Altitude of residential area affects salt intake in a rural area in Japan: Shimane CoHRE Study

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Abstract

BACKGROUND There has been increasing evidence for an association between residential environment and hypertension. As shown in our previous study, inconvenience due to the residential area might be one of the factors influencing blood pressure in habitants. Salt intake is one of likely mediators between inconvenience and hypertension. In this study, we therefore evaluated the association between altitude of residential area and salt intake in a Japanese rural region because altitude may be one of the proxies for inconvenience.

METHODS In this cross-sectional study, 1016 participants living in a mountainous region in Japan were recruited at health examinations. Altitude of the living place was estimated with a geographical information system according to the address of each participant. Subjects were divided into quartile groups according to the altitude of their living place. To evaluate salt intake, we employed the 24h salt intake estimated according to Kawano et al. (e24h salt intake) and urinary sodium-to-potassium ratio (uNa/K).

RESULTS Linear regression analyses indicated that the altitude was an independent factor influencing both the e24h salt intake and uNa/K after adjustment with age, sex, body mass index, physical activity, drinking, triglyceride and the county the participants lived. The same result was observed when the subjects without antihypertensive medication were employed (N=633).

CONCLUSIONS The present study indicated that the altitude of living place had a significant positive influence on salt intake in a rural area of Japan.

Introduction

There is a growing interest in the association between residential environment and hypertension.[1-5] Residential environment has both physical (e.g. climate and geography) and social (e.g. socioeconomic condition and social capital) aspects that may attribute to individual health.[6] Inconvenience in daily life may be one of such factors. Japan has wide mountainous regions (hilly and mountainous areas occupy approximately 70% of the land), in which people have much less accessibility to facilities supporting their health and daily life (food shops, hospitals, etc.).[7-9]

In the previous study, we showed that distance from a city area influenced blood pressure (BP) of habitants.[10] Considering the mechanisms underlying this observation, we hypothesized that inconvenience determined by the geographic feature may influence salt intake, which may result in increase in BP.[11] Evidence from the previous studies showed detrimental effects of high salt intake on BP both among hypertensive and normotensive individuals.[12] Furthermore, a recent study in UK reported that salt intake differed among subjects according to their socio-economic status and the geographic feature of the living area.[13]

In this study, we therefore examined the association of altitude of living place, which is a possible index of inconvenience in Japan, with salt intake in a rural area.

Materials and Methods

1) Participants

This cross-sectional population-based study was conducted as a part of Shimane CoHRE Study, a cohort study designed to determine factors of lifestyle-related diseases including hypertension. Health examinations were performed in 6 counties (Kakeya, Mitoya, Daito, Kamo, Yoshida and Kisuki) located in Un-nan city in 2012. Un-nan city is located in a rural mountainous area in the eastern part of Shimane prefecture, Japan. Participants of the health examination were invited to the study, and were involved in the study when they gave a written informed consent. After excluding individuals with missing data, we recruited 1016 individuals in the study. This study was approved by the local ethics committee of Shimane University.

2) Measurement

BP was measured twice after a 15-min resting at sitting position with automatic sphygmomanometers, and the lower value was taken as a representative BP. History of hypertension was asked in the interview and usage of antihypertensive drugs was checked on prescriptions. Regular physical activity, drinking and smoking habit were asked in the interview as well. Subjects taking one hour or more of physical activities (e.g. walking) per day were categorized to those with high physiological activity. Drinkers were defined as those taking alcohol once a week or more.

High-density and low-density lipoprotein cholesterol (HDL-C and LDL-C, respectively), triglyceride (TG) and fasting blood glucose (FBG) were measured in serum by standard methods.

Altitude of the living place was estimated with a geographical information system (GIS) according to the address of each participant (ESRI Japan Corp, Tokyo, Japan). In the analysis, subjects were divided into quartile groups according to the altitude of their living place; the first

(29 - 44 m, N=261), the second (45 - 68 m, N=237), the third (69 - 195 m, N=245) and the fourth quartile (196 - 485 m, N=250).

