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Relationship of household salt intake level with long-term all-cause and cardiovascular disease mortality in Japan: NIPPON DATA80

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Abstract

In Asian countries, a major source of salt intake is from seasoning or table salt added at home. However, little is known about the adverse effects of salt intake evaluated according to household unit. We investigated the relationship between household salt intake level and mortality from all-cause and cardiovascular diseases (CVDs). Participants included 8,702 individuals (56% women) who were living with someone else and who were aged 30–79 years and enrolled in the National Nutritional Survey of Japan in 1980 with a 24-year follow-up. Household nutrient intake was evaluated using a 3-day weighing record method in which all foods and beverages consumed by any of the household members were recorded. The household salt intake level was defined as the amount of salt consumed (g) per 1000 kcal of total energy intake in each household, and its average was 6.25 (2.02) g/1000 kcal. During the follow-up, there were 2,360 deaths (787 CVD, 168 coronary heart disease [CHD], and 361 stroke). Cox proportional hazard ratios (HRs) for an increment of 2 g/1000 kcal in household salt intake were calculated and adjusting for sex, age, body mass index, smoking status, alcohol consumption status, self-reported work exertion level, household potassium intake, household saturated fatty acid intake, and household long-chain n-3 polyunsaturated fatty acid intake. The HRs (95% confidence intervals) were 1.07 (1.02, 1.12) for all-cause mortality, 1.11 (1.03, 1.19) for CVD, 1.25 (1.08, 1.44) for CHD, and 1.12 (1.00, 1.25) for stroke. The household salt intake level was significantly associated with long-term risk of all-cause, CVD, CHD, and stroke

mortality in a representative Japanese population.

Key words: Household, Salt intake, Cardiovascular diseases, Cohort study

Introduction

Many studies have clearly shown that excessive salt intake is associated with elevated blood pressure (BP) [1–3] and cardiovascular disease (CVD) risks,[4–11] and evidence from randomized controlled trials has shown that a low-salt diets lower BP,[5,12] thereby reducing the risks of CVD and long-term mortality.[13] As such, the World Health Organization recommends a reduction in salt intake to <5 g/day.[14] However, the average salt intake in most countries remains higher than the recommended level.[15]

To reduce salt intake in the population, the perspective of family members on salt intake might be important because members of the same household often eat similar foods in the home environment. For example, hot pot dishes are usually cooked at home and are consumed by all household members in Asian countries, including Japan. On the other hand, the main source of salt in western countries was processed foods.[16,17] In any case, household members cannot modify the amount of salt that has already been added to a meal. Moreover, salt taste sensitivity develops early in life,[18] and salt taste preference is reported to be acquired via exposure to salty foods.[19] Several studies have reported an association of salt intake among families.[20,21] In Japan, salt taste preference among adults is associated with salt intake and the frequency of salty-food intake.[22,23] However, there are few reports on the adverse effects of salt intake, evaluated according to household unit.

In the National Nutrition Survey in Japan (NNSJ), salt intake was evaluated by

household unit using the dietary weighing record method. In the present study, we investigated the relationship between household salt intake levels and long-term mortality from all-cause, CVD, coronary heart disease (CHD), and stroke in a representative Japanese cohort based on the NNSJ.

Methods

Study cohort and ethics

The National Integrated Project for Prospective Observation of Non-Communicable Disease and its Trend in Aged 1980 (NIPPON DATA80) is a cohort study based on the NNSJ and the National Survey on Circulatory Disorders in Japan conducted by the Japanese government in 1980. The details of the cohort are provided elsewhere.[24–27]

Briefly, 300 survey districts were randomly selected throughout Japan, and a total of 10,546 individuals aged 30 years and over participated in the baseline survey, with a participation rate of 77%. Baseline data consisted of a nutritional survey, medical examinations including BP measurement and blood tests, and a self-administered questionnaire on health-related status and medical history.

The present study was conducted in accordance with the Ethics Committee of Shiga University of Medical Science (R2005-021).

