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Neighbourhood food store availability in relation to 24 h urinary sodium and potassium excretion in young Japanese women

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Previous studies on the relationship of local food environment with residents' diets have relied exclusively on self-reported information on diet, producing inconsistent results. Evaluation of dietary intake using biomarkers may obviate the biases inherent to the use of self-reported dietary information. This cross-sectional study examined the association between neighbourhood food store availability and 24 h urinary Na and K excretion. The subjects were 904 female Japanese dietetic students aged 18–22 years. Neighbourhood food store availability was defined as the number of food stores within a 0·5-mile (0·8-km) radius of residence. Urinary Na and K excretion and the ratio of urinary Na to K were estimated from a single 24 h urine sample. After adjustment for potential confounding factors, neighbourhood availability of confectionery stores/bakeries was inversely associated with urinary K, and was positively associated with the ratio of Na to K (*P* for trend = 0·008 and 0·03, respectively). Neighbourhood availability of rice stores showed an independent inverse association with urinary K (*P* for trend = 0·03), whereas neighbourhood availability of supermarkets/grocery stores conversely showed an independent positive association with this variable (*P* for trend = 0·03). Furthermore, neighbourhood availability of fruit/vegetable stores showed an independent inverse association with the ratio of Na to K (*P* for trend = 0·049). In a group of young Japanese women, increasing neighbourhood availability of supermarkets/grocery stores and fruit/vegetable stores and decreasing availability of confectionery stores/bakeries and rice stores were associated with favourable profiles of 24 h urinary K (and Na) excretion.

Neighbourhood: Food store availability: Diet: 24 h Urine

Growing recognition of the importance of diet on health has been accompanied by increasing attention to factors associated with access to healthy foods. However, findings in the increasing albeit still limited number of studies examining associations between local food environment and residents' diets have been inconsistent[1–10]. Among a number of US studies, the availability of ≥1 supermarket in census tracts was associated with a higher likelihood that guidelines for the intake of fruits and vegetables and total and saturated fats would be met by adults living in these census tracts[1]; a shorter distance from home to a food store was associated with higher use of fruits in low-income households[2]; proximity to a supermarket was associated with better diet quality in pregnant women[3]; participants with no supermarket near their homes were less likely to have a healthy diet than those with the most stores near their homes[4] and the presence of a large grocery store in the neighbourhood was associated with a higher intake of fruits and vegetables[5]. Furthermore, increasing neighbourhood store availability for confectioneries and bread was associated with a higher intake of these items in young Japanese women[6]. In a national study in New Zealand, conversely, access to supermarkets was not associated with fruit and vegetable consumption, although better access to convenience stores was associated with a lower intake of vegetables, but not of fruits[7]. Additionally, better access to food stores was not associated with the consumption of fruits or vegetables

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in adults in the USA[8], UK[9] or Australia[10]. To our knowledge, however, all previous studies on this topic have used self-reported information on diet[1–10]. Evaluation of dietary intake using biomarkers may obviate the biases inherent to the use of self-reported dietary information.

Here, we conducted an observational cross-sectional study of the association between neighbourhood food store availability and 24 h urinary Na and K excretion, an established biomarker of Na and K intake[11–13], in a group of young Japanese women. High Na and low K intakes are established determinants of several chronic illnesses such as hypertension and CVD[14,15]. According to the Intersalt Study, Japanese are characterised by high urinary excretion of Na and low urinary excretion of K, and hence a high ratio of urinary Na to K[16]. According to the National Health and Nutrition Survey in Japan, the major contributor of dietary Na was seasonings (67 %), while the top contributor of dietary K was vegetables (28 %), followed by fish (10 %), fruits (9 %), potatoes (8 %) and dairy products (8 %)[17]. Also, Japan has a high population density (339 persons/km^2)[18], and hence a high food store density[19]. A clear understanding of the relationship of neighbourhood food store availability with urinary Na and K excretion in Japanese is thus of public health importance. Furthermore, these characteristics of the Japanese diet and food store environment may likely provide insights into the influence of local food environment on an individual's diet.

Subjects and methods

Study sample

This observational study was based on the data obtained from the Japan Dietetic Students' Study for Nutrition and Biomarkers, which is a cross-sectional multi-centre survey conducted from February to March 2006 and from January to March 2007 among female dietetic students from fifteen institutions in Japan. A total of 1176 Japanese women took part in the study. A detailed description of the study design and survey procedure has been published elsewhere[6,20–26]. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by the ethics committees of the National Institute of Health and Nutrition, Japan. Written informed consent was obtained from all the subjects/patients.

