Validity of a Self-Administered Diet History Questionnaire for Assessment of Sodium and Potassium
— Comparison With Single 24-hour Urinary Excretion —

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We developed a self-administered diet history questionnaire (DHQ) for use in prevention and control of cardiovascular diseases and cancer, and validated it by comparison with single 24-h urinary excretion of sodium (Na) and potassium (K). The subjects were 154 male and 69 female freshmen university students. Mean intakes (mmol/day) assessed by DHQ and the urinary excretion of Na were 196 and 165 respectively for men and 179 and 136 respectively for women. Those of K were 61.5 and 43.9 respectively for men and 56.8 and 41.6 respectively for women. The ratios of urinary excretion to dietary intake of Na were 0.97 in men and 0.84 in women. Those of K were 0.78 in men and 0.80 in women. The results for both Na and K were reasonable, except for Na in men. When Pearson correlation was examined between dietary and urinary Na and K, no significant correlations for Na in men ($r=0.14$) or women ($r=0.23$, $p=0.06$), or significant correlations for K in men ($r=0.34$, $p<0.001$) or women ($r=0.40$, $p<0.001$) were observed. The results suggest a reasonable ability to estimate a subject mean for Na in women, K in both sexes, and individual level for K for both sexes. The validity for individual level for Na intake is not conclusive because the duration of urine collection was too short. (*Jpn Circ J* 1998; **62:** 431–435)

Key Words: Dietary assessment; Urinary excretion; Validity; Sodium; Potassium

Several epidemiologic studies have suggested a relationship between intake level of sodium (Na) and hypertension[1], stroke[2] and stomach cancer[3,4] A negative relationship between intake level of potassium (K) and hypertension[1] and stroke mortality[1,5] has also been reported. These 2 nutrients are important for the prevention and control of these diseases. Reliable dietary assessment methods on these nutrients are necessary both for epidemiologic studies and for prevention and dietary therapy. Dietary assessment of Na is considered especially difficult because the intra-subject variation is wider than the inter-subject variation[6] and assessment of seasoning is difficult by either diet record or diet recall[7] Measurement of urinary Na excretion with multiple days of collection is considered a reliable method[6] It is, however, difficult to use in field settings and for general populations. Several questionnaires for the assessment of Na and/or K intake levels have therefore been developed and validated to date[8–10] Although some questionnaires were also developed and validated in Japan[11,12] they were all designed to categorize subjects into groups. To our knowledge, no questionnaire has been developed to assess Na and K intake levels as a quantitative value, ie, in mmol/day or g/day in Japan.

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We developed a self-administered diet history questionnaire (DHQ) for use in evaluation of nutrient intake levels and health education for both healthy individuals and high-risk populations. The DHQ was designed to obtain dietary habits for the previous month for total energy and 17 nutrients including Na and K. The test version of the DHQ was validated by a 3-day diet record and showed reasonable validity for most nutrients examined, but not Na[13] For a validation study of a newly developed dietary assessment questionnaire, studies with biomarkers of target nutrients are recommended[14] We therefore compared the dietary intake levels of Na and K estimated by the DHQ and the urinary excretion levels measured by a single 24-h urine collection in university students.

Methods

Data Collection

The subjects were freshmen students at Tokyo University of Fisheries. They filled out the DHQ in April, 1996. A single 24-h urine collection was performed 3 or 4 days after the dietary survey[15] The subjects collected their urine into 1-L plastic containers. Three and 2 containers were given to the male and female students, respectively. For subjects who habitually drank beer or relatively large quantities of non-alcoholic beverages, an additional container was given. All the subjects attended a class on how to collect 24-h urine and then voided all the urine in the bladder at that time, recorded the time, and started the urine collection. They were requested to record the estimated volume of urine when they failed to collect urine. They were also requested to record the time at which they finished the urine collection. They submitted

Table 1 Sodium (Na) and Potassium (K) Intake Assessed by a Self-Administered Diet History Questionnaire and Urinary Excretion Measured by Single 24-h Urinary Collection. Fresh Students of Tokyo University of Fisheries, April, 1996