Participants

For the present analysis, we selected 10,147 participants who were living with someone else, such as another family member, at baseline. Among the participants, 92 were excluded due to extreme values of simple mean energy intake among household members [<0.5th percentile (1062 kcal/day) and >99.5th percentile (3520 kcal/day)]. Another 1353 participants were excluded for the following reasons: age 80 years or older (n=164), history of myocardial infarction (n=48) or stroke (n=101), missing baseline information from the nutritional survey (n=114) and/or self-administered questionnaire (n=36) and/or medical examinations (n=14), and loss to follow-up (n=886). The remaining 8,702 participants were included in the analysis.

Definition of household salt intake level and other nutrients

In the NNSJ of 1980, dietary records for an entire household were collected for 3 consecutive days, excluding Saturday, Sunday, and national holidays, using a weighing food record method. Trained dietitians visited the home of participants at least once during the survey, asked to weigh all foods and beverages, and recorded the amounts consumed by any of the household members during the 3 days. The dietitians reviewed and confirmed the accuracy of the data and assigned food codes using standard food tables. The dietary records

were then used to calculate nutrient and food group intakes for each household.[28,29]

In the present study, we used a simple density of salt as the household salt intake level (g/1000 kcal). Specifically, we obtained the simple salt density by dividing the total salt consumption (g) by the total energy intake (per 1000 kcal). Similarly, we used densities to assess other nutrients. For energy-supplying nutrients, intake was calculated as the % of total energy intake (% kcal); other nutrients were calculated as g/1000 kcal or mg/1000 kcal.

Other measurements

Details of the baseline medical examination are described elsewhere.[24–27] Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Trained observers measured baseline BP using a standard mercury sphygmomanometer. Nonfasting blood samples were obtained and centrifuged soon after collection. Concentrations of total cholesterol and glucose were measured enzymatically. Information on medical history, smoking status (never, past, and current), alcohol consumption status (none, occasional, and daily) was collected using a self-administered questionnaire. We used self-reported work exertion level (heavy, relatively heavy, moderate, relatively mild, and mild) as a proxy for daily physical activity.

Follow-up survey

Participants were followed until 2004. The survival status of participants was followed up using registration records required under the Family Registration Law in the municipalities where participants resided. National Vital Statistics were used to identify causes of death, with permission from the Management and Coordination Agency of the Japanese government. The underlying causes of mortality in the National Vital Statistics were coded according to the International Classification of Diseases, 9th Revision (ICD-9) until the end of 1994, and the International Classification of Diseases, 10th Revision (ICD-10) from the beginning of 1995. The details of classification are described elsewhere.[26] The corresponding ICD-9 and ICD-10 codes used in the present study were as follows: CVD mortality included 393-459 (ICD-9) and I00-I99 (ICD-10), CHD mortality included 410-414 (ICD-9) and I20-I25 (ICD-10), and stroke mortality included 430-438 (ICD-9) and I60-I69 (ICD-10).

Statistical analysis

Hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated using a Cox proportional hazards model to evaluate the relationship between household salt intake level and all-cause mortality, CVD mortality, CHD mortality, and stroke mortality. First, we treated household salt intake level as a continuous variable and calculated HRs per 2 g/1000 kcal increment in household salt intake level; 1 standard deviation of household salt intake

level was 2.02 g/1000 kcal. Second, we calculated HRs for quartiles of household salt intake level, using the lowest quartile as the reference group.

For both analyses, we ran three models: Model 1 was adjusted for sex and age; model 2 was adjusted for sex, age, BMI, smoking status, alcohol consumption status, and work exertion level; and model 3 was adjusted for variables in model 2 plus household intake density of potassium, saturated fatty acids, and long-chain n-3 polyunsaturated fatty acids (the sum of eicosapentaenoic acid and docosapentaenoic acid).[27] In considering covariates, we did not include BP in the above three models because we considered that salt intake was a factor that modifies BP.

As a sensitivity analysis, we performed the same analysis excluding those participants who reported the use of antihypertensive medication at baseline. In addition, for CHD mortality, we tested a model in which serum total cholesterol was adjusted instead of nutrients that effect lipid metabolism, as well as a model in which BMI was not adjusted. We ran all models to calculate p values for trends, using household salt intake level as a continuous variable. All analyses were performed as sex-combined analyses because the interaction by sex was not significant in most of the analyses. All data were analyzed using IBM SPSS version 22 (IBM Japan Ltd., Tokyo, Japan). All reported p-values are two-tailed; $p<0.05$ was considered to indicate statistical significance.

