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Original Article

Availability of two self-administered diet history questionnaires for pregnant Japanese women: A validation study using 24-hour urinary markers

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A B S T R A C T

Background: Accurate and easy dietary assessment methods that can be used during pregnancy are required in both epidemiological studies and clinical settings. To verify the utility of dietary assessment questionnaires in pregnancy, we examined the validity and reliability of a self-administered diet history questionnaire (DHQ) and a brief-type self-administered diet history questionnaire (BDHQ) to measure energy, protein, sodium, and potassium intake among pregnant Japanese women.
Methods: The research was conducted at a university hospital in Tokyo, Japan, between 2010 and 2011. The urinary urea nitrogen, sodium, and potassium levels were used as reference values in the validation study. For the reliability assessment, participants completed the questionnaires twice within a 4-week interval.
Results: For the DHQ ($n = 115$), the correlation coefficients between survey-assessed energy-adjusted intake and urinary protein, sodium, and potassium levels were 0.359, 0.341, and 0.368, respectively; for the BDHQ ($n = 112$), corresponding values were 0.302, 0.314, and 0.401, respectively. The DHQ-measured unadjusted protein and potassium intake levels were significantly correlated with the corresponding urinary levels ($r_s = 0.307$ and $r_s = 0.342$, respectively). The intra-class correlation coefficients for energy, protein, sodium, and potassium between the time 1 and time 2 DHQ ($n = 58$) and between the time 1 and time 2 BDHQ ($n = 54$) ranged from 0.505 to 0.796.
Conclusions: Both the DHQ and the BDHQ were valid and reliable questionnaires for assessing the energy-adjusted intake of protein, sodium, and potassium during pregnancy. In addition, given the observed validity of unadjusted protein and potassium intake measures, the DHQ can be a useful tool to estimate energy intake of pregnant Japanese women.

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Introduction

Maternal nutrition is a significant factor for the well-being of both mother and fetus.[1–3] Deficiencies in energy and protein during pregnancy have been associated with low birth weight,[4] and the pathogeneses of preeclampsia and gestational diabetes mellitus (GDM) have been associated with excess energy and fat intake, as well as vitamin and mineral deficiencies.[1,2,5] The recent increase in the incidence of low birth weight and GDM in Japan[6,7] emphasizes the importance of adequate nutritional status. Therefore, accurate

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assessment of dietary intake, especially energy intake, is required to estimate the risk of pregnancy complications. Nonetheless, no validated questionnaires for assessing energy intake, which is an indirect indicator of the overall quantity and quality of dietary intake, exist for pregnant Japanese women.

Dietary questionnaires, including diet history questionnaires (DHQs) and food frequency questionnaires, are often used in large epidemiological studies because they are less burdensome for participants and less costly than other dietary assessment methods. A self-administered DHQ and a brief-type self-administered diet history questionnaire (BDHQ) have already been validated for assessing energy intake and the intake of most nutrients using the dietary record, 24-hour urine collection, and doubly-labeled water methods in the non-pregnant, adult Japanese population.[8–11] The DHQ is a semi-quantitative questionnaire that assesses dietary intake for a total of 150 food and beverage items in the previous 1 month based on the following categories: the reported consumption frequency and portion size, usual cooking methods, and general dietary behavior.[8–11] The DHQ takes about 40 min to complete. On the other hand, the BDHQ is a fixed-portion questionnaire that assesses dietary intake for a total of 58 food and beverage items based on the reported consumption frequency, usual cooking methods, and general dietary behavior.[8] The BDHQ takes 10–15 min to complete. To identify the utility of the DHQ and the BDHQ as assessment tools for energy intake during pregnancy, validation studies with pregnant women are necessary.

Other studies in non-pregnant women have used energy expenditures derived from the doubly-labeled water method, human calorimeters, accelerometer or heart-rate monitoring to assess the validity of estimated energy intake.[12] Of these, the doubly-labeled water method has been regarded as the gold standard. However, this method cannot be applied to pregnant women because safety during pregnancy has not been verified. The other objective methods also have implementation problems: large-scale equipment is needed, the estimation of energy expenditure is difficult during pregnancy, or the value is easily affected by psychological status.[13] On the other hand, 24-hour dietary recalls and dietary records are often used as reference methods. However, these subjective methods have the possibility of reporting bias.