		Men (n=154)		Women (n=69)	
		Mean±SD	Range	Mean±SD	Range
Dietary intake					
Na	(mmol/day)	196±70	49–410	179±59	61–332
From seasonings[1]	(% of total Na)	36		42	
From pulses[2]	(% of total Na)	11		12	
From vegetables and fruits[3]	(% of total Na)	19		17	
From other vegetable products[4]	(% of total Na)	6		6	
From animal products[5]	(% of total Na)	17		18	
From others[6]	(% of total Na)	12		6	
K	(mmol/day)	61.5±22.9	19.7–165.5	56.8±19.5	19.1–102.1
From seasonings[1]	(% of total K)	2		1	
From pulses[2]	(% of total K)	5		6	
From vegetables and fruits[3]	(% of total K)	23		20	
From other vegetable products[4]	(% of total K)	28		34	
From animal products[5]	(% of total K)	34		33	
From others[6]	(% of total K)	8		6	
Na/K	(mmol/mmol)	3.32±0.96	1.16–7.21	3.33±1.16	1.75–9.36
Total energy	(kcal/day)	2395±632	1140–4049	1877±521	1004–3829
Urinary excretion					
Na	(mmol/day)	165±54	57–357	136±59	25–359
K	(mmol/day)	43.9±17	13.4–132.9	41.6±17.5	13.8–96.8
Na/K	(mmol/mmol)	4.09±1.59	1.36–9.92	3.58±1.57	1.02–8.27
Creatinine	(g/day)	1.52±0.28	0.76–2.52	0.95±0.20	0.50–1.59
Volume	(ml/day)	880±286	350–1670	814±289	240–1580
Urinary-dietary ratio					
Urinary Na/dietary Na	(mmol/mmol)	0.97±0.66	0.24–6.59	0.84±0.46	0.23–2.29
Urinary K/dietary K	(mmol/mmol)	0.78±0.36	0.16–2.27	0.80±0.39	0.27–1.94

[1]Seasonings added during cooking processes are included. [2]Miso for miso soup is included. [3]Salted pickles, mushrooms, and sea plants are included. [4]Cereals, potatoes, nuts, and sweets. [5]Meats, fish, and dairy products. [6]All others not included in the above 5 food groups, such as noodle soup.

the collected urine and the above reports to the staff of the university health center. The completed questionnaires were checked by the authors and 1 nurse. Questionnaires with missing and/or illogical answers were filled in again by the subjects 1 week after the first survey. A total of 312 DHQs and 339 urine samples were obtained. The volume of voided urine was reported by the subject's estimation. Both sets of data were obtained from 310 subjects.

Estimation of Na, K, and Total Energy from DHQ

The questionnaire contained the following 7 sections: food frequencies, main staples, seasonings, alcoholic beverages, dietary behavior, nutrient supplements, and open-ended questions. Food intake was mainly calculated from the questions on frequency and relative quantity of foods listed in the questionnaire. The use of seasonings such as soy sauce, salt, oil, and sugar was estimated from the answers to questions on preference for cooking methods and seasonings and food items consumed. The calculation method was based on the diet history method developed by Burke[16] and others.[17] A specially designed program was used for the estimation of Na, K, and total energy intake in this analysis.

Measurement of Na, K, and Creatinine from the Urine Samples

The urine samples were analyzed for Na and K by flame photometry and creatinine by Jaffe's procedure. The 24-h urine volume was estimated from the collected and voided urine. The reported collection time was not considered for estimation of 24-h urine volume because most of the students collected urine over 24 h±30 min.

Data Analysis

Subjects were excluded from the analysis if they met either of the following criteria: (1) sex, body height, or body weight was missing; (2) the creatinine (mg)/body weight (kg) ratio was smaller than 14.4 or greater than 33.6 in men or smaller than 10.8 or greater than 25.2 in women.[18] A total of 310 subjects (154 men and 69 women) remained and were included in the analysis.