To evaluate salt intake, we employed two different parameters; 1) estimated 24 hours salt intake (e24h salt intake) calculated with the formula proposed by Kawano *et al*.[14] and 2) urinary sodium-to-potassium ratio (uNa/K). The uNa/K was reported to be an index of salt intake,[15-17] and, in fact, a significant correlation was observed between the e24h salt intake and the log-transformed uNa/K in the present study (Pearson's r=0.72; p<0.0001, see Fig. S1). Spot urine samples were collected at the site of the health examination, and the concentration of sodium and potassium was measured using the electrode method (TBA-c16000, Toshiba Medical System Corporation, Tochigi, Japan).

3) Statistical analysis

All the measures were represented as mean±SD. Parameters influencing salt intake were analyzed by the linear regression analysis. *P*<0.05 was considered statistically significant. All statistical analyses were performed using JMP 11 (SAS Institute, Cary, NC, USA).

Results

Characteristics of the studied population are shown in Table 1. We found significant differences in the e24h salt intake as well as in the uNa/K among the quartiles according to the altitude of living place. A post-hoc analysis indicated that the e24h salt intake and the uNa/K significantly differed between the quartile (Q) 1 and the others (Dennett's test under Q1 was the reference).

Factors influencing the salt intake were listed in Table 2. By the Spearman's non-parametric correlation analysis, sex, age, body-mass index (BMI), systolic and diastolic BP (SBP and DBP, respectively), HDL-C, TG and the drinking status showed a significant correlation with the salt intake in addition to the altitude. Besides the factors included in this univariate analysis, we took into account effects of the county that the subjects lived in; as shown in the Figure, the county seemed to have an effect on the e24h salt intake independently to their altitude.

We therefore performed a linear regression analysis on the e24 salt intake including the county as a nominal variance. As BP was probably the result of salt intake, we excluded SBP/DBP from the model. The result was summarized in Table 3. Even if the county was included in the model, the highest quartile of the altitude (Q4) showed an independent effect on the salt intake in addition to sex, age, BMI and the physical activity. Collinearity was not estimated to be high when variance inflation factors (VIFs) were calculated (the maximal VIF was 3.7 for the county Kakeya). When the analysis was performed on the uNa/K, the altitude was a significant independent factor influencing it in parallel with sex and the county as well (see Table S1). Further, addition of SBP (or DBP) in the model did not affect the result; the altitude was still an independent factor affecting the salt intake (data not shown).

In the participants, we had 383 who were under the treatment with antihypertensive drugs. We therefore performed the same analysis on those who had no antihypertensive drugs (N=633) to avoid potential perturbation by antihypertensive treatment. The results indicated that the effect of the altitude was significant in this population as well (see Table S2).

Discussion

To the best of our knowledge, this is the first study to examine the association between altitude of living place and salt intake. The major finding of our study was that the salt intake was associated with increased altitude in a rural area of Japan. This association seemed robust even after adjustment with the county that the subjects lived in (see Table 3). Further, the same significant association was observed after excluding the subjects taking antihypertensive drugs (Table S2), and between the altitude and the uNa/K, another estimate of the daily salt intake (see Table S1).

Previous studies pointed out that climbing up to high altitude increased BP acutely.[18, 19] Several factors in addition to lower air pressure were suggested to be responsible, such as hypoxia, low temperature, wind, stress and dehydration.[20, 21] In contrast, chronic effect of living at high altitude was controversial.[22] In anyway, however, the subjects employed in this study lived in a range between 29 and 485 m in height, which was much less than that in the previous studies (mostly, higher than 2000 m). Accordingly, the effect of altitude observed in this study was probably not through physical effects of altitude *per se*.

In this context, it is of interest that Tyrovolas *et al*. reported that people living in mountainous regions (upper than 400 m in height) in Mediterranean islands showed a greater incident of the metabolic syndrome including hypertension.[23] They argued that people living in mountainous regions had less opportunity to use health-promoting facilities due to inconvenience or remoteness. To examine whether the similar inconvenience was indeed observed in our population, we checked a number of food shops and bus stops in the studied counties according to the altitude using the GIS. As expected, the result indicated that number of these facilities decreased according to the altitude, suggesting that the living place in high altitude was more inconvenient (Fig. S1). Based on the analysis above, it is possible to hypothesize that people living higher altitude in this area might have more preserved food containing more salt because of the less accessibility to fresh food. This hypothesis needs to be examined in future studies.