Protein and potassium intake are used as alternative markers to explore the validity of overall dietary intake because these nutrients are present in a variety of foods.[14–17] For example, protein is primarily found in meat, fish, beans, and cereals, while potassium is present in fruits, vegetables, beans, and potatoes. Protein and potassium intake measures are frequently validated using a 24-hour urinary excretion test. The 24-hour urine collection method is acceptable even for pregnant women because it is not a physically invasive procedure. In addition, the intake of sodium, which can be validated using a 24-hour urinary sodium level test, may be helpful for assessing energy intake[18] because it also reflects the consumption of a wide range of foods, including fish, shellfish, and processed foods.[19] Previous studies have indicated that the reporting accuracy of sodium intake, as well as those of protein and potassium intake, had a significant positive correlation with the reporting accuracy of energy intake,[20] and that the degree of misreporting did not greatly differ among energy, protein, sodium, and potassium intakes.[21] Protein, sodium, and potassium intake might complement each other as alternative markers of energy intake owing to their different sources. Thus, we assessed the indirect validity of energy intake by carefully interpreting the availability of these nutrients. It is also important to evaluate the validity and the reliability of protein, sodium, and potassium intake measures themselves during pregnancy, since an excess or deficiency of these nutrients affects fetal growth and may result in pregnancy complications.[22–24]

The present study was designed 1) to assess the validity of the DHQ and the BDHQ for estimating protein, sodium, and potassium intake levels using the 24-hour urinary markers; 2) to assess the validity of the DHQ and the BDHQ for estimating energy intake levels using unadjusted intake of protein, sodium, and potassium as alternative indicators; and 3) to investigate the reliability of the DHQ and the BDHQ via comparing the dietary intake levels estimated using repeated administrations of the questionnaires.

Methods

Overview of the recruitment criteria and study design

Validation study

The present study was conducted at a university hospital in Tokyo, Japan. The BDHQ was administered between June and December 2010, while the DHQ was administered between January and June 2011. Thus, participants of the DHQ validation study and those of the BDHQ validation study were recruited separately. Healthy Japanese women with singleton pregnancies were recruited at 15–19 weeks of gestation. Those with diabetes, hypertension, and psychological diseases, as well as those who were less than 20 years of age and those who had a low Japanese literacy level, were excluded from the study. These inclusion and exclusion criteria were the same in validation studies for both the DHQ and BDHQ. Each participant received written and verbal information about the study protocol before providing written informed consent. The research ethics committee of the Graduate School of Medicine at the University of Tokyo approved the study procedures and protocol.

The participants responded to the questionnaires while waiting for their pregnancy checkup at 19–23 weeks of gestation. Participants received instructions on how to complete the DHQ and the BDHQ before answering them. The participants who did not have sufficient time to complete the questionnaires in the hospital filled them out after returning home (within 7 days) and submitted them via mail. We resolved missing or unclear data face-to-face or through a telephone interview.

Twenty-four-hour urine collection was conducted within the 5 days preceding the pregnancy checkup at 19–23 weeks of gestation.

Reliability study

To assess the reliability of the BDHQ and the DHQ, pregnant women at 15–19 weeks of gestation were recruited between October and December 2010 and between January and March 2011, respectively. The participants were a subsample from each validation study. The first measurement (time 1) was completed upon recruitment, and participants were later asked to complete the questionnaire a second time. The second measurement (time 2) was completed 4 weeks after the time 1 survey.

Diet history questionnaire

The DHQ was designed to assess the dietary intake of Japanese adults over the previous month[8–11] and has been previously validated for some fatty acids and vitamins in pregnant Japanese women.[25–28] Estimates of dietary intake for a total of 150 food and beverage items were calculated using an *ad hoc* computer algorithm, which included weighting factors for the DHQ. The estimates were based on consumption frequency and portion size of selected food and beverage items, daily intake of staple foods (rice, other grains, bread, noodles, and other wheat products), soup for noodles, and miso soup; usual cooking methods for fish, meat, eggs, and vegetables; and general dietary behavior, such as seasoning preferences. Information from usual cooking methods and general dietary behavior was used for estimation of dietary intake of four seasonings and soy sauce. Food item and standard portion size measures were derived from primary data from the National Nutrition Survey of Japan and various Japanese recipe books.[8] Each consumption frequency item had eight response options, ranging from "more than twice per day" to "almost never". Five response options for portion size were listed, ranging from "less than half of the standard portion size" to "more than 1.5 times the standard portion size". The DHQ also includes questions of dietary supplements and open-ended items for foods consumed more than once weekly but not appearing in the DHQ. However, this information was not used in the calculation of dietary intake.