There is no definite consensus on the cut-off point for unreliable reporters for dietary assessments.[19] We compared 2 results analyzed with and without the exclusion criteria on unreliable reporters of DHQs. The difference in the results were almost negligible. Therefore, the results analyzed without the exclusion criteria on unreliable reporters of DHQ are presented.

The purpose of the study was to examine 2 types of validity of the questionnaire: one for population mean and the other for individual ranking. The means between dietary intake and urinary excretion were compared for each cation. Pearson correlation coefficients were calculated to examine the validity of individual level. Because of the skewed distribution of the values, log-transformed values were used for the analysis. When the data on nutrient intake levels obtained by a questionnaire are analyzed, adjustment for total energy is recommended.[20] Besides crude values, energy-adjusted intake levels and

Table 2 Pearson Correlation Coefficients for Sodium Between Dietary Intake and Urinary Excretion (mmol/day)

		Men (n=154)	Women (n=69)
Total sodium	*Crude[1]*	0.09	0.16
	Adjusted[1,2]	0.14	0.23#
Sodium from each food group[3]	*Adjusted[1,2]*		
Seasonings		0.05	0.13
Pulses		0.18*	0.24*
Vegetables and fruits		−0.01	−0.10
Other vegetable products		0.14	0.17
Animal products		0.05	0.13
Others		0.09	−0.12

*[1]After log transformation. [2]Adjusted for total energy for dietary sodium and for urinary creatinine for urinary sodium. [3]See Table 1 for the definition of food group. Significantly different from null correlation: #p=0.05−0.06, *p<0.05.*

Table 3 Pearson Correlation Coefficients for Potassium Between Dietary Intake and Urinary Excretion (mmol/day)

		Men (n=154)	Women (n=69)
Total potassium	*Crude[1]*	0.35***	0.28**
	Adjusted[1,2]	0.34***	0.40***
Potassium from each food group[3]	*Adjusted[1,2]*		
Seasonings		0.03	−0.21
Pulses		0.26***	0.15
Vegetables and fruits		−0.07	−0.03
Other vegetable products		0.19	0.42***
Animal products		0.28***	0.11
Others		0.09	0.04

*[1]After log transformation. [2]Adjusted for total energy for dietary potassium and for urinary creatinine for urinary potassium. [3]See Table 1 for the definition of food group. Significantly different from null correlation: *p<0.05, **p<0.01, ***p<0.001.*

Table 4 Means (±SDs) of Urinary Sodium Excretion Levels (mmol/day) Adjusted for Creatinine Excretion by Soup-Eating Behavior Assessed in a Self-Administered Diet History Questionnaire[1]

	Men (n=154)		Women (n=69)	
	n	Mean±SD	n	Mean±SD
Seldom	10	157±43	25	128±40
20%	33	164±56	21	145±73
40%	25	164±42	7	138±30
60%	22	159±56	5	122±24
80%	34	177±55	7	140±39
Almost all	29	157±56	4	109±31

[1]Question; how much soup do you eat when you eat noodle with soup?

creatinine-adjusted urinary excretion levels were used in the correlation analysis. Specifically for Na, the relationship between urinary Na excretion levels and answers to some salt-related questions were examined. The significance level was set at $p<0.05$ for all analyses.

Results

Table 1 shows means and standard deviations of the dietary intake assessed by DHQ and the urinary excretion of Na and K. Mean intake of Na was 196 mmol/day in men and 179 mmol/day in women. The mean intake as assessed by urinary excretion was 165 mmol/day and 136 mmol/day, respectively. The ratio of urinary excretion to dietary intake was 0.97 and 0.84, respectively. Mean intake of K was 61.5 mmol/day in men and 56.8 mmol/day in women. The mean intake as assessed by urinary excretion was 43.9 mmol/day and 41.6 mmol/day in men and women, respectively. The ratio of urinary excretion to dietary intake was 0.78 in men and 0.80 in women. Thirty-six percent and 42% of total Na derived from seasonings in men and in women, respectively. Seasonings were the largest source of Na. Vegetables and fruits, other vegetable products, and animal products were the main sources of K. Eighty-five percent and 87% of total K derived from these 3 food groups in men and women, respectively. When the ratio of Na to K was compared between dietary intake and urinary excretion, the former (3.32) showed a lower value than the latter (4.09) in men. The values were similar in women: 3.33 for the former and 3.58 for the latter.

