Original Article

Prevalence and characteristics of misreporting of energy intake in Japanese adults: the 2012 National Health and Nutrition Survey

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Background and Objectives: Information on a whole array of characteristics associated with dietary misreporting in a representative sample in each country is still limited. Using data from the 2012 National Health and Nutrition Survey, Japan, we investigated the prevalence and characteristics of under- and over-reporting of energy intake among 19,986 Japanese adults aged ≥20 years. **Methods and Study Design:** Each individual's energy intake was calculated based on a 1-day semi-weighed dietary record. Under-, plausible, and over-reporters were identified based on the 95% confidence limits 1) for agreement between the ratio of energy intake to basal metabolic rate and a physical activity level for sedentary lifestyle (1.55), and 2) of the expected ratio of energy intake to estimated energy requirement of 1.0, assuming 'low active' level of physical activity. **Results:** Almost all subjects (≥92.8%) were classified as plausible reporters by any of the methods applied, with very low percentages of under- and over-reporters (≤6.3% and ≤2.0%, respectively). Under-reporting was associated with younger age, overweight and obesity (compared with normal weight), current smoking (compared with never smoking), no alcohol drinking (compared with drinking everyday), and household consisting of a single person (compared with that consisting of two persons). Over-reporting was associated with gender (female), normal weight (compared with overweight), and household consisting of a single person. **Conclusions:** Overall mean energy intake obtained in this sample of Japanese adults appears to be plausible, but caution should be exercised when assessing the plausibility of energy intake in some subgroups.

Key Words: under-reporting, over-reporting, energy intake, national survey, Japan

INTRODUCTION

Misreporting of dietary intake is a pervasive problem and appears to occur both randomly and non-randomly.[1-3] Moreover, it may be selective for different kinds of foods and nutrients,[4,5] but in the absence of biomarkers for each food and nutrient of interest this is difficult to articulate with absolute certainty, and may differ by population. The resulting potential for differential errors in dietary data complicates the interpretation of studies on diet and health and, at worst, might produce spurious diet-health relations.[1,3,5] Thus, it is important to identify the characteristics associated with misreporting (under- and over-reporting) of dietary intake to better understand this issue.

Because all nutrients must be provided within the quantity of food needed to fulfill the energy requirement, energy intake (EI) is the foundation of the diet.[1] Unfortunately, under-reporting of EI has long been a serious problem in almost all dietary surveys.[1,6] In particular, overweight and obese subjects tend to under-report EI to a greater extent than normal weight subjects.[1-6] Moreover, recent studies have shown that, in addition to under-reporting, over-reporting of EI also needs to be taken into account, in some populations at least, such as those with low body mass index (BMI).[3,7,8] Investigation of dietary misreporting should be conducted in each country, as it is conceivable that the way in which survey participants comply with dietary assessment procedures may differ from one country to another. Nevertheless, information on a whole array of characteristics associated with dietary misreporting in a representative sample in each country is still limited.[7-13]

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In the current study, the prevalence and characteristics of under- and over-reporting of EI among Japanese adults were evaluated, based on data from the National Health and Nutrition Survey, Japan (NHNSJ).

METHODS

Study population

The NHNSJ, which has been running since 1945, is an annual nationwide nutrition survey conducted by local public health centers under the supervision of the Japanese Ministry of Health, Labour and Welfare on the basis of the Health Promotion Law. The present cross-sectional study was based on the data from the 2012 NHNSJ, with permission from the Ministry of Health, Labour and Welfare, Japan. Full details of the 2012 NHNSJ have been described elsewhere.[14] Briefly, 475 census units were randomly sampled as survey areas based on the population census. All the non-institutionalized Japanese people aged ≥1 y living in these areas were invited to participate. The survey was conducted from 25th October and 7th December 2012. Dietary data were obtained from a total of 12,750 out of 24,555 eligible households (52%). The final sample used in this analysis comprised 19,986 male and non-lactating and non-pregnant female participants aged ≥20 y with complete information on the variables of interest.