The BDHQ is a short-version of the DHQ and can be easily used in clinical settings. The BDHQ is a fixed-portion questionnaire that assesses dietary intake during the previous 1 month. Estimates of dietary intake for a total of 58 food and beverage items were calculated using an *ad hoc* computer algorithm, which included weighting factors for the BDHQ. The estimates were based on consumption frequency of selected food and beverage items, daily intake of rice and miso soup, usual cooking methods for fish and meat, and general dietary behavior.[8] Most food and beverage items were selected from the DHQ food list.[8] Standard portion sizes for women were determined based on the National Nutrition Survey of Japan and various Japanese recipe books. Intakes of five seasonings were estimated using qualitative information of usual cooking methods and general dietary behavior. Each consumption frequency item included seven response options, ranging from "more than twice per day" to "almost never".

The unadjusted intake of energy and nutrients (g/day) measured by the DHQ and the BDHQ were calculated using an *ad hoc* computer algorithm based on the Japanese standard of food composition tables.[29] We excluded participants who reported an extremely unrealistic energy intake: those whose reported energy intake less than half the energy intake required for the lowest physical activity category or more than 1.5 times the energy intake required for the moderate physical activity category (as outlined by the Dietary Reference Intakes for Japanese) were excluded.[30,31]

We used nutrient density to establish energy-adjusted values to evaluate the usefulness of the DHQ and the BDHQ in epidemiological studies. Using energy-adjusted values is recommended to help reduce intra-individual measurement errors.[32]

Twenty-four-hour urine collection

A single 24-hour urine collection was conducted to measure the 24-hour total urine volume and levels of urea nitrogen, sodium, and potassium. Upon enrollment, each participant received written and verbal instructions regarding the 24-hour urine collection method. The participants were provided with a 3-L plastic bottle, a 1-L plastic bottle, a 50-mL plastic bottle, and 350-mL cups. On the day before the urine collection, we called the participants to confirm the urine collection procedure. On the date of collection, the participants discarded their first urine specimen of the day and collected all subsequent specimens for the next 24 h. After all the urine samples were collected, the total urine volume was marked on the 3-L bottle with a felt-tipped marker. The well-stoppered 3-L bottle was shaken approximately 10 times and an aliquot of pooled urine was placed into a 50-mL plastic bottle. We collected the 50-mL bottle with the urine sample and the marked 3-L bottle emptied of its contents.

The urine samples were stored at room temperature until submission and then were stored at -80 °C until analysis. The urinary urea nitrogen level was determined via the urease and leucine dehydrogenase method using the Iatro-LQ UN rate (A) II assay (LSI Medience Corporation, Tokyo, Japan). The urea nitrogen level in the 24-hour urine sample was used for estimating the amount of dietary protein. Urinary levels of sodium and potassium were measured using ion-selective electrodes. The urinary creatinine level was measured via the enzyme method using the Iatro-LQ CRE (A) II assay (LSI Medience Corporation). These assays were analyzed by LSI Medience Corporation using an automated analyzer (BM6050; JEOL Ltd, Tokyo, Japan).

Creatinine excretion in relation to body weight (creatinine level [mg/day] divided by body weight [kg]) was used to verify the completeness of the 24-hour urine collection.[33] Participants with values of <10.8 or >25.2 were excluded from the analysis.[33]

General questionnaires

Demographic and lifestyle information, such as age and smoking habits, was collected from questionnaires administered during medical checkups at 19–23 weeks of gestation. Participants were also asked about pregnancy-associated nausea during the preceding month. The pre-pregnancy body mass index (BMI) was calculated from the self-reported pre-pregnancy weight and height.

Statistical analysis

All statistical analyses were conducted using the IBM Statistical Package for Social Sciences for Windows version 20.0 (IBM Japan, Tokyo, Japan), and differences with a two-tailed *P*-value <0.05 were considered statistically significant.

Validation study

We assumed that the level of validity between dietary intake and the corresponding urinary levels was greater than $r = 0.30$, with 80% power and a 5% significance level. This was based on studies showing that a correlation coefficient between dietary assessment methods greater than 0.50 was considered good and values of 0.30–0.50 were considered acceptable.[34,35] Therefore, a sample size greater than 85 was required.[36]

Spearman's correlation coefficients were calculated to examine the associations between dietary intake and the corresponding urinary nutrient levels. The analyses were conducted after the urinary nutrient levels were divided by the urinary creatinine levels. Creatinine adjustment has been used frequently to adjust for urinary dilution. In addition, all pregnant women were classified into quartiles according to their intake and 24-hour urinary protein (urea nitrogen), sodium, and potassium levels. Concordance in quartile ranking based on intake and urinary levels was assessed as the percentage of pregnant women who were classified in the same and adjacent quartiles. Discordance in quartile ranking was assessed as the percentage of pregnant women who were classified in the opposite quartiles for the highest and lowest quartiles (first quartile vs. fourth quartile). We calculated Spearman's correlation coefficients to examine the association between energy intake and the intake of other nutrients. These analyses were conducted for the participants of both the DHQ study and the BDHQ study.