In contrast to salt intake, the altitude did not influence BP. When factors influencing SBP were evaluated by a linear regression analysis, the e24h salt intake was a strong independent risk factor increasing SBP ($B \pm SE = 1.1 \pm 0.2$, $p<0.0001$) along with age and BMI (data not shown). This result indicated that, although the altitude indeed affected salt intake in this population, many factors other than the altitude, especially those related to an individual life style, probably had larger influence on salt intake as well as on BP of each subject. In the previous study, we showed that a distance from a city area was an independent risk factor for hypertension.[10] In that report, we argued that the distance from a city area was a parameter representing 'inconvenience' as well. At the moment, we cannot provide any good interpretation about the reason why the altitude and the distance from a city area gave different results on hypertension. Further analyses may be essential to solve this inconsistency between the two parameters.

It is of interest that the county had an independent effect on the salt intake in addition to the altitude. Many potential factors such as difference in urbanization might attribute to this observation. In fact, the counties with higher adjusted salt intake are more urbanized (as far as the central area of the county is concerned) than the others (see Table S3). Further analyses would be warranted on this issue as well.

Our study has several limitations. First, due to a cross-sectional study design, it was, in general, difficult to argue the causal relationship between independent and dependent parameters. However, in the present case, it seemed reasonable to assume that the altitude of living place causally influence salt intake as the opposite was not likely. Second, our data did not allow the assessment of other important socioeconomic factors for hypertension, such as income, education and occupation. In spite of those limitations, this is a unique study evaluating the altitude of living place as a factor influencing dietary habits of people. Implementation of such a geographical factor as a risk factor may be warranted in future studies of life-style related diseases.

Disclosure

The authors declared no conflict of interest.

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access and ~~Prevalence~~ prevalence of the ~~Metabolic~~ metabolic ~~Syndrome~~ syndrome ~~Among~~ among ~~Elders~~ elders ~~Living~~ living in ~~High~~high-~~Altitude~~ altitude ~~Areas~~ areas of the ~~Mediterranean~~ mediterranean ~~Islands~~islands: ~~The~~ the MEDIS Study. *Rev Diabet Stud* 2011; 8:468-76.

Figure legends

Figure. The altitude and the e24h salt intake in each county

A closed circle indicates the median of altitude and the mean of the e24h salt intake of each county. Vertical lines and horizontal broken lines are for the S.D. of the e24h salt intake and for the 25/75 percentile of the altitude, respectively.

Table 1 Demographic data of the studied subjects

	Quartile 1	Quartile 2	Quartile 3	Quartile 4	p
Number	261	237	245	250	
Altitude, m	38±5	53±6	125±38	307±82	<0.0001
Sex, % male	37.2	38.8	40.4	40.8	0.8
Age, years	71±7	70±8	70±7	71±7	0.02
BMI, kg/m^2	22.2±3.2	22.3±3.5	21.9±2.7	22.6±2.9	0.06
SBP, mmHg	129±16	128±15	127±15	128±15	0.8
DBP, mmHg	77±10	78±10	76±10	77±10	0.3
Physical activity, %yes	47.3	46.6	47.5	51.2	0.7
Drinking, %	44.7	42.5	54.5	46.8	0.04
Smoking, %	5.3	6.5	4.3	5.2	0.8
e24h salt intake, g/day	9.2±2.0	9.7±2.0	9.6±2.2	9.7±2.0	0.02
uNa/K	2.3±1.6	2.6±1.6	2.6±1.7	2.6±1.7	0.01
HDL-C, mg/dL	66±14	64±17	66±15	63±16	0.2
LDL-C, mg/dL	123±28	124±27	118±29	122±30	0.1
TG, mg/dL	85±1.5	89±1.5	83±1.5	83±1.5	0.3
FBG, mg/dL	96±15	95±13	96±13	96±13	0.8

Log-transformed uNa/K and TG were used in the analysis. The means and the SDs calculated back to the untransformed form were shown in the table.