Results

The mean age (standard deviation) of the 8,702 participants was 49.4 (12.6) years, and 44.4% of participants were men. Table 1 summarizes the baseline characteristics of the participants. Sixty-three percent of participants belonged to households consisting of three to five people. The mean household salt intake level (standard deviation) was 6.25 (2.02) g/1000 kcal. The proportion of participants taking antihypertensive medication was 10.3%.

During the 186,186 person-years of follow-up (mean follow-up period, 21.4 years), there were 2,360 deaths; of these, 33.3% (n=787) were due to CVD, 7.0% (n=168) were due to CHD, and 15.3% (n=361) were due to stroke.

As shown in Table 2, the HRs for a 2.0 g/1000 kcal increment in household salt intake level were significantly higher for all-cause mortality, CVD mortality, and CHD mortality in model 1. The association was similar after adjusting for BMI, smoking status, alcohol consumption status, and work exertion level in model 2. When we adjusted for the intakes of other nutrients in model 3, the positive association also became significant for stroke mortality; the HRs (95% CIs) for a 2.0 g/1000 kcal increment in household salt intake level were 1.07 (1.02, 1.12) for all-cause mortality, 1.11 (1.03, 1.19) for CVD mortality, 1.25 (1.08, 1.44) for CHD mortality, and 1.12 (1.00, 1.25) for stroke mortality. The results were similar after adjustment for systolic BP at baseline (data not shown). The results were also similar when we used a multilevel analysis including household as a random effect (data not

shown).

When we conducted the same analysis after excluding 893 participants with antihypertensive medication use at baseline, the results were similar (Supplemental Table 1). Additionally, in the sensitivity analysis for CHD mortality, the results were similar in the model where serum total cholesterol was adjusted instead of nutrients affecting lipid metabolism and in the model where BMI was not adjusted (data not shown).

Discussion

In the present study, we found a considerable association between household salt intake level and the risk of all-cause, CVD, CHD, and stroke mortality in a long-term cohort study of a representative Japanese population from a national survey. The relationship was significant and independent of other confounding factors, including sex, age, BMI, smoking and alcohol consumption status, work exertion level, and the intake of several other nutrients.

To our knowledge, this is the first study examining the effect of household salt intake level on long-term mortality risk. We could perform household-based analysis by using the NNSJ as a baseline assessment of salt intake level, in which all foods and beverages consumed by any household member were assessed as a household unit. Another strength lies in the methods of the baseline survey. Participants were enrolled from 300 survey districts

randomly selected from across Japan. Dietary data obtained for 3 days were reviewed by trained dieticians using weighed food dietary records, a standardized method applied in the NNSJ.

Regarding individual salt intake, many cohort studies and meta-analyses have clearly shown the adverse effect of excessive salt intake on cause-specific mortality.[4,5,7] In Japan, where the salt intake is far above the recommended levels,[29] cohort studies have reported a positive relationship between individual salt intake and CVD events,[6] CVD mortality,[9] and stroke mortality,[8] although these findings were obtained using food frequency questionnaires. However, we could not find any studies focusing on the effect of household salt intake levels. Therefore, we could not simply compare our findings with previous studies. Considering our results, the HRs for a 2.0 g/1000 kcal increment in household salt intake level were higher in model 3 in which we added household intake density of potassium and long-chain n-3 polyunsaturated fatty acids as covariates. In Japan, a considerable amount of salt was consumed as salted pickles, miso soup, salted fish, and boiled foods.[30] Participants in households with a high salt intake level may consume many vegetables and fish, and the adjustment of the intakes of the nutrients contained in these foods would have increased the HRs because these nutrient intakes have been reported to be inversely associated with CVD risk.[27,31]

In our analysis, the results were similar after adjustment for systolic BP at baseline,

even though BP was considered to be an important mediator between salt intake and mortality.[1-3] This finding can be explained as follows: Participants who belonged to a household with a high salt intake level would consume a large amount of salt regularly, which might cause long-term BP increase during the follow-up period. Therefore, the relationship between household salt intake and long-term mortality could not be significantly adjusted for only BP at baseline. When we excluded the participants with antihypertensive medication use at baseline, the results were also similar but appeared to be clearer than those of the main analysis. This may be due to a reverse causality that, in households with treated participants, salt intake level may have already been reduced or salt intake level would decrease during the follow-up period.