Reliability study

We assumed that the levels of reliability for the DHQ and the BDHQ were greater than $r = 0.50$, with 80% power and a 5% significance level. This was based on studies showing that good intraclass correlation coefficients (ICCs) for the repeatability of a dietary assessment questionnaire range from 0.50 to 0.70.[37] Therefore, a sample size greater than 29 was required.[36]

The unadjusted and energy-adjusted intakes estimated from the time 1 and time 2 DHQ and the time 1 and time 2 BDHQ were compared using the paired *t*-test. The dietary intake ICCs between the time 1 and time 2 questionnaires were also calculated. The analyses were performed after the log transformation of all dietary intake (except energy intake) data.

Results

Validation study

For the DHQ validation study, 180 pregnant women met the inclusion criteria and 147 (81.7%) provided written informed consent (Fig. 1). Thirty-two pregnant women were excluded from the analyses (4 dropped out, 11 had missing data, 2 had extremely unrealistic energy intake, 12 did not successfully complete all the urine collections, and 3 did not meet the creatinine-weight criteria). Thus, data from 115 women (63.9%) were included in the final analysis.

For the BDHQ validation study, 171 pregnant women met the inclusion criteria and 140 (81.9%) provided written informed consent (Fig. 2). Twenty-eight women were excluded from the analyses (4 dropped out, 9 had missing data, 5 had extremely unrealistic energy intake, 7 did not successfully complete all the urine collections, and 3 did not meet the creatinine-weight criteria). Therefore, data from 112 women (65.5%) were analyzed for the BDHQ validation study.

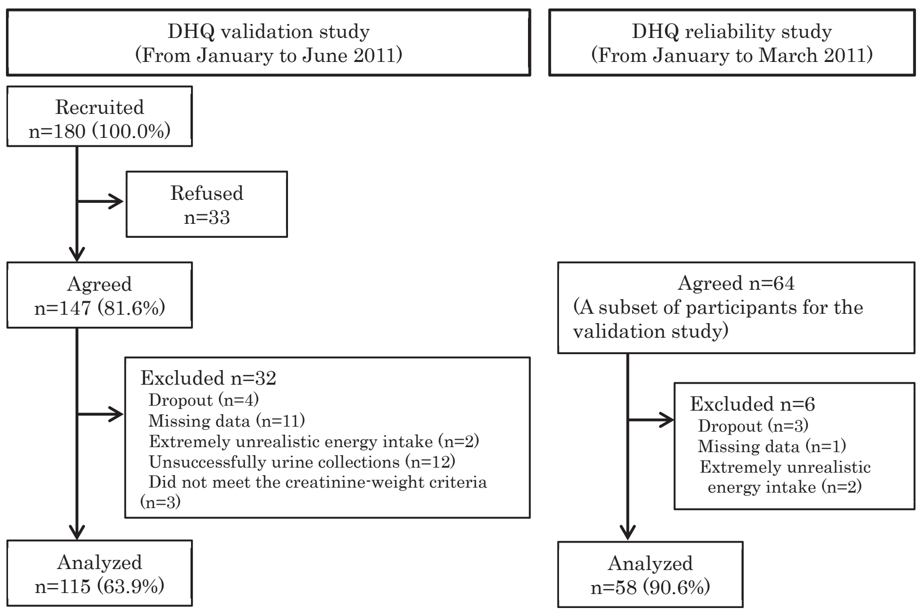

Fig. 1. Flowchart of the participants of the DHQ study. DHQ, diet history questionnaire.