Table 2 Factors correlated with e24h salt intake

	ρ	p
Sex, M vs. F	0.11	0.0003
Age	-0.11	0.0008
BMI	0.18	<0.0001
SBP	0.17	<0.0001
DBP	0.16	<0.0001
HDL-C	-0.06	0.05
LDL-C	-0.03	0.3
TG	0.08	0.006
FBS	-0.05	0.09
Smoking, Y vs. N	0.004	0.9
Drinking, Y vs. N	0.10	0.002
Physical activity, Y vs. N	0.05	0.08
Altitude, quartile	0.10	0.002

Spearman's ρ was employed in the analysis.

Table 3 Linear regression analysis on the e24h salt intake

	B±SE	t	p
Sex, M vs. F	0.37±0.15	2.43	0.02
Age	-0.02±0.009	-2.51	0.01
BMI	0.11±0.02	4.89	<0.0001
Physical act, y vs. n	0.27±0.12	2.13	0.03
Altitude			
Q2 vs. 1	0.23±0.19	1.23	0.2
Q3 vs. 2	0.20±0.18	1.07	0.3
Q4 vs. 3	0.48±0.21	2.27	0.02
County			
Kakeya	-0.60±0.20	-3.10	0.002
Yoshida	-0.50±0.20	-2.53	0.01
Mitoya	0.29±0.13	2.18	0.03
Kamo	0.06±0.19	0.30	0.8
Kisuki	0.07±0.15	0.43	0.7
Daito	0.69±0.13	5.42	<0.0001

HDL-C, TG, drinking status and FBS were excluded from the independent factors by the analysis,

Table S1 Linear regression analysis on the urinary Na/K ratio

	B±SE	t	p
Sex, M vs. F	0.05±0.016	3.06	0.002
Altitude			
Q2 vs. 1	0.04±0.02	2.03	0.04
Q3 vs. 2	0.01±0.02	0.67	0.5
Q4 vs. 3	0.06±0.02	2.55	0.01
County			
Kakeya	-0.06±0.02	-2.81	0.005
Yoshida	-0.08±0.02	-3.48	0.0005
Mitoya	0.05±0.01	3.70	0.0002
Kamo	0.0003±0.02	0.13	0.9
Kisuki	0.02±0.02	1.35	0.18
Daito	0.06±0.01	4.01	<0.0001

Log transformation of Na/K ratio was done before the analysis due to a skewed distribution of the ratio. Age, BMI, HDL-C, TG, FBS, drinking status and the physical activity were excluded from independent factors by the analysis.

Table S2. Linear regression analysis on the e24h salt intake in the subjects without using antihypertensive drugs (N=633)

	B±SE	t	p
Sex, M vs. F	0.32±0.17	1.88	0.06
Age	-0.03±0.01	-2.87	0.004
BMI	0.14±0.03	5.04	<0.0001
Physical activity, y vs. n	0.30±0.14	2.10	0.04
Altitude			
Q2 vs. 1	0.26±0.21	1.25	0.2
Q3 vs. 2	0.15±0.21	0.71	0.5
Q4 vs. 3	0.68±0.26	2.65	0.008
County			
Kakeya	-0.54±0.24	-2.21	0.03
Yoshida	-0.54±0.24	-2.29	0.02
Mitoya	0.35±0.15	2.30	0.02
Kamo	0.12±0.22	0.54	0.6
Kisuki	-0.10±0.18	-0.55	0.6
Daito	0.71±0.14	4.98	<0.0001

HDL-C, TG, FBS and drinking status were excluded from the independent factors by the analysis. Sex had a marginal effect on the e24h salt intake.

Table S3. e24h salt intake and uNa/K according to the altitude and the county adjusted by the linear regression analysis