In Asian countries such as Japan, a main source of salt is seasoning used in cooking, including salt, soy sauce, miso paste, and table salt used at home.[16,17,32] In Japan, eating out is not very common. According to the results of the NNSJ in 2016, approximately 80% of participants ate breakfast and dinner at home, and approximately 60% also ate lunch at home.[33] Women in Japan spend much more time engaged in food management (1.5 hours/day) than men (0.2 hours/day);[34] therefore, women generally prepare meals for household members. Hot pot dishes such as miso soup and *nimono* (simmered dishes, mostly seasoned with soy sauce) are usually cooked at home and consumed by all household members. Furthermore, household members share table salt and self-serve soy sauce in the

same dining environment. Under these circumstances, Michikawa et al. reported that a woman's salt taste influenced her husband's BP.[35] Therefore, it is important to understand the effect of household salt intake in countries where meals cooked at home are most frequently consumed.

In many Western countries, the main source of salt is salt added to processed foods produced by the food industry.[16,36] A public health intervention in the United Kingdom to reduce the amount of salt in bread led to successfully lowering salt intake among the population that consumed commercially prepared bread.[37,38] It has been suggested that the preference for salty taste begins to develop around the age of 4 months,[18] but the preference for salt can be lowered after approximately 3 months on a low-salt diet, even in adults.[19] Household members cannot modify the amount of salt that has already been added to a meal. Therefore, the perspective of the household is important in Western countries as well as in other regions. Further investigation of household salt intake levels is needed among different populations.

Several limitations of our study need to be considered. First, in the evaluation of household salt intake level, table salt added by household members themselves and salt added to foods consumed when eating out could not be accurately assessed. However, household members usually use salt and other condiments on the same table, and the proportion of the Japanese population that consumed meals outside the home in 1980 was not high. Second,

household salt intake level and other variables were assessed only at baseline in 1980; we did not consider the changes in household and dietary habits, although the number of single-person households has been increasing[39] and the consumption of processed foods and eating out has been increasing especially in the younger generation during the long follow-up period.[17] Third, we did not adjust for alcohol intake in the multivariate-adjusted models. Fourth, we did not consider other factors of the household, such as family members with similar genetic factors and socioeconomic status.

Conclusion

In the present 24-year cohort study of a representative Japanese population, we found a positive linear association between household salt intake level and all-cause, CVD, CHD, and stroke mortality. Our findings highlight the importance of considering the entire household to improve health interventions for salt reduction. Further investigation is needed among different populations to confirm our results.

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Conflicts of interest: All authors declare that there are no conflicts of interest.

Appendix

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Table 1. Baseline characteristics of study participant: NIPPON DATA80, 1980.

	Total	Men	Women
No. of participants	8702	3871	4831
Age, years	49.4 (12.6)	49.4 (12.6)	49.3 (12.6)
Body mass index, kg/m^2	22.7 (3.1)	22.6 (2.8)	22.9 (3.4)
Blood pressure, mmHg			
Systolic	135 (21)	138 (21)	133 (21)
Diastolic	81 (12)	84 (12)	80 (12)
Antihypertensive medication, n (%)	893 (10.3)	369 (9.5)	524 (10.8)
Serum total cholesterol, mg/dL	188.4 (33.5)	186.1 (32.8)	190.2 (34.0)
Blood glucose, mg/dL	100.0 (29.8)	100.8 (31.6)	99.3 (28.2)
Diabetes, n (%)[a]	330 (3.8)	205 (5.3)	125 (2.6)
Smoking status, n (%)			
Never	5032 (57.8)	702 (18.1)	4330 (89.6)
Past	797 (9.2)	700 (18.1)	97 (2.0)
Current	2873 (33.0)	2469 (63.8)	404 (8.4)
Alcohol consumption status, n (%)			
None	4833 (55.5)	961 (24.8)	3872 (80.1)
Occasional	1862 (21.4)	1034 (26.7)	828 (17.1)
Daily	2007 (23.1)	1876 (48.5)	131 (2.7)
Work exertion level, n (%)			
Heavy	774 (8.9)	534 (13.8)	240 (5.0)
Relatively heavy	1494 (17.2)	881 (22.8)	613 (12.7)
Moderate	3127 (35.9)	1392 (36.0)	1735 (35.9)
Relatively mild	1644 (18.9)	604 (15.6)	1040 (21.5)
Mild	1616 (18.6)	453 (11.7)	1163 (24.1)
Unknown	47 (0.5)	7 (0.2)	40 (0.8)
Number of household members, n (%)			
2	1363 (15.7)	586 (15.1)	777 (16.1)
3–5	5511 (63.3)	2447 (63.2)	3064 (63.4)
6 or more	1828 (21.0)	838 (21.6)	990 (20.5)
Household-based nutrient intake			
Salt, g/1000 kcal	6.25 (2.02)	-	-
Potassium, mg/1000 kcal	1327 (229)	-	-
Saturated fatty acids, % kcal	6.76 (1.70)	-	-
LCn-3FA, % kcal	0.43 (0.23)	-	-