This survey was conducted according to the guidelines laid down in the Declaration of Helsinki, and verbal informed consent was obtained from all the individual subjects and their parents/guardians. The NHNSJ had stringent protocols and procedures, which ensure confidentiality and protect individual participants from identification.[14] Additionally, the present secondary analysis was based on public use dataset consisting of only information which has already been anonymized. Thus, institutional review board approval was not required.[15]

Assessment of energy intake

Dietary intake data were collected using a 1-d semi-weighed household dietary record, the procedure of which has been described in detail elsewhere.[14,16] Briefly, the subject (and the main record-keeper) was given both written and verbal instructions by trained fieldworkers (registered dietitians) on the purpose of the dietary record and how to weigh and record food items consumed by household members in the diary. When household members shared foods from the same dish, the record-keeper was also asked to record approximate proportions of the food taken by each of members so that dietary intake of each individual could be calculated. When weighing was not possible (e.g., eating out), the record-keeper was asked to record as much information as possible, including the portion size consumed and details of any leftovers. The recording day was freely selected by each household, except for Sundays, national holidays and days with some special events (e.g., wedding party or funeral). Trained fieldworkers visited the household and checked the completeness of food recording, and if necessary, additional information was added. An estimate of EI for each individual was calculated from the record of household food consumption and, for shared dishes or foods, approximate proportions consumed by each household member, based on the Standard Tables of Food Composition in Japan.[17]

The utility of this household dietary record for estimating dietary intake at the individual level in the Japanese population has previously been examined.[16] Briefly, dietary intakes among young women (about 20 y of age) estimated by this 1-d household dietary record by mothers (mean age: 49 y) were compared with those estimated by a 1-d weighed dietary record, which was independently conducted by the young women themselves (n=32). Mean differences between intakes estimated by the two methods were 6.2 % for energy, 5.7 % for protein, 6.7 % for fat, and 6.3 % for carbohydrate, while the Pearson correlation coefficients were 0.90 for energy, 0.89 for protein, 0.91 for fat, and 0.90 for carbohydrate.

Assessment of non-dietary variables

Anthropometric measurements were performed on approximately 70 % of the participants by trained fieldworkers using standardized procedures; height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg) were measured while the subject was barefoot and wearing light clothes only. Otherwise, height and weight were either measured by other household members at home or self-reported. BMI (kg/m^2) was calculated as weight (kg) divided by height (m) squared. Weight status was defined based on BMI according to World Health Organization recommendations as follows:[18] underweight (<18.5 kg/m^2), normal (≥18.5 to <25 kg/m^2), overweight (≥25 to <30 kg/m^2), and obese (≥30 kg/m^2). In accordance with the NHNSJ report,[14] six age categories were defined (20-29, 30-39, 40-49, 50-59, 60-69, and ≥70 y). Information on smoking status (never, past, and current), alcohol drinking (nondrinker, ≤2 d/wk, 3-6 d/wk, and 7 d/wk), and household size (1, 2, 3-4, and ≥5) was also collected.

Evaluation of the accuracy of energy intake reporting

Misreporting of EI was evaluated based on the ratio of EI to basal metabolic rate (BMR) (the Goldberg cutoff),[19] and the ratio of EI to estimated energy requirement (EER), namely the procedure proposed by Huang and colleagues.[20] Subjects were identified as plausible, under- and over-reporters of EI according to whether the individual's ratio was within, below, or above the 95 % confidence limits for agreement between EI:BMR and the respective physical activity level (PAL) or of the expected EI:EER of 1.0. For the principles of the Goldberg cutoff, the PAL for sedentary lifestyle (i.e., 1.55)[19] was assumed for all subjects. This decision was because of a lack of sufficient information on physical activity in NHNSJ. Although daily step counts were measured by a pedometer,[14] a previous study showed that the counts were not associated with physical-activity-related or total energy expenditure.[21] Additionally, exercise habits were assessed by a single self-report question, but there were a lot of participants with missing information (22%; n=4368).[14] In any case, the procedure used has been applied in a number of national representative dietary surveys,[8,10-13] facilitating comparisons of the results obtained in the present study with those in other countries. BMR was estimated using sex-specific equations developed for Japanese, based on age, body height, and body weight