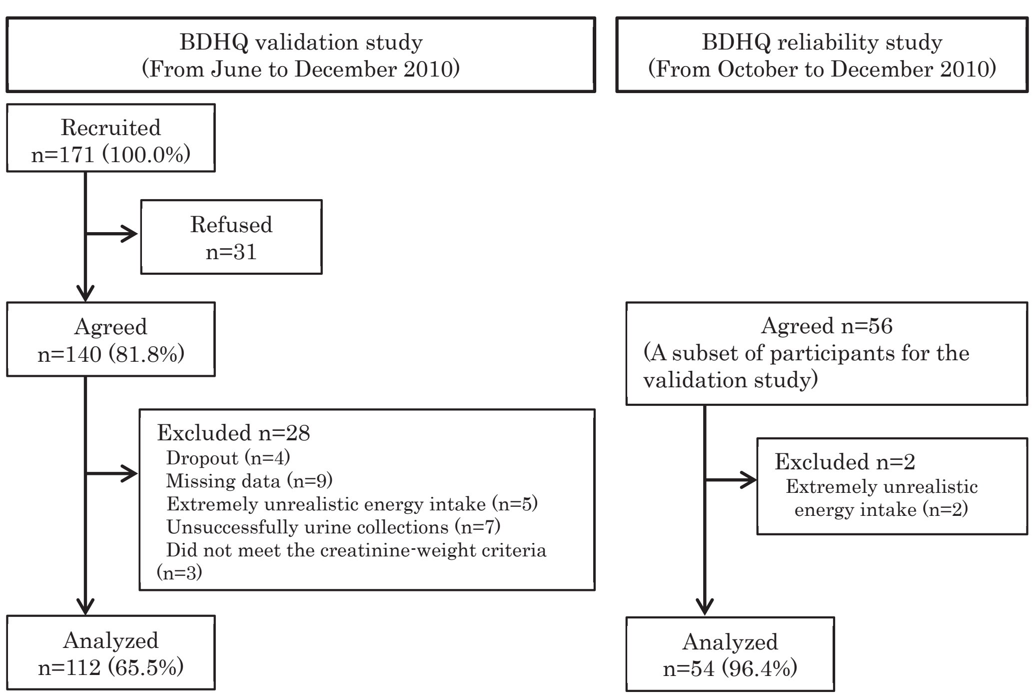

Fig. 2. Flowchart of the participants of the BDHQ study. BDHQ, brief-type diet history questionnaire.

Table 1
Characteristics of participants.

	DHQ		BDHQ	
	Validation study (n = 115)	Reliability study (n = 58)	Validation study (n = 112)	Reliability study (n = 54)
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)
Age, years	34.2 ± 4.1	33.8 ± 4.2	34.3 ± 4.0	34.6 ± 3.6
Gestational age, weeks	20.1 ± 1.1		20.2 ± 1.2	
Gestational age at first survey, weeks		16.9 ± 1.5		16.1 ± 1.4
Gestational age at second survey, weeks		21.0 ± 1.3		20.5 ± 1.2
Height, cm	159.0 ± 4.8	159.1 ± 5.4	158.9 ± 4.8	159.7 ± 5.5
Pre-pregnancy body mass index, kg/m^2	20.4 ± 2.6	20.2 ± 3.0	20.3 ± 2.2	20.5 ± 2.7
Parity: Primigravida, n (%)	72 (62.6)	38 (65.5)	75 (67.0)	35 (64.8)
Education level, n (%)				
High school	7 (6.1)	3 (5.2)	7 (6.2)	6 (11.1)
Junior or technical college	46 (40.0)	24 (41.4)	48 (42.9)	19 (35.2)
College or university	62 (53.9)	31 (53.4)	57 (50.9)	29 (53.7)
Income, Japanese yen/year, n (%)				
<5,000,000	16 (13.9)	7 (12.0)	15 (13.4)	9 (16.7)
5,000,000–9,000,000	57 (49.6)	27 (46.6)	52 (46.4)	27 (50.0)
>9,000,000	42 (36.5)	24 (41.4)	45 (40.2)	18 (33.3)
Regular smoker during pregnancy, n (%)	1 (0.9)	1 (1.7)	1 (0.9)	1 (1.9)
Pregnancy-related nausea, n (%)	30 (25.6)	10 (17.2)	30 (26.8)	12 (22.2)

BDHQ, brief-type self-administered diet history questionnaire; DHQ, self-administered diet history questionnaire; SD, standard deviation.

Table 1 summarizes the characteristics of the participants. The mean maternal age was 34 years, and the mean pre-pregnancy BMI was 20.2–20.5 kg/m^2. More than 60.0% of the participants were primigravidae.