Abbreviation: LCn-3FA: Long-chain n-3 polyunsaturated fatty acids.

Notes: Values are mean (standard deviation) or number (%).

[a] Diabetes was defined as having history of diabetes and/or fasting blood glucose 126 mg/dL or over, and/or non-fasting blood glucose 200 mg/dL or over.

Table 2. Multivariable-adjusted HRs and 95% CIs for mortality by quartiles among 8,702 participants aged 30–79 years: NIPPON DATA80, 1980-2004.

	Quartiles of household salt intake level, g/1000 kcal				2.0 g/1000 kcal increment of household salt intake level	p for trend
	Q1 (≤4.9)	Q2 (4.9–5.9)	Q3 (5.9–7.2)	Q4 (≥7.2)		
Number of participants	2179	2175	2174	2174		
All causes, n (%)	530 (24.3)	521 (24.0)	617 (28.4)	692 (31.8)		
Model 1	1.00	0.91 (0.81, 1.03)	1.02 (0.91, 1.14)	1.04 (0.93, 1.16)	1.04 (1.00, 1.08)	0.032
Model 2	1.00	0.91 (0.80, 1.02)	1.02 (0.90, 1.14)	1.04 (0.93, 1.17)	1.04 (1.01, 1.08)	0.025
Model 3	1.00	0.92 (0.82, 1.04)	1.04 (0.92, 1.17)	1.08 (0.95, 1.23)	1.07 (1.02, 1.11)	0.004
CVD, n (%)	168 (7.7)	171 (7.9)	206 (9.5)	242 (11.1)		
Model 1	1.00	0.94 (0.76, 1.16)	1.05 (0.86, 1.29)	1.13 (0.93, 1.37)	1.08 (1.01, 1.14)	0.018
Model 2	1.00	0.93 (0.75, 1.15)	1.05 (0.85, 1.28)	1.11 (0.91, 1.35)	1.07 (1.01, 1.14)	0.027
Model 3	1.00	0.95 (0.76, 1.17)	1.08 (0.88, 1.33)	1.17 (0.93, 1.46)	1.11 (1.03, 1.19)	0.007
CHD, n (%)	33 (1.5)	38 (1.7)	37 (1.7)	60 (2.8)		
Model 1	1.00	1.07 (0.67, 1.70)	0.97 (0.61, 1.55)	1.43 (0.94, 2.19)	1.20 (1.06, 1.35)	0.003
Model 2	1.00	1.05 (0.66, 1.68)	0.96 (0.60, 1.54)	1.42 (0.92, 2.17)	1.19 (1.06, 1.34)	0.003
Model 3	1.00	1.08 (0.67, 1.73)	1.00 (0.61, 1.61)	1.49 (0.92, 2.40)	1.25 (1.08, 1.44)	0.002
Stroke, n (%)	68 (3.1)	81 (3.7)	103 (4.7)	109 (5.0)		
Model 1	1.00	1.10 (0.79, 1.51)	1.30 (0.96, 1.76)	1.25 (0.93, 1.70)	1.07 (0.97, 1.17)	0.159
Model 2	1.00	1.08 (0.78, 1.50)	1.28 (0.94, 1.74)	1.22 (0.90, 1.65)	1.06 (0.96, 1.16)	0.233
Model 3	1.00	1.13 (0.82, 1.57)	1.38 (1.01, 1.90)	1.39 (0.99, 1.95)	1.12 (1.00, 1.25)	0.044

Abbreviations: HR, hazard ratio; CI, confidence interval; CVD, cardiovascular disease; CHD, coronary heart disease.