(BMR_{JPN}).[22,23] BMR was also estimated using Schofield sex- and age-specific equations based on body height and weight ($BMR_{Schofield}$).[24] The 95% confidence limits for agreement (upper and lower cutoff values) between EI:BMR and the PAL were calculated, taking into account coefficients of variation in intakes and other components of energy balance (i.e., the within-subject variation in EI: 23%; the precision of the estimated BMR relative to the measured BMR: 8.5 %; the between-subject variation in PAL: 15%).[19] Consequently, under-, plausible, and over-reporters were defined as having EI:BMR <0.87, 0.87-2.75, and >2.75, respectively.

EER was calculated using sex- and age-specific equations for use in populations with a range of weight statuses, published from the US Dietary Reference Intakes, based on sex, age, body height and weight, and physical activity.[25] In the absence of sufficient information on physical activity as mentioned above, we assumed 'low active' level of physical activity (i.e., PAL ≥1.4 to <1.6)[25] for all subjects during this calculation. The 95% confidence limits of the expected EI:EER ratio of 0 on the natural log scale were calculated, taking into account coefficients of variation in intakes and other components of energy balance (i.e., the within-subject variation in EI: 23%; the error in the EER equations: 11%; the day-to-day variation in total energy expenditure: 8.2%).[19,20,25] Consequently, under-, plausible, and over-reporters were defined as having EI:EER <0.59, 0.59-1.71, and >1.71, respectively.

Statistical analysis

All statistical analyses were performed using SAS statistical software (version 9.4, SAS Institute, Cary, North Carolina). All reported *p* values are two-tailed, and $p<0.01$ was considered to be statistically significant to reduce the likelihood of making a type 1 error. Mean and SE values for EI, BMR_{JPN}, $BMR_{Schofield}$, EER, EI:BMR_{JPN}, EI:$BMR_{Schofield}$, and EI:EER were calculated according to each of the basic characteristics as well as for all subjects. Percentages of under-, plausible, and over-reporters of EI were also calculated in the same manner. The risk of being classified as an under-reporter compared with a plausible reporter or as an over-reporter compared with a plausible reporter was estimated using logistic regression (PROC LOGISTIC procedure). First, crude odds ratio (OR) and 99% confidence interval (CI) for the risk of being classified as an under- or over-reporter were calculated for each category of factors selected a priori that could be associated with EI misreporting, namely sex (reference: men), age (reference: 20-29 y), weight status (reference: normal), smoking status (reference: never), alcohol drinking (reference: nondrinker), and household size (reference: 1). Multivariate-adjusted OR and 99% CI were then calculated by entering all variables simultaneously into the regression model to assess the independent effect on risk. As crude and multivariate models showed similar results only the latter is shown in this paper.

RESULTS

Basic characteristics of the subjects are shown in Table 1. About two-thirds of subjects were classified as normal weight (67.3%) while about one-fifth of subjects were classified as overweight (21.2%), with the remaining 7.6% and 3.8% of subjects being classified as underweight and obese, respectively. Overall mean EI was 8109 kJ/d. When assessed against the PAL for sedentary lifestyle (1.55), EI was on average over-reported by 6% on the basis of EI:BMR_{JPN} (mean: 1.64) while under-reported by 10% on the basis of EI:$BMR_{Schofield}$ (mean: 1.41). When compared with EER, EI was on average under-reported by 2% (mean EI:EER: 0.98). Women had a higher mean EI:EER than men. Age was positively associated with EI:EER. Compared with normal weight subjects, overweight and obese subjects had lower mean values of EI:EER. Mean EI:EER also differed among smoking status groups, with the highest value in never smokers and the lowest value in current smokers; and among alcohol drinking groups, with the highest in every day drinkers and the lowest in subjects drinking ≤2 d/wk. Household size was inversely associated with EI:EER. Similar associations of these characteristics with the two EI:BMR variables were also observed, except for no association for alcohol drinking.