Table 5 Means (±SDs) of Urinary Sodium Excretion Levels (mmol/day) Adjusted for Creatinine Excretion by Frequency of eating on Selected Foods Rich in Salt in a Self-Administered Diet History Questionnaire

	Men (n=154)		Women (n=69)	
	n	Mean±SD	n	Mean±SD
Miso soup				
Once a month or less	0		0	
2−3 times a month	24	150±61	9	102±40
Once a week	25	162±56	8	94±31
2−3 times a week	34	155±42	16	157±63
4−6 times a week	26	161±48	16	143±30
Once a day	23	172±37	12	140±63
More than or equal to twice a day	22	192±64	8	136±26
Salted pickles				
Once a month or less	30	154±51	11	121±42
2−3 times a month	27	150±58	15	132±61
Once a week	30	165±51	8	121±35
2−3 times a week	36	175±41	16	133±44
4−6 times a week	21	167±51	10	125±34
Once a day	8	198±67	8	172±71
More than or equal to twice a day	2	135±104	1	190
Dried and salted fish				
Once a month or less	27	156±63	17	129±58
2−3 times a month	44	163±46	23	127±41
Once a week	46	169±47	16	127±41
2−3 times a week	30	165±56	11	169±64
4−6 times a week	6	170±82	2	117±2
Once a day	1	148	0	
More than or equal to twice a day	0		0	

The Pearson correlation coefficients for Na between dietary intake and urinary excretion are shown in Table 2. The energy- and creatinine-adjusted correlation was 0.14 in men and 0.23 ($p=0.06$) in women. Table 3 shows the corresponding values for K. The energy- and creatinine-adjusted correlation was 0.34 ($p<0.001$) in men and 0.40 ($p<0.001$) in women.

Table 4 shows the means of urinary Na excretion levels according to soup-eating behavior. Table 5 shows the means of urinary Na excretion levels according to the frequency of eating 3 selected foods rich in salt. Table 6 shows the mean urinary Na excretion levels according to the level of salt preference. Three questions about salt preference were asked. No statistical difference,

Table 6 Mean (±SD) of Urinary Sodium Excretion Levels (mmol/day) Adjusted for Creatinine Excretion by Salt Preference Assessed by 2 Questions in a Self-Administered Diet History Questionnaire

	Men		Women	
	n	*Mean±SD*	*n*	*Mean±SD*
Question A: Are foods at your home saltier than those in restaurants?				
		(n=153)		*(n=69)*
Much less salty	17	155±53	13	126±62
Less salty	57	169±40	29	135±53
Similar	58	162±52	20	134±46
Saltier	18	166±74	6	144±38
Much saltier	3	169±123	1	130
*Question B: Count the number of foods for which you use sauce or salt when you eat the following 13 kinds of foods?**				
		(n=154)		*(n=69)*
1	1	206	0	
3	3	145±70	0	
4	8	174±29	5	133±30
5	13	155±50	3	86±8
6	25	164±66	13	132±57
7	23	153±46	14	125±62
8	34	172±51	18	146±51
9	22	164±37	12	127±37
10	17	162±49	4	172±42
11	3	192±107	0	
12	5	169±94	0	
13	0		0	
*Queation C: Do you use more sauce or salt than others do when you eat the following 13 kinds of foods?**				
		(n=154)		*(n=69)*
Much less	5	165±57	8	120±66
Relatively less	25	153±47	20	138±56
Usual	97	166±55	31	131±39
Relatively more	27	169±49	10	143±62
Much more	0		0	

**The 13 foods were curry and rice, raw fish, sliced cabbage, Tenpura, pickled Chinese cabbage, boiled and seasoned spinach, raw tofu, sunny side up, grilled salmon, Chinese dumplings (Gyoza), fermented soy beans (Natto), dried small fish, and wakame and vinegar.*

examined by one-way ANOVA, was observed in any analyses in Tables 4–6. Only for the frequencies of eating "miso-soup" and "salted pickles" in men were slight gradients observed (Table 5).