Mean dietary intake and mean 24-hour urinary levels are shown in Table 2. Spearman's correlation coefficients between the energy-adjusted intakes and corresponding urinary levels were 0.359 (DHQ) and 0.302 (BDHQ) for protein, 0.341 (DHQ) and 0.314 (BDHQ) for sodium, and 0.368 (DHQ) and 0.401 (BDHQ) for potassium (Table 3). Unadjusted protein and potassium intakes from the DHQ and unadjusted potassium intake from the BDHQ had correlation coefficients greater than 0.30 with the corresponding urinary nutrient levels ($r_s = 0.307$, 0.342, and 0.354, respectively). However, the DHQ-measured unadjusted sodium intake and the BDHQ-measured unadjusted protein and sodium intake showed poor correlations with the corresponding urinary nutrient levels ($r_s = 0.105$, 0.231, and 0.250, respectively).

When the DHQ participants were classified into quartiles based on the dietary intake and urinary nutrient levels, more than 70% of the participants were classified in the same or adjacent quartiles for unadjusted protein and potassium intake and energy-adjusted protein, sodium, and potassium intake (Table 4). Similarly, among BDHQ participants, more than 70% of the participants were classified in the same or adjacent quartiles for unadjusted potassium intake as well as energy-adjusted protein, sodium, and potassium intake.

Table 2
Dietary intakes and 24-hour urinary levels of the validation study.

	DHQ (n = 115)	BDHQ (n = 112)
	Median (Interquartile range)	Median (Interquartile range)
Dietary intake		
Energy, kcal/day	1743 (1499–2037)	1454 (1291–1693)
Protein, g/day	61.6 (52.2–72.7)	53.6 (45.1–66.2)
% of energy	14.2 (13.3–15.2)	14.6 (13.4–16.3)
Sodium g/day	3.94 (3.31–4.84)	3.42 (2.80–3.85)
g/1000 kcal	2.26 (1.95–2.51)	2.30 (2.03–2.53)
Potassium, g/day	2.13 (1.66–2.50)	2.13 (1.64–2.69)
g/1000 kcal	1.19 (1.05–1.35)	1.42 (1.24–1.73)
Urinary markers		
24-hour total urine volume, mL/day	1330 (1060–1705)	1406 (1075–1690)
Urea nitrogen, g/day	6.79 (5.74–7.59)	6.77 (5.70–7.84)
Sodium, g/day	3.20 (2.63–4.06)	3.41 (2.72–4.07)
Potassium, g/day	1.81 (1.43–2.26)	1.92 (1.46–2.25)
Creatinine, g/day	0.90 (0.80–1.01)	0.91 (0.82–1.01)

DHQ, self-administered diet history questionnaire; BDHQ, brief-type self-administered diet history questionnaire.

Table 3
Spearman's correlation coefficients for protein, sodium, and potassium between the dietary intakes and the corresponding 24-hour urinary levels.

		DHQ (n = 115)		BDHQ (n = 112)	
		r_s	P	r_s	P
Dietary intake					
Protein	g/day	0.307	0.001	0.231	0.014
	% of energy	0.359	<0.001	0.302	0.001
Sodium	g/day	0.105	0.263	0.250	0.008
	g/1000 kcal	0.341	<0.001	0.314	0.001
Potassium	g/day	0.342	<0.001	0.354	<0.001
	g/1000 kcal	0.368	<0.001	0.401	<0.001

Dietary intakes were assessed using a self-administered diet history questionnaire (DHQ) or a brief-type self-administered diet history questionnaire (BDHQ).
The 24-hour urinary excretion levels of urea nitrogen (a marker of dietary protein intake), sodium, and potassium were adjusted by urinary creatinine levels.

In the DHQ study, energy intake showed significant correlations with intake of protein ($r_s = 0.875$, $P < 0.001$), sodium ($r_s = 0.654$, $P < 0.001$), and potassium ($r_s = 0.771$, $P < 0.001$). In the BDHQ study, energy intake also showed significant correlations with intake of protein ($r_s = 0.825$, $P < 0.001$), sodium ($r_s = 0.700$, $P < 0.001$), and potassium ($r_s = 0.706$, $P < 0.001$).

Reliability study

All the participants in each reliability study were included in the corresponding validation study. Sixty-four pregnant women completed the time 1 DHQ (Fig. 1). Of these 64 women, 6 were excluded from the analyses (1 had missing data, 2 had an extremely unrealistic energy intake in the first DHQ, and 3 dropped out at time 2). Ultimately, 58 women were included in the DHQ reliability analysis.

Fifty-six women completed the time 1 BDHQ (Fig. 2). Of them, 2 women were excluded from the analyses because of severely

Table 4
Concordance and discordance between the quartiles of dietary intakes and corresponding urinary levels.