In total, 1105 women took part in the 24 h urine collection procedure. For analysis, we selected women aged 18–22 years (*n* 1083). We then excluded women who did not provide sufficient information on their home address (*n* 151) and those with missing information on the variables used (*n* 1). We further excluded those whose 24 h urine collection was considered incomplete (*n* 35), as assessed using information on urinary creatinine excretion and body weight based on a strategy proposed by Knuiman *et al.*[27]; this creatinine-based strategy has been validated against the *para*-aminobenzoic acid check method in a subsample of the present participants[24]. As some participants were in >1 exclusion category, the final analysis sample comprised 904 women, residing in a wide range of geographical areas in Japan (i.e. 25 (of 47) prefectures, 276 (of 2372) municipalities and 647 (of 386 877) 1-km mesh blocks).

Neighbourhood food store availability

Neighbourhood food store availability was defined as the number of retail stores offering food within a 0·5-mile (0·8-km) radius of residence. Based on the definitions of retail food stores used in the census of commerce, Japan[19], the following seven types of retail food stores were selected for investigation: meat stores, fish stores, fruit/vegetable stores, confectionery stores/bakeries, rice stores, convenience stores and supermarkets/grocery stores. Confectionery stores and bakeries were combined because of the widespread availability of various breads with sweet fillings (e.g. sweetened azuki bean paste) in Japan, and because bakeries commonly offer not only bread but also confectioneries such as cakes, cookies and biscuits[6]. Supermarkets and grocery stores were also combined because both types of stores in Japan generally provide a wide range of food options, including fresh produce[6].

Due to the unavailability of raw data obtained from the census of commerce in Japan (except those of civil servants in relevant departments) and the widespread distribution of our participants, neighbourhood food store availability was assessed based on a commercial electronic database of telephone business directories (version 13, business special, 2008, Nippon Software Service, Inc., Tokyo, Japan). This database consists of information appearing in all telephone business directories published in Japan as of October, 2007, including data on telephone and fax numbers, (store) name and street address. The street addresses in the database were geocoded by exact address matching, along with the participants' home addresses as reported in a lifestyle questionnaire. For data identified within a 0·5-mile (0·8-km) radius of a participant's home, food stores were systematically categorised based on name recognition by one of us (K. M.), after the exclusion of duplicate data (i.e. same telephone numbers and same names). Store names that were vague were assigned to a category by one of us (K. M.) after checking the business pages of the online telephone business directory (http://phonebook.yahoo.co.jp/) or, in some cases, company and community websites. Finally, the number of seven types of food stores within a 0·5-mile (0·8-km) radius of residence was calculated for each participant.

Twenty-four-hour urinary sodium and potassium excretion

A single 24 h urine sample was collected from each participant. A detailed description of the 24 h urine collection procedure has been published elsewhere[23–26]. Briefly, the participants were asked to collect all urine voided during a 24 h period, and to record the time of the start and end of the collection period and the estimated volume of all missing urine specimens. The 24 h urine volume was adjusted by self-reported collection time (calculated from the self-reported time of the start and end of the collection period) and missing urine volume. This adjustment strategy has been validated using the *para*-aminobenzoic acid check method in a subsample of the present participants[24].

All urine samples taken over the 24 h period were carefully mixed, and several aliquots were taken and transported at −20°C to a laboratory (SRL, Inc., Tokyo, Japan in 2006 and Mitsubishi Kagaku Bio-Clinical Laboratories Inc., Tokyo,

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Japan in 2007). In accordance with the standard procedure at each laboratory, Na and K concentrations were measured using the ion-selective electrode method[28], and creatinine concentration (for the assessment of the completeness of urine collection, as described earlier) was measured using the enzymatic assay method[29].