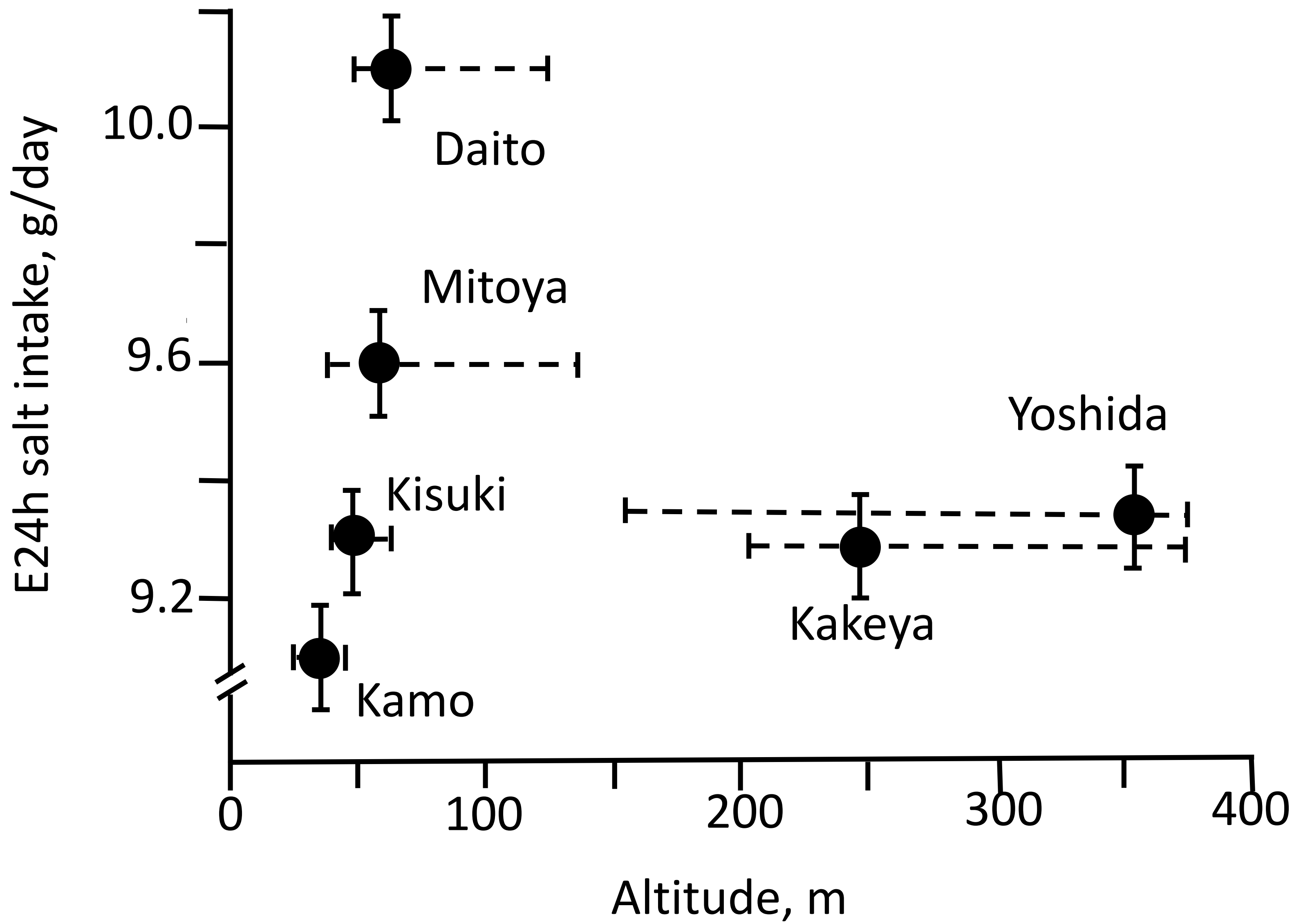
A) Altitude

altitude	e24h salt intake, g/day	log uNa/K
Q1	9.07±0.15	0.34±0.016
Q2	9.30±0.15	0.39±0.016
Q3	9.50±0.13	0.40±0.015
Q4	9.96±0.16	0.46±0.017