		DHQ (n = 115)		BDHQ (n = 112)	
		Concordance[a] (% classified into the same or adjacent quartile)	Discordance[b] (% classified into the opposite quartile)	Concordance[a] (% classified into the same or adjacent quartile)	Discordance[b] (% classified into the opposite quartile)
Dietary intake					
Protein	g/day	77.6	6.9	66.1	8.0
	% of energy	70.7	5.2	72.3	6.3
Sodium	g/day	63.8	8.6	68.8	7.1
	g/1000 kcal	73.3	4.3	74.1	7.1
Potassium	g/day	72.4	6.0	70.5	4.5
	g/1000 kcal	74.1	6.9	73.2	5.4

DHQ, self-administered diet history questionnaire; BDHQ, brief-type self-administered diet history questionnaire.
[a] Concordance in quartile ranking based on intakes and 24-hour urinary levels was assessed as the percentage of pregnant women who were classified in the same and adjacent quartiles.
[b] Discordance in quartile ranking was assessed as the percentage of pregnant women who were classified in the opposite quartiles for the highest and lowest quartiles (first quartile vs. fourth quartile).

Table 5
Dietary intake estimated from the repeated administrations of the DHQ and the repeated administrations of the BDHQ.

		DHQ (n = 58)				BDHQ (n = 54)			
		1st DHQ	2nd DHQ	P[a]	1st DHQ vs. 2nd DHQ Intraclass correlation coefficient	1st BDHQ	2nd BDHQ	P[a]	1st BDHQ vs. 2nd BDHQ Intraclass correlation coefficient
		Median (Interquartile range)	Median (Interquartile range)			Median (Interquartile range)	Median (Interquartile range)		
Energy	kcal/day	1675 (1491–1935)	1742 (1487–2050)	0.362	0.599	1515 (1277–1814)	1490 (1354–1854)	0.558	0.705
Protein	g/day[b]	56.6 (49.0–71.7)	60.0 (47.4–72.9)	0.807	0.601	56.2 (47.2–75.1)	60.2 (50.2–74.9)	0.473	0.731
	% of energy[b]	13.7 (12.6–15.2)	14.0 (12.8–14.7)	0.805	0.599	15.2 (13.4–17.1)	15.7 (13.9–18.2)	0.223	0.549
Sodium	g/day[b]	3.65 (2.93–4.53)	3.66 (2.91–4.66)	0.645	0.589	3.57 (2.90–4.63)	3.73 (3.12–4.31)	0.839	0.720
	g/1000 kcal[b]	2.23 (1.91–2.52)	2.14 (1.84–2.46)	0.280	0.517	2.35 (2.10–2.67)	2.34 (2.05–2.67)	0.839	0.505
Potassium	g/day[b]	2.11 (1.55–2.39)	2.05 (1.58–2.46)	0.748	0.716	2.18 (1.79–3.00)	2.37 (1.93–2.98)	0.115	0.796
	g/1000 kcal[b]	1.17 (1.04–1.36)	1.15 (1.05–1.29)	0.073	0.631	1.45 (1.26–1.65)	1.50 (1.26–1.81)	0.059	0.602

DHQ, self-administered diet history questionnaire; BDHQ, brief-type self-administered diet history questionnaire.
1st questionnaire: 15–19 weeks of gestation, 2nd questionnaire: 19–23 weeks of gestation.
[a] Paired *t*-test.
[b] The analyses were performed after log transformation of the variables.

under-reported energy intake at time 1. Therefore, data of 54 participants were included in the final analysis of BDHQ reliability.

No significant differences were detected in the log-transformed mean energy, protein, sodium, or potassium intake levels between the time 1 and time 2 DHQ or BDHQ (Table 5). The ICCs for the DHQ-measured energy and nutrient levels between the time 1 and time 2 surveys ranged from 0.517 to 0.716, while the ICCs between the time 1 and time 2 BDHQ ranged from 0.505 to 0.796.

Discussion

This is the first study to establish the validity and reliability of dietary questionnaires for evaluating the energy-adjusted intake of protein, sodium, and potassium among pregnant Japanese women and to validate unadjusted protein and potassium (as measured by the DHQ) as a proxy of energy intake.

In general, a correlation coefficient greater than 0.30 between different dietary assessment methods is considered acceptable in a validation study.[34,35] According to this criterion, the energy-adjusted intake of protein, sodium, and potassium measured using both the DHQ and the BDHQ had acceptable validity. In addition, the results of quartile concordance of energy-adjusted intake showed satisfactory ranking ability. In epidemiological studies, the use of energy-adjusted values is recommended to control for confounding, to reduce extraneous variation, and to minimize reporting bias.[32] The results of the present study indicate that both the DHQ and the BDHQ can be valuable assessment tools for epidemiological studies examining protein, sodium, and potassium intake levels.