Other variables

Assessment of other variables has been described in detail elsewhere[20–22]. Briefly, based on the reported home address, each participant was grouped into one of six regions (Hokkaido and Tohoku, Kanto, Hokuriku and Tokai, Kinki, Chugoku and Shikoku, and Kyushu), and into one of three municipality levels (ward, city, and town and village). Each participant was also grouped into one of four institution types (4-year private, 2-year private, 4-year public and 2-year public) based on the institution she attended, and into one of three residential statuses (living with family, living alone and living with others), as self-reported in the lifestyle questionnaire. As part of a dietary questionnaire, the frequency of eating out (including school cafeteria) during the preceding month was self-reported ($\geq$1 time/d, 4–6, 2–3, 1 and $<$1 time/week). Physical activity was computed as the average metabolic equivalents – hours score per day[30] on the basis of the frequency and duration of five activities (sleeping, high- and moderate-intensity activities, walking and sedentary activities) over the preceding month, as reported in the lifestyle questionnaire. Body weight and height were measured to the nearest 0·1 kg and 0·1 cm, respectively, while wearing light clothes and no shoes. BMI was calculated as body weight (kg) divided by the square of body height (m^2).

Statistical analysis

All statistical analyses were performed using SAS statistical software (version 9.1, 2003, SAS Institute, Inc., Cary, NC, USA). Total 24 h excretion was calculated by multiplying the measured concentration by the (adjusted) volume of 24 h urine. Estimates of urinary Na and K and the ratio of urinary Na to K were natural log transformed ($y = \ln(x + 1)$). Using the PROC GLM (general linear model) procedure, linear regression models were constructed to examine the association of neighbourhood food store availability (number of seven types of food stores (meat stores, fish stores, fruit/vegetable stores, confectionery stores/bakeries, rice stores, convenience stores and supermarkets/grocery stores) within a 0·5-mile (0·8-km) radius of residence) with urinary biomarkers (24 h urinary Na and K excretion and the ratio of urinary Na to K). For analyses, the participants were categorised into approximate quartiles (or tertiles, depending on distribution) according to neighbourhood availability of each type of food store. Multivariate-adjusted mean values (with 95 % CI) of urinary biomarkers were calculated by approximate quartiles (or tertiles) of neighbourhood availability of each type of food store. Potential confounding factors included in the multivariate models were survey year; geographic variables, i.e. region and municipality level; household socioeconomic status variables, i.e. institution type and living status; lifestyle variables, i.e. frequency of eating out, physical activity (continuous) and BMI (continuous); and neighbourhood availability of other food stores (quartile (or tertile))[6,20–22,31,32]. We tested for linear trends with increasing levels of neighbourhood food store availability by assigning each participant the median value for the category, and by modelling this value as a continuous variable. All reported P values are two-tailed, and P values $<$0·05 were considered statistically significant.

Results

Basic characteristics of the participants are given in Table 1. As expected, neighbourhood availabilities of the seven types of food stores examined were positively correlated with each other (Spearman's correlation coefficients: 0·24–0·68).

Table 1. Basic characteristics of the 904 Japanese women aged 18–22 years
(Mean values and standard deviations; median and interquartile range values)

	Mean	SD	Median	Interquartile range
Age (years)	19·5	1·0		
Body height (cm)	158·3	5·4		
Body weight (kg)	53·3	7·3		
BMI (kg/m^2)	21·3	2·5		
Physical activity (total metabolic equivalents – h/d)	34·0	3·2		
Neighbourhood food store availability (number of food stores within a 0·5-mile (0·8-km) radius of residence)				
Meat stores			1	0–2
Fish stores			1	0–2
Fruit/vegetable stores			1	0–3
Confectionery stores/bakeries			6	2–11
Rice stores			1	0–3
Convenience stores			4	2–6
Supermarkets/grocery stores			4	2–6
All stores			20	10–30
24 h Urinary excretion				
Na (mmol/d)			139·8	107·0–177·1
K (mmol/d)			41·7	33·0–52·4
Ratio of Na (mmol/d) to K (mmol/d)			3·27	2·49–4·27

Table 2. Selected characteristics of the 904 Japanese women aged 18–22 years according to the approximate quartile category of neighbourhood availability of confectionery stores/bakeries (number of stores within a 0·5-mile (0·8-km) radius of residence)

(Mean values and standard deviations or percentages)