Discussion

The study examined the relationship between dietary intake of Na and K assessed by a DHQ and urinary excretion measured by single 24-h urine collection. The observed mean ratio of urinary excretions to dietary intake, for Na 84% in women and 78% in men and for K 80% in women (Table 1), were similar to the values obtained by a previous carefully designed study: 86% for Na and 77% for K.[21] The ratio of Na in men was higher in this study (97%) than in the previous study (82%).[21] The results suggest a reasonable validity of the DHQ for the assessment of subject means of K for both sexes and of Na only for women. The reasonable results for K indicate that incompleteness of the urine collection would only be a minor problem if it occurred. The Na intake assessed by DHQ in men seems to be less reliable judging from the higher excretion/intake ratio for Na in men than in the previous study.[21]

For the individual ranking, only K showed a significant correlation between dietary intake and urinary excretion (Table 3). The Pearson correlation coefficients between urinary excretion of K and dietary intake assessed by diet record or recall varied from 0.23 to 0.76 in 5 methodologic studies.[22–26] All the studies assessed the diets over the same period as or some days before the urine collection. In contrast, the DHQ asked for dietary habits of the previous month. Moreover, most studies collected urine for more than 1 day. Considering these differences, the validity of K intake at an individual level obtained in the present study might have been underestimated.

The DHQ seemed valid enough for the assessment of subject mean of Na intake, at least for women. But the mean in men seemed less reliable. Thirty-six percent and 42% of Na derived from seasonings in men and in women, respectively. Although comparison is difficult because of the different population characteristics such as sex and age range, these values are lower than the average level for Japanese (58%) reported in the National Nutrition Survey, Japan, in 1994.[27] The lower mean intake of Na observed in men may be due partly to the underreporting of Na derived from seasonings. For the individual ranking, there was a positive, but not significant, correlation between dietary intake and urinary excretion of Na (Table 2). Only the correlation in women showed a borderline significance ($r=0.23$, $p=0.06$). All but 1 of the previous 6 studies that examined a correlation between urinary excretion of Na and dietary intake assessed by diet record or recall showed a higher degree of correlation ($r=0.04-0.91$).[22–25,28,29] This may be due to a difference in study designs between the previous studies and the present study as discussed above for K. A single 24-h urine collection was used in this study because this was easy for the study population. However, it has been suggested that it is necessary to collect urine for at least 8 days to achieve a precision of less than 10% error in order to estimate Na intake at an individual level from urinary excretion.[6] Therefore, urine collection over a longer period of time is necessary to validate the questionnaire for individual ranking of Na intake.

Tables 4–6 do not show any significant relationship between urinary excretion of Na and the answers to salt-related questions. Pietinen et al[9] reported significant differences for single 24-h urinary Na excretion by category for similar questions in a Finnish population. The sample size was, however, much greater: 751 men and 720 women. On the other hand, a recent study reported that salt preference was unrelated to sodium consumption in both young and older adults.[30] It suggested that the correlation between salt preference and total Na intake was low. Intake of Na measured by diet analysis in 6 subjects over a week showed a high degree of correlation with meal size in grams ($r=0.53$, $p<0.001$).[31] Two studies indicated the relative importance of amount of foods consumed rather than subjective measures of salt preference. They support the approach taken in the DHQ for the calculation of Na intake, ie including both salt preference and amount of foods consumed.

Some questionnaires have been developed to assess Na intake.[9–12,29] They reported a significant correlation between a single 24-h urinary Na excretion and the score or category calculated from the questions. But these questionnaires were designed to assess Na intake level only. Not only Na but also other nutrients are suggested as dietary risk factors for cardiovascular disease[1,2,32] and stomach cancer[1,2,33] A dietary assessment method that can measure intake levels of multiple nutrients other than Na only would seem to be more useful. The DHQ was designed to assess 17 nutrients including Na and K, and total energy.