The DHQ-assessed unadjusted intake of protein and potassium also showed acceptable validity according to the criteria of previous studies.[34,35] However, DHQ-assessed unadjusted sodium intake was not associated with corresponding urinary levels, and the results of quartile ranking showed low concordance. Thus, our findings indicate that the DHQ cannot effectively estimate unadjusted sodium intake. A previous DHQ validation study in non-pregnant women showed similar results.[11] This may be because unadjusted intake values are more readily affected by other factors than energy-adjusted intake values, which reduce intra-individual measurement errors.[32] In addition, obtaining an accurate assessment of sodium intake using a single 24-hour urine collection is challenging. This is because sodium intake often varies daily according to salt consumption,[38] urinary sodium levels are easily affected by sodium loss from sweat,[39] and estimating sodium intake from seasonings is difficult. Regardless of the difficulty of estimating sodium intake using a dietary questionnaire, we included sodium intake in the study in an attempt to show the indirect validity of sodium intake to estimate energy intake. This method has not been thoroughly discussed and is controversial.[18,20,21] However, the observed validity of DHQ-assessed unadjusted protein and potassium intake and the strong correlations between energy intake and the intake of these nutrients should be sufficient to provide an indication of the indirect validity of using these nutrient intakes as a proxy for energy intake. This is supported by previous studies that have proposed protein and potassium intakes as effective estimators of energy intake.[14–17] Misreporting of protein and potassium intake is indicative of a degree of misreporting of energy intake because the two nutrients are contained in a variety of foods contributing to energy.[15,17] Thus, accurate reporting (i.e., validity) of these two nutrients would result in accurate reporting for energy intake.

On the other hand, the BDHQ was not shown to be a valid measure of unadjusted protein and sodium intake during pregnancy, indicating that estimating energy intake with this questionnaire is difficult. A previous study among non-pregnant Japanese adults also showed low validity for energy intake, as measured by the BDHQ, when compared to the DHQ, for which low-to-modest validity for energy intake have been shown.[8,9] One reason might be that the BDHQ does not include questions about portion size. In addition, estimating dietary quantity for pregnant women using uniform fixed portion sizes may be more challenging than for non-pregnant women because portion sizes are likely to vary with food cravings and aversions experienced by most women during pregnancy.[40] Therefore, the DHQ, which can estimate intake from both the consumption frequency and portion size of each food, is recommended as a diet assessment tool for estimating energy intake among pregnant women.

In general, good ICCs for the reliability of a dietary assessment questionnaire range from 0.50 to 0.70.[37] Accordingly, the estimated intake of energy, protein, sodium, and potassium showed good ranking ability between the repeated administrations of the DHQ and the BDHQ. The results of the paired *t*-test also indicated that the two questionnaires were reliable for measuring these dietary intakes. Thus, both the DHQ and the BDHQ are reliable methods for assessing the intake of energy, protein, sodium, and potassium in pregnant Japanese women.

The participants of this study were not representative of all pregnant Japanese women. Maternal age and education levels were slightly higher than those in other studies[6,41]; however, there is little reason to believe that such differences would affect the relationships between survey-assessed nutrient intakes and urinary nutrient levels. In fact, the intake of protein, sodium, and potassium were similar to those found in other Japanese studies.[41,42] Thus, the DHQ and the BDHQ are valid and reliable measurement tools for estimating energy-adjusted protein, sodium, and potassium intake, and the DHQ is a valid tool for measuring energy intake in pregnant Japanese women.

This study had a few limitations. First, some selection bias may have occurred in choosing the participants because the research was conducted in a single urban university hospital. Although the dietary intakes of our participants were equivalent to similar reports, differences in demographic characteristics, including age, education level, and BMI, might potentially affect dietary intake. Second, the 24-hour urine collection was performed only once. A single 24-hour urine collection might make it difficult to establish common excretion levels.

In conclusion, the present study showed that the DHQ and the BDHQ have acceptable validity and reliability for the assessment of energy-adjusted protein, sodium, and potassium intake in pregnant Japanese women. These results indicate that both the DHQ and the BDHQ could be useful assessment tools in epidemiological studies. In addition, given the observed validity of unadjusted protein and potassium intake measures, the DHQ can be a useful tool for estimating energy intake. However, the BDHQ may not be useful for estimating energy intake.

Conflicts of interest

None declared.

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