	Quartile 1 (lowest, *n* 251)		Quartile 2 (*n* 221)		Quartile 3 (*n* 202)		Quartile 4 (highest, *n* 230)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P**
Survey year (%)									0·01
2006	33·1		42·1		41·6		44·8		
2007	66·9		57·9		58·4		55·2		
Region (%)									0·003
Hokkaido and Tohoku	5·6		2·7		2·0		0·4		
Kanto	43·4		62·0		61·4		67·0		
Hokuriku and Tokai	15·1		8·1		8·9		7·0		
Kinki	14·3		7·2		10·4		13·5		
Chugoku and Shikoku	3·2		1·8		4·0		2·6		
Kyushu	18·3		18·1		13·4		9·6		
Municipality level (%)									<0·0001
Ward	4·8		15·8		22·8		27·8		
City	79·7		78·3		75·3		71·7		
Town and village	15·5		5·9		2·0		0·4		
Institution type (%)									<0·0001
4-year private	56·6		72·4		77·2		79·6		
2-year private	12·4		4·5		2·5		1·3		
4-year public	17·5		10·9		12·9		16·1		
2-year public	13·6		12·2		7·4		3·0		
Residential status (%)									<0·0001
Living with family	84·5		75·6		54·5		41·7		
Living alone	12·4		24·0		40·6		53·5		
Living with others	3·2		0·5		5·0		4·8		
Frequency of eating out (%)									0·003
≥ 1 time/d	8·0		8·1		8·4		11·7		
4–6 times/week	17·9		21·3		18·3		27·4		
2–3 times/week	30·7		24·0		38·1		26·1		
1 time/week	18·7		24·4		19·8		15·7		
< 1 time/week	24·7		22·2		15·4		19·1		
Physical activity (total metabolic equivalents – h/d)	33·8	2·8	34·2	3·6	34·1	2·7	34·0	3·4	0·63
BMI (kg/m^2)	21·1	2·5	21·2	2·3	21·5	2·7	21·3	2·5	0·48

* For categorical variables, a Mantel–Haenszel χ^2 test was used; for continuous variables, a linear trend test was used with the median value in each quartile category as a continuous variable in linear regression. Similar patterns were generally observed according to the approximate quartile (or tertile) category of neighbourhood availability of other food stores, except for a lack of association between meat stores, convenience stores, and supermarkets/grocery stores and survey year, and between meat stores, fish stores, fruit/vegetable stores, rice stores, and supermarkets/grocery stores and frequency of eating out, and a positive association between supermarkets/grocery stores and BMI.

Potential confounding factors according to the approximate quartile category of neighbourhood availability of confectionery stores/bakeries (as an example) are given in Table 2. Neighbourhood availability of confectionery stores/bakeries was associated with survey year, region, municipality level, institution type, living status and frequency of eating out. The higher quartiles of availability included more participants in the 2006 survey; more participants living in Kanto and fewer living in Hokkaido and Tohoku, Hokuriku and Tokai, and Kyushu; more participants living in wards and fewer living in cities, and towns and villages; more participants attending 4-year private institutions and fewer attending 2-year private and 2-year public institutions; more participants living alone and fewer living with family; and more participants with a higher frequency of eating out. No association was observed for physical activity or BMI. According to the approximate quartile (or tertile) category of neighbourhood availability of other food stores, similar patterns were generally observed for potential confounding factors, except for a lack of association between meat stores, convenience stores, and supermarkets/grocery stores and survey year, or between meat stores, fish stores, fruit/vegetable stores, rice stores, and supermarkets/grocery stores and the frequency of eating out, while a positive association was observed between supermarkets/grocery stores and BMI (data not shown).

Twenty-four-hour urinary Na and K excretion and the ratio of urinary Na to K according to the approximate quartile (or tertile) category of neighbourhood availability of seven types of food stores are given in Table 3. After adjustment for potential confounding factors, no association between urinary biomarkers and neighbourhood food store availability was observed for meat stores, fish stores or convenience stores.

However, neighbourhood availability of confectionery stores/bakeries was independently associated inversely with urinary excretion of K (*P* for trend=0·008) and positively with the ratio of urinary Na to K (*P* for trend=0·03), although it was not associated with urinary excretion of Na. Also, neighbourhood availability of rice stores was independently and inversely associated with urinary excretion of K (*P* for trend=0·03), although it was not associated with urinary

Table 3. Twenty-four-hour urinary excretion of sodium (mmol/d) and potassium (mmol/d) and the ratio of urinary sodium (mmol/d) to potassium (mmol/d) of the 904 Japanese women aged 18–22 years according to the approximate quartile (or tertile) category of neighbourhood food store availability (number of food stores within a 0·5-mile (0·8-km) radius of residence)

(Mean and 95 % confidence intervals)