Model 1: Adjusted for sex and age.

Model 2: Adjusted for sex, age, body mass index, smoking status, alcohol consumption status, and work exertion level.
Model 3: Adjusted for variables in model 2 plus household-based potassium, saturated fatty acids, and long-chain n-3 polyunsaturated fatty acids.
p values for trend were calculated using household-based salt intake/1000 kcal as a continuous variable.

Supplemental table 1. Multivariable-adjusted HRs and 95% CIs for mortality by quartiles, only in 7,809 participants Aged 30–79 years who did not use antihypertensive agents at baseline: NIPPON DATA80 (1980).

	Quartiles of household salt intake level, g/1000 kcal				2.0 g/1000 kcal increment of household salt intake level	p for trend
	Q1 (≤4.9)	Q2 (4.9–5.9)	Q3 (5.9–7.2)	Q4 (≥7.2)		
Number of participants	1988	1992	1930	1899		
All causes, n (%)	426 (21.4)	415 (20.8)	475 (24.6)	539 (28.4)		
Model 1	1.00	0.91 (0.80–1.05)	1.03 (0.90–1.17)	1.07 (0.94–1.21)	1.04 (1.00–1.09)	0.047
Model 2	1.00	0.91 (0.80–1.04)	1.04 (0.91–1.18)	1.07 (0.94–1.22)	1.05 (1.00–1.09)	0.035
Model 3	1.00	0.93 (0.81–1.06)	1.06 (0.93–1.22)	1.12 (0.97–1.29)	1.07 (1.02–1.12)	0.010
CVD, n (%)	113 (5.7)	130 (6.5)	136 (7.0)	168 (8.8)		
Model 1	1.00	1.07 (0.83–1.38)	1.09 (0.85–1.40)	1.24 (0.98–1.58)	1.09 (1.01–1.17)	0.025
Model 2	1.00	1.06 (0.82–1.37)	1.10 (0.85–1.41)	1.22 (0.96–1.56)	1.08 (1.01–1.16)	0.034
Model 3	1.00	1.09 (0.84–1.40)	1.14 (0.88–1.48)	1.30 (0.99–1.70)	1.12 (1.02–1.22)	0.013
CHD, n (%)	23 (1.2)	27 (1.4)	28 (1.5)	39 (2.1)		
Model 1	1.00	1.10 (0.63–1.93)	1.12 (0.64–1.94)	1.43 (0.85–2.39)	1.16 (1.00–1.34)	0.043
Model 2	1.00	1.08 (0.62–1.89)	1.12 (0.64–1.94)	1.42 (0.84–2.39)	1.15 (1.00–1.33)	0.051
Model 3	1.00	1.13 (0.64–1.98)	1.21 (0.68–2.14)	1.60 (0.89–2.87)	1.23 (1.04–1.47)	0.019
Stroke, n (%)	42 (2.1)	64 (3.2)	66 (3.4)	79 (4.2)		
Model 1	1.00	1.41 (0.96–2.08)	1.41 (0.96–2.07)	1.56 (1.07–2.27)	1.11 (1.01–1.23)	0.039
Model 2	1.00	1.41 (0.95–2.08)	1.42 (0.96–2.10)	1.53 (1.05–2.23)	1.10 (0.99–1.22)	0.063
Model 3	1.00	1.47 (0.99–2.18)	1.52 (1.02–2.27)	1.73 (1.14–2.63)	1.16 (1.03–1.32)	0.018

Abbreviations: HR, hazard ratio; CI, confidence interval; CVD, cardiovascular disease; CHD, coronary heart disease.

Model 1: Adjusted for sex and age.

Model 2: Adjusted for sex, age, body mass index, smoking status, alcohol consumption status, and work exertion level.
Model 3: Adjusted for variables in model 2 plus household-based potassium, saturated fatty acids, and long-chain n-3 polyunsaturated fatty acids.
p values for trend were calculated using household-based salt intake/1000 kcal as a continuous variable.