	166.7 (7.0)	***
BW (kg)	47.6 (4.4)	56.5 (1.7)	63.0 (2.2)	77.0 (8.3)	***
BMI (kg/m^2)	20.9 (2.5)	23.3 (2.0)	24.1 (2.4)	27.8 (2.9)	***
Drinking (times/week)	0.7 (1.9)	1.2 (2.6)	2.3 (3.1)	2.7 (3.1)	***
Exercise (times/week)	3.5 (2.9)	3.1 (2.6)	3.9 (2.9)	3.3 (2.7)	
Smoking					
never (%)	77.0	62.7	34.8	24.2	***
past (%)	21.3	33.9	52.2	59.1	***
present (%)	1.6	3.4	13.0	16.7	**
Medication					
diabetes (%)	55.7	54.2	56.5	71.2	
hypertension (%)	62.3	72.9	75.4	68.2	
dyslipidemia (%)	52.5	66.1	62.3	63.6	
Salt intake/day (unadjusted)					
g	9.4 (2.8)	11.2 (3.7)	11.0 (3.6)	15.0 (6.0)	***
g/kg BW	0.196 (0.054)	0.199 (0.066)	0.175 (0.056)	0.195 (0.071)	
Salt intake/day (adjusted for age and the frequency of drinking)$					
g	9.8 (0.5)	11.5 (0.5)	11.0 (0.5)	14.4 (0.5)	***
g/kg BW	0.202 (0.008)	0.203 (0.008)	0.174 (0.007)	0.186 (0.008)	*

Variables are given as means ± SD except for $ where variables are given as means ± SE. *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$
BW: body weight, BH: body height, BMI: body mass index

salt intake in the highest quartile was approximately 1.5 times greater than in the lowest quartile.

Discussion

Our results indicate that salt intake is very closely associated with BW. Among our study participants, salt intake in men was significantly greater than in women, though no differences were observed when intake was adjusted for BW. Partial correlation coefficients and multiple regression analyses revealed a close association between BW and salt intake. Salt intake among participants with BW in the highest quartile was approximately 1.5 times greater than that in the lowest quartile. Individuals with higher BWs are generally thought to

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eat more food to meet their total energy requirements, resulting in a higher salt intake compared with those with lower BWs.

However, the daily salt intakes recommended by academic societies are independent of individual total energy requirements. For example, the Japanese Society of Hypertension recommends a salt intake of <6g daily for people with hypertension[5] and the recommendation of the Japan Diabetes Society is <6g for diabetic patients with stage 3–5 nephropathy[8]. Therefore, it is likely that achieving the targets for daily salt intake is more difficult for individuals who require more energy than for those who require less.

Clinical trials have shown the difficulty in reducing sodium intake levels[9–11]. In the Trial of Hypertension Prevention (TOHP)-II, 24-h urinary sodium excretion in the intervention group was 2.5 g at 6 months and 3.1 g at 36 months, despite the target sodium intake being 1.8 g[11]. The extended post-trial surveillance of the TOHP trial revealed that only 1.4% of participants consumed <1.5 g sodium per day and 10% consumed <2.3 g/day[12]. This study suggested overall health benefits from reducing sodium intake to the 1.5–2.3 g/day range. However, whether a sodium intake of <1.5 g/day is safe remains unclear because data are sparse for this level of intake. Some studies have shown a J-shaped association between cardiovascular events and 24-h urinary sodium excretion, which was estimated from fasting morning specimens instead of 24-h urine collections[13,14]. Pooled analysis of data from four studies by Mente *et al.* showed that in both normotensive and hypertensive populations, sodium excretion of <3 g/day was associated with increased risk of cardiovascular events and death compared with sodium excretion of 4–6 g/day[14]. An association between high cardiovascular mortality and low sodium intake has also been reported in both type 1 and type 2 diabetes, where sodium intake was estimated from 24-h urine collections[15,16]. Although the mechanisms of this J-shaped association are unknown, an interesting hypothesis is that low sodium intake activates the renin system[17], resulting in increased cardiovascular events[14,18].

In this study, we estimated sodium intake from 24-h urine collections without adjusting for sodium excretion from routes other than urine. Holbrook *et al.* reported that 86% of sodium consumed orally was excreted into the urine[19] and Mickelsen *et al.* that 93.4% of sodium was recovered in urine during cool weather[20]. Considering excretion rates into urine, salt intake in our participants was markedly greater than the average Japanese salt intake obtained from the 2015 National Health and Nutrition Survey[1], which was based on household-level records[21]. This discrepancy may partly be explained by differences in measurement methods. Dietary questionnaires reportedly underestimate sodium intake, compared with 24-h urinary collections[22]. The amount of salt intake in our participants was close to amounts reported by Asakura *et al.*, which were estimated from 24-h urine collections[23].

One result that deserves consideration is that no difference in salt intake was observed between participants consuming and those not consuming antihypertensive medications. Long, long-term adherence to low sodium intake reportedly tends to be poor[10,11]. Therefore, it would be worth repeating urinary sodium measurements to encourage salt restriction. Another result that deserves consideration is that salt intake in our participants was negatively associated with age. This result is different from that of the 2015 National Health and Nutrition Survey[1], in which salt intake was greatest in the sixth decade of life. This difference may be explained by the fact that our participants had lifestyle-related diseases and were more careful about their health at higher ages.

In summary, we have shown a close association between sodium intake and BW. It is likely that achieving the level of salt intake recommended by academic societies is more difficult for individuals with higher energy requirements than for those with lower energy requirements. In the Dietary Approaches to Stop Hypertension Sodium trial, which investigated the effects of three different amounts of sodium intake on blood pressure, sodium levels were defined as those included in energy intakes of 2,100 kcal, and sodium intakes were proportionate to total energy requirements of individual participants[9]. It would be important to elucidate whether daily salt intakes appropriate for individuals are independent of their total energy requirements

Conflict of interest

The authors have no conflict of interest to declare.

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