	Quartile 1 (lowest)				Quartile 2				Quartile 3				Quartile 4 (highest)				
	Mean*	95 % CI†	Median	Range	Mean*	95 % CI†	Median	Range	Mean*	95 % CI†	Median	Range	Mean*	95 % CI†	Median	Range	*P*‡
Meat stores			0	0			1	1			2	2			4	3–17	
n	285				268				160				191				
Na§	133·4	125·8, 141·5			132·4	125·8, 139·3			142·3	133·3, 151·9			134·1	124·6, 144·3			0·78
K§	41·0	39·0, 43·2			41·3	39·5, 43·2			43·4	41·0, 46·0			42·0	39·4, 44·8			0·54
Ratio of Na to K§	3·33	3·13, 3·55			3·28	3·10, 3·46			3·35	3·12, 3·59			3·27	3·02, 3·54			0·78
Fish stores			0	0			1	1			3	3–19			–		
n	364				270				270				–				
Na§	134·1	127·8, 140·7			137·6	130·6, 144·9			133·0	125·2, 141·3			–				0·79
K§	42·1	40·4, 43·9			40·8	39·0, 42·7			42·2	40·0, 44·5			–				0·98
Ratio of Na to K§	3·25	3·09, 3·43			3·45	3·26, 3·65			3·24	3·03, 3·45			–				0·88
Fruit/vegetable stores			0	0			1	1			2	2			4	3–24	
n	329				172				140				263				
Na§	138·2	130·4, 146·5			135·5	127·3, 144·2			134·7	124·9, 145·3			130·2	122·3, 138·7			0·24
K§	41·3	39·3, 43·5			41·3	39·1, 43·6			41·5	38·8, 44·3			42·7	40·4, 45·1			0·38
Ratio of Na to K§	3·43	3·23, 3·65			3·37	3·15, 3·60			3·33	3·07, 3·61			3·10	2·90, 3·32			0·049
Confectionery stores/bakeries			1	0–2			4	3–6			8	7–10			14	11–57	
n	251				221				202				230				
Na§	136·5	126·8, 146·8			131·4	124·3, 138·9			136·8	128·9, 145·2			134·5	125·5, 144·1			0·92
K§	43·6	40·9, 46·5			42·9	40·9, 45·0			42·0	39·8, 44·2			38·6	36·3, 41·0			0·008
Ratio of Na to K§	3·21	2·96, 3·47			3·14	2·95, 3·33			3·34	3·13, 3·56			3·56	3·31, 3·83			0·03
Rice stores			0	0			1	1–2			4	3–21			–		
n	366				291				247				–				
Na§	134·0	127·7, 140·6			135·4	129·1, 142·0			135·2	126·9, 144·1			–				0·90
K§	43·3	41·5, 45·2			41·6	39·9, 43·4			39·6	37·5, 41·9			–				0·03
Ratio of Na to K§	3·17	3·00, 3·34			3·33	3·16, 3·50			3·50	3·27, 3·74			–				0·06
Convenience stores			1	0–1			2	2–3			4	4–6			10	7–67	
n	200				198				300				206				
Na§	132·2	122·6, 142·5			135·4	127·7, 143·6			136·8	130·1, 143·8			133·9	124·5, 144·0			0·91
K§	40·8	38·2, 43·6			41·9	39·8, 44·1			40·9	39·1, 42·8			43·7	41·0, 46·6			0·15
Ratio of Na to K§	3·33	3·07, 3·61			3·31	3·11, 3·52			3·40	3·22, 3·59			3·14	2·90, 3·40			0·22
Supermarkets/ grocery stores			0	0–1			2	2–3			4	4–5			8	6–23	
n	224				212				218				250				
Na§	132·4	123·1, 142·5			133·6	126·4, 141·2			137·3	129·7, 145·3			135·8	127·5, 144·6			0·71
K§	39·6	37·2, 42·3			41·2	39·2, 43·3			41·6	39·6, 43·8			44·3	41·9, 46·8			0·03
Ratio of Na to K§	3·42	3·16, 3·69			3·33	3·13, 3·53			3·37	3·17, 3·59			3·14	2·93, 3·36			0·14

* Calculated using back transformation of natural-log transformed values ($y = \ln(x + 1)$) as follows: back-transformed values for mean = exp(mean values of natural-log transformed value) − 1.