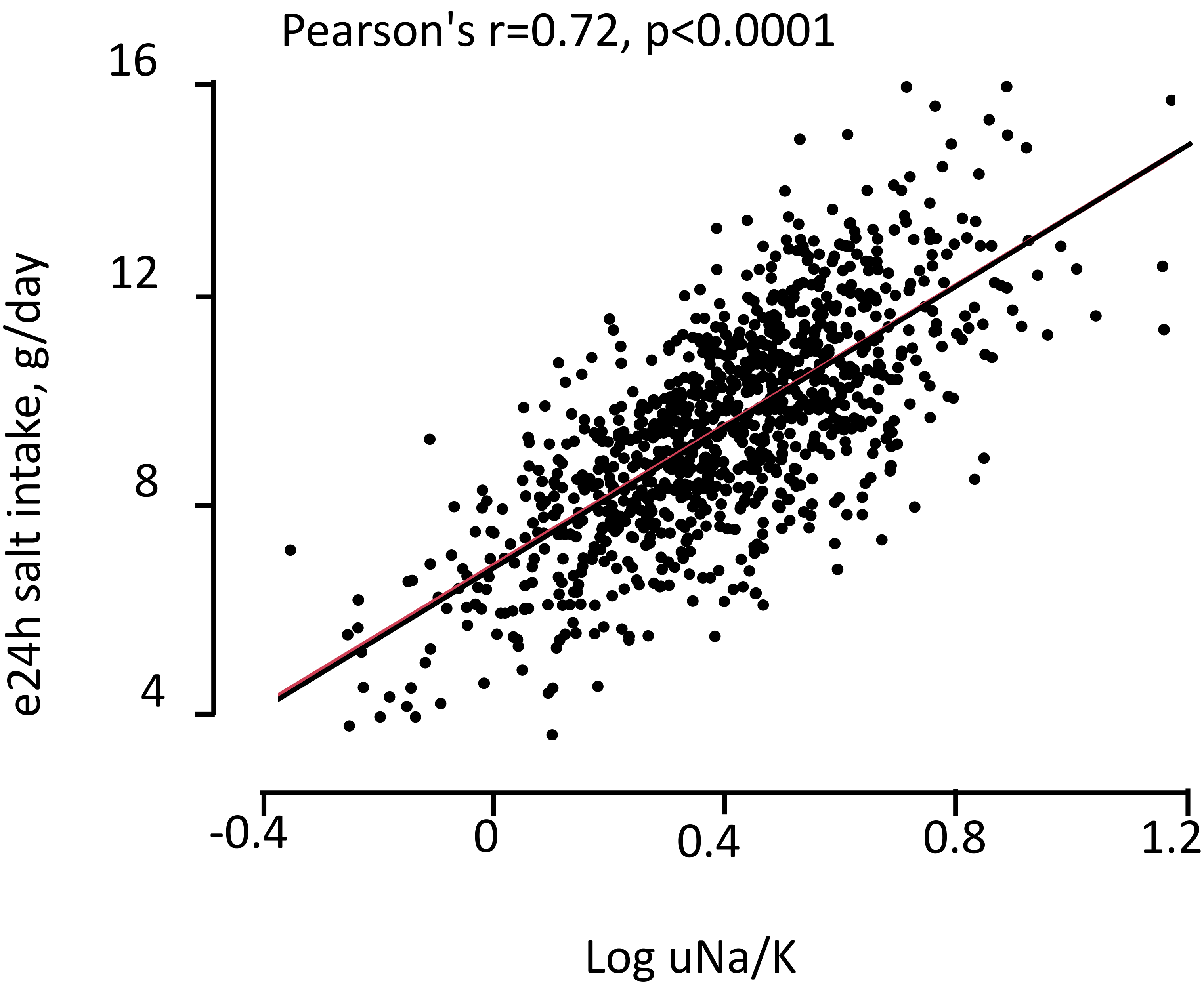
B) County

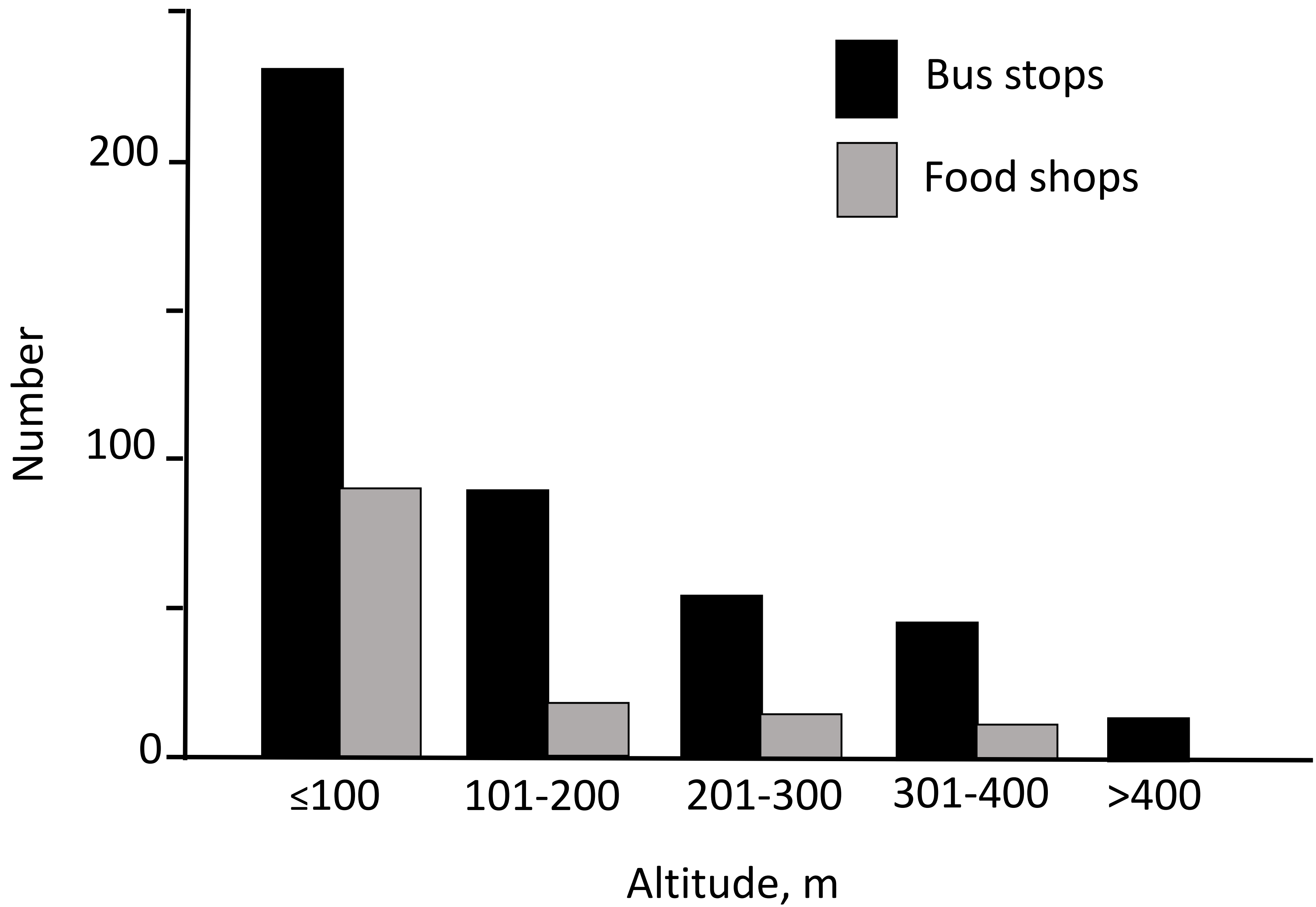
county	e24 salt intake, g/day	log uNa/K
Kakeya	8.47±0.28	0.29±0.03
Yoshida	8.56±0.29	0.27±0.03
Mitoya	9.35±0.18	0.40±0.02
Kamo	9.12±0.19	0.35±0.02
Kisuki	9.13±0.18	0.37±0.02
Daito	9.75±0.19	0.40±0.02

The e24h salt intake and the uNa/K were adjusted with sex, age, BMI, HDL-C, TG, FBS and the physical activity.



E24h salt intake, g/day
10.0
9.6
9.2
Daito
Mitoya
Kisuki
Kamo
Yoshida
Kakeya
0
100
200
300
400
Altitude, m


Pearson's r=0.72, p<0.0001
16
12
8
4
e24h salt intake, g/day
-0.4
0
0.4
0.8
1.2
Log uNa/K


Bus stops
Food shops
Number
200
100
0
≤100
101-200
201-300
301-400
>400
Altitude, m