This study examined the validity of a DHQ for assessment of Na and K intake using adolescents living in an urban area. This age range is important from the viewpoint of primary prevention because cardiovascular disease and cancer are related to long-term lifestyle[34,35] Populations at high risk of cardiovascular disease and cancer are, however, older than the population examined in this study. A validation study is also necessary for older populations.

The procedures used to calculate nutrient intake levels in the DHQ were developed theoretically from an extensive review of the literature. However, the data in the literature were mostly obtained in clinical settings or laboratory experiments. The applicability of these data to the development of a calculation procedure for nutrient intake levels in DHQs remains unresolved.

In conclusion, a reasonable validity for the DHQ was obtained for K for subject mean and individual ranking in both sexes, and for Na for subject mean in women. Based on the results, further validation studies with multiple-day urine collection using broader populations, such as elderly and rural populations, are necessary, as well as the improvement of the DHQ itself.

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References

1. Intersalt Cooperative Research Group: Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 h urinary sodium and potassium excretion. *Br Med J* 1988; **297:** 319–328
2. Sasaki S, Zhang XH, Kesteloot H: Dietary sodium, potassium, saturated fat, alcohol and stroke mortality. *Stroke* 1995; **26:** 783–789
3. Tsugane S, Akabane M, Inami T, Matsushima S, Ishibashi T, Ichinowatari Y, et al: Urinary salt excretion and stomach cancer mortality among 4 Japanese populations. *Cancer Causes Control* 1991; **2:** 165–168
4. Joossens JV, Hill MJ, Stamler R, Lesaffre E, Dyer A, Nichols R, et al: Dietary salt, nitrate and stomach cancer mortality in 24 countries. *Int J Epidemiol* 1996; **25:** 494–504
5. Khaw KT, Barrett-Connor E: Dietary potassium and stroke-associated mortality. A 12-year prospective population study. *N Engl J Med* 1987; **316:** 235–240
6. Liu K, Cooper R, McKeever J, McKeever P, Byington R, Soltero I, et al: Assessment of the association between habitual salt intake and high blood pressure: methodological problems. *Am J Epidemiol* 1979; **110:** 219–226
7. Paul AA, Southgate DAT: Conversion into nutrients. *In:* Cameron ME, van Staveren WA, editors. Manual on methodology for food consumption studies. Oxford: Oxford University Press, 1988: 121–144
8. Hill L, Montandon CM, Scott L, Hammond GS, Tristan MP, Baer P: Validation of a salt intake questionnaire by urinary electrolyte excretion (abstract). *Prev Med* 1980; **9:** 436
9. Pietinen P, Tanskanen A, Tuomilehto J: Assessment of sodium intake by a short dietary questionnaire. *Scand J Soc Med* 1982; **10:** 105–112
10. Miller BD, Beard TC: Avoidance of dietary sodium – a simple questionnaire. *Med J Aust* 1988; **149:** 190–192
11. Nagayama I, Osato S, Ozeki S, Kora H, Matsuda T, Yasutake R, et al: A check on the accuracy of methods in estimating sodium intake (in Japanese). *J Jpn Soc Nutr Food Sci* 1985; **38:** 89–93
12. Ikeda J, Higashi A, Watanabe Y, Kawai K: A method for estimation of salt intake from the results of a food frequency questionnaire (in Japanese). *Jpn J Hyg* 1988; **43:** 907–916
13. Sasaki S, Yanagibori R: Validity of self-administered diet history questionnaire: comparison with 3-day diet record (Abstract, in Japanese, authors' translation). *Jpn J Public Health* 1996; **43:** 809
14. Bates CJ, Thurnham DI, Bingham SA, Margetts BM, Nelson M: Biochemical markers of nutrient intake. *In:* Margetts BM, Nelson M, editors. Design concepts in nutritional epidemiology. Oxford: Oxford University Press, 1991: 192–265