† Calculated using back transformation of natural-log transformed values ($y = \ln(x + 1)$) as follows: back-transformed values for 95 % CI = exp(95 % CI of natural-log transformed value) − 1(= exp((mean values of natural-log transformed value) ± 1·96 × (standard error values of natural-log transformed value)) − 1).

‡ A linear trend test was used with the median value in each quartile (or tertile) category as a continuous variable in linear regression.

§ Adjusted for survey year (2006 and 2007), region (Hokkaido and Tohoku, Kanto, Hokuriku and Tokai, Kinki, Chugoku and Shikoku, and Kyushu), municipality level (ward, city, and town and village), institution type (4-year private, 2-year private, 4-year public and 2-year public), residential status (living with family, living alone and living with others), frequency of eating out (≥1 time/d, 4–6 times/week, 2–3 times/week, 1 time/week and <1 time/week), physical activity (total metabolic equivalents – h/d, continuous), BMI (kg/m^2, continuous), and neighbourhood availability of all other stores (number of food stores within a 0·5-mile (0·8-km) radius of residence, quartile (or tertile)).

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excretion of Na or the ratio of urinary Na to K. Conversely, neighbourhood availability of supermarkets/grocery stores was independently and positively associated with urinary excretion of K (P for trend=0·03), although it was not associated with urinary excretion of Na or the ratio of urinary Na to K. Furthermore, although neighbourhood availability of fruit/vegetable stores was not associated with urinary excretion of Na or K, it was independently and inversely associated with the ratio of urinary Na to K (P for trend=0·049).

Discussion

In this cross-sectional study of a group of young Japanese women, we found that increasing availability of supermarkets/grocery stores and fruit/vegetable stores and decreasing availability of confectionery stores/bakeries and rice stores in neighbourhoods were associated with favourable profiles of 24 h urinary K (and Na) excretion. In contrast, neighbourhood availability of meat stores, fish stores and convenience stores was not associated with these urinary biomarkers. To our knowledge, this is the first study to investigate the association between local food environment and residents' diets using objective biomarkers of dietary intake.

Our findings based on dietary biomarkers are consistent with several previous studies which relied on self-reported dietary information, showing that local food environment is associated with at least some aspects of a resident's diet[1–6]. The associations observed in the present study seem to be reasonable, although exact mechanisms of the associations are not known and are in any case beyond the scope of the study. Lower K excretion and a higher ratio of Na to K in relation to higher neighbourhood availability of confectionery stores/bakeries may be due to increased access to (and hence intake of) confectioneries and bread, which are generally ready-to-eat, resulting in decreased intake of foods largely contributing to K such as fruits and vegetables. The association between higher availability of fruit/vegetable stores and lower ratio of Na to K (which may be derived from high (but non-significant) K and low (but non-significant) Na excretion) may be due to increased access to (and hence intake of) fruits and vegetables, some of which require a low degree of preparation (e.g. peeling and heating), possibly influencing intake of other foods (in the direction of healthier diets). The inverse association between the availability of rice stores and K excretion may be due to increased access to (and hence intake of) rice, which is a major staple food, possibly resulting in decreased consumption of main and side dishes consisting of mainly vegetables as well as fish and meat. The positive association between the availability of supermarkets/grocery stores and K excretion may be due to increased access to (and hence intake of) foods making a large contribution to K intake in Japanese, such as fruits and vegetables, fish, and dairy products. The lack of associations for the availability of meat and fish stores may be due to a low distribution of (or low access to) these stores and the high degree of preparation required for meat and fish. The lack of association for the availability of convenience stores despite the fact that convenience stores generally offer a variety of ready-to-eat foods may be due to the higher nutritional knowledge of our participants, who were all dietetic students. The lack of association of urinary Na excretion with any measure of neighbourhood food store availability may be due to the strong influence of a taste preference for Na intake relative to availability. Nevertheless, because we have no information on the intake of each food itself, these ideas remain speculative. Also, in view of the multiple analyses and the P values, it is possible that some (or all) of the findings in the present study occurred by chance. Further research using biomarkers reflecting specific foods, such as blood concentrations of carotenoids (for fruits and vegetables)[32] and EPA and DHA fatty acids (for fish)[33], would be of interest.

In our previous study of young Japanese women[6], neighbourhood store availability for confectioneries and bread (based on confectionery stores/bakeries, supermarkets/grocery stores and convenience stores) was positively associated with the intake of confectioneries and bread, whereas no such association was observed between neighbourhood store availability for the other foods examined, including meat (meat stores and supermarkets/grocery stores), fish (fish stores and supermarkets/grocery stores), fruits and vegetables (fruit/vegetable stores and supermarkets/grocery stores) and rice (rice stores, supermarkets/grocery stores and convenience stores), and the intake of each food. One may speculate that some of the present findings (i.e. inverse association between the availability of fruit/vegetable stores and ratio of Na to K, inverse association between the availability of rice stores and K excretion, and positive association between the availability of supermarkets/grocery stores and K excretion) and speculations are not consistent with the previous results[6]. However, it is difficult to draw direct comparisons between the previous[6] and the present results, owing to substantial differences in dietary variables (food intake and nutrient intake), dietary assessment methodology (self-reported dietary assessment questionnaire and 24 h urine), food store categories (combinations of food stores and each of the food stores), data sources of food store availability (census of commerce of 2002 and telephone business directories published in 2007) and definition of neighbourhood (1-km mesh block and 0·5-mile (0·8-km) radius of residence). Nevertheless, both studies suggest that neighbourhood food store availability is associated with at least some aspect of a resident's diet.

Several limitations of the present study warrant mention. First the present results are based on a highly selected population, and thus, they probably cannot be extrapolated to the general Japanese population. Female dietetic students were selected as the participants, and owing to the recruitment procedure used, the response rate could not be precisely determined, although the approximate response rate was 56 %. These elements of the design may have produced recruitment bias. As such, the participants had a higher education level and greater knowledge of diet and nutrition than the general population. Given the finding of an association in this population, in which education and nutritional knowledge likely had a greater influence on food choice than the local food environment, associations between availability and intake might be expected to be stronger in the general Japanese population.

Second, mainly because of the unavailability of retail food store data from a government source (i.e. census of commerce), we relied on a commercial database of telephone business directories to estimate neighbourhood food store availability. Use of telephone directories may be problematic because the same store may be listed several times under different store names, store addresses may be omitted or incorrect, and stores may be listed even after they have moved or closed[34]. Also, categorisation of the stores was based on name recognition, and supplemented with information obtained in websites. There is thus likely to be error in the categorisation of the stores, although these procedures were conducted by one of us (K. M.) to reduce biases possibly occurring when different raters are involved. Nevertheless, any errors in the assessment of neighbourhood food store availability should be theoretically independent of errors in urinary biomarkers, and we observed reasonable associations between neighbourhood food store availability and urinary biomarkers, which might lend support to the potential use (and reliability) of this strategy for the assessment of neighbourhood food store availability in epidemiological research in Japan.

Third, we did not have information on where participants actually shopped for food. As such our exposure variable is only a proxy for the neighbourhood food environment. Fourth, we used an arbitrary unit (i.e. 0·5-mile (0·8-km) radius of residence) as an approximation of a neighbourhood, but this unit may not represent the area of actual relevance to the food shopping habits of a particular individual. For example, reliance on the neighbourhood environment for food may differ by other factors such as transportation use, information which was not available in the present study. Fifth, the number and type of stores used as proxies for availability may be a limitation; more specific information regarding the types and costs of foods sold at these establishments may have been useful. Sixth, because data for food stores (2007) and dietary biomarkers (2006 and 2007) were collected at different times, the present study had to be based on the assumption that the food environment remained constant between 2006 and 2007. Seventh, urinary excretion of Na and K was estimated based on a single 24 h urine sample, which is not optimal for characterising individual habitual dietary intake and introduces random errors[35]. Eighth, we were unable to control for other factors that may influence individual dietary choices, and these may also be associated with the neighbourhood food environment (e.g. personal food preferences). Finally, the cross-sectional nature of the study hampers the drawing of any conclusions on causal inferences between neighbourhood food store availability and dietary intake.

In conclusion, this cross-sectional study of a group of young Japanese women showed that increasing availability of supermarkets/grocery stores and fruit/vegetable stores and decreasing availability of confectionery stores/bakeries and rice stores in neighbourhoods were associated with favourable profiles of 24 h urinary K (and Na) excretion. In contrast, neighbourhood availability of meat stores, fish stores and convenience stores was not associated with these urinary biomarkers. These findings suggest that neighbourhood food store availability influences dietary intake. Whether favourable changes in neighbourhood food store availability will improve diet quality and reduce disparities in diet deserves further investigation in studies using quasi-experimental or experimental designs.

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