15. Kesteloot H, Joossens JV: The relationship between dietary intake and urinary excretion of sodium, potassium, calcium and magnesium: Belgian Interuniversity Research on Nutrition and Health. *J Hum Hypertens* 1990; **4:** 527–533
16. Burke BS: The dietary history as a tool in research. *J Am Diet Assoc* 1947; **23:** 104–111
17. Marr JW: Individual dietary surveys: purposes and methods. *World Rev Nutr Dietet* 1971; **13:** 106–164
18. WHO Regional Office for Europe: Estimation of sodium intake and output: review of methods and recommendations for epidemiological studies. Report on a WHO meeting by the WHO collaborating center for research and training in cardiovascular diseases. Geneva: WHO, 1984
19. Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, et al: Critical evaluation of energy intake data using fundamental principals of energy physiology. 1. Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr* 1991; **45:** 569–581
20. Willett W, Stampfer MJ: Total energy intake: implications for epidemiologic analysis. *Am J Epidemiol* 1986; **124:** 17–27
21. Holbrook JT, Patterson KY, Bodner JE, Douglas LW, Veillon C, Kelsay JL, et al: Sodium and potassium intake and balance in adults consuming self-selected diets. *Am J Clin Nutr* 1984; **40:** 786–793
22. Schachter J, Harper PH, Radin ME, Caggiula AW, McDonald RH, Diven WF: Comparison of sodium and potassium intake with excretion. *Hypertension* 1980; **2:** 695–699
23. Caggiula AW, Wing RR, Nowalk MP, Milas NC, Lee S, Langford H: The measurement of sodium and potassium intake. *Am J Clin Nutr* 1985; **42:** 391–398
24. Clark AJ, Mossholder S: Sodium and potassium intake measurements: dietary methodology problems. *Am J Clin Nutr* 1986; **43:** 470–476
25. Gregory J, Foster K, Tyler H, Wiseman M: The dietary nutritional survey of British Adults. London: HMSO, 1990
26. Bingham AS, Gill C, Welch A, Cassidy A, Runswick SA, Oakes S, et al: Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-h urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers. *Int J Epidemiol* 1997; **26:** S137–S151
27. Ministry of Health and Welfare: Kokumin Eiyou no Genjou (Results of National Nutrition Survey, 1994) (in Japanese). Tokyo: Daiichi Shuppan Publishers, 1996
28. Yamori Y, Kihara M, Fujikawa J, Soh Y, Nara Y, Ohtaka M, et al: Dietary risk factors of stroke and hypertension in Japan, Part 2: Validity of urinarysis for dietary salt and protein intakes under a field condition. *Jpn Circ J* 1982; **46:** 939–943
29. Shepherd R, Farleigh CA, Land DG: Estimation of salt intake by questionnaire. *Appetite* 1985; **6:** 219–233
30. Drewnowski A, Henderson SA, Driscoll A, Rolls BJ: Salt taste perceptions and preferences are unrelated to sodium consumption in healthy older adults. *J Am Diet Assoc* 1996; **96:** 471–474
31. Yoshida S, Ikebe K: Correlation between analyzed and calculated values of daily sodium and potassium intake by duplicate portion study during a one-week period (in Japanese). *J Jpn Soc Nutr Food Sci* 1988; **41:** 315–319
32. Ascherio A, Rimm EB, Giovannucci EL, Colditz GA, Rosner B, Willett WC, et al: A prospective study of nutritional factors and hypertension among US men. *Circulation* 1992; **86:** 1475–1484
33. Kono S, Hirohata T: Nutrition and stomach cancer. *Cancer Causes Control* 1996; **7:** 41–55
34. Klag MJ, Ford DE, Mead LA, He J, Whelton PK, Liang K-Y, et al: Serum cholesterol in young men and subsequent cardiovascular disease. *N Engl J Med* 1993; **328:** 313–318
35. Doll R, Peto R, Wheatley K, Gray R, Sutherland I: Mortality in relation to smoking: 40 years' observations on male British doctors. *Br Med J* 1994; **309:** 901–911