Numbers and percentages of under-, plausible, and over-reporters of EI are shown in Table 2. Almost all subjects (≥92.8%) were classified as acceptable reporters by any of the methods applied, with the very low percentages of under- and over-reporters (≤6.3% and ≤2.0%, respectively). Using EI:EER, the percentage of under-reporters was higher in men but that of over-reporters was higher in women. With regard to age, there were more under-reporters among younger age categories, while there were more over-reporters among older age categories. There were more under-reporters and fewer over-reporters among overweight and obese subjects. Current smokers had a higher percentage of under-reporters. The proportion of under- and over-reporters differed among alcohol drinking groups, with few under-reporters in every day drinkers. Among household size groups, there were few under-reporters in households consisting of two persons and more over-reporters in households comprising a single person. The results were generally similar based on using the two EI:BMR variables to estimate misreporters.

OR and 95 % CI for the risk of being an under-reporter compared with a plausible reporter are shown in Table 3. Irrespective of the methods applied, under-reporting was less likely in the 50-59, 60-69, and ≥70 y age groups (compared with age 20-29 y), drinking everyday (compared with nondrinking), and household consisting of two persons (compared with that consisting of a single person). A higher likelihood of being an under-reporter was consistently associated with overweight and obesity (compared with normal weight) and current smoking (compared with never smoking). In some analyses, a lower likelihood of being an under-reporter was associated with female sex (EI:$BMR_{Schofield}$ only), age 40-49 y (EI:EER only), drinking alcohol ≤2 d/wk (except for EI:BMR_{JPN}) and 3-6 d/wk (EI:$BMR_{Schofield}$ only), and household consisting of 3-4 persons (except for EI:EER), while a higher likelihood of being an under-reporter was associated with past smoking (except for EI:BMR_{JPN}).

Table 4 lists the OR and 95% CI for the risk of being an over-reporter compared with a plausible reporter.

Table 1. Characteristics of the participants: the 2012 National Health and Nutrition Survey, Japan (*n*=19,986)

			EI (kJ/d)		BMR_{JPN} (kJ/d)†		$BMR_{Schofield}$ (kJ/d)‡		EER (kJ/d)§		EI:BMR_{JPN}		EI:$BMR_{Schofield}$		EI:EER	
	n	%	Mean	se	Mean	se	Mean	se	Mean	se	Mean	se	Mean	se	Mean	se
All	19986	100	8109	17	5039	7	5818	7	8420	11	1.64	0.003	1.41	0.003	0.98	0.002
Sex																
Men	8878	44.4	9148	26	5868	8	6830	6	9631	13	1.58	0.005	1.34	0.004	0.96	0.003
Women	11108	55.6	7277	18	4376	6	5009	5	7451	9	1.69	0.005	1.46	0.004	0.99	0.003
p¶			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Age (years)																
20-29	1363	6.8	8249	76	5637	25	6128	30	9769	39	1.47	0.012	1.35	0.011	0.84	0.007
30-39	2477	12.4	8094	51	5591	20	6136	19	9516	30	1.46	0.008	1.32	0.007	0.85	0.005
40-49	2867	14.3	8193	45	5449	18	6119	17	9157	27	1.52	0.008	1.35	0.007	0.90	0.005
50-59	3139	15.7	8310	41	5179	16	6037	15	8617	22	1.62	0.008	1.38	0.006	0.97	0.004
60-69	4771	23.9	8306	33	4911	12	5661	15	8125	17	1.71	0.007	1.49	0.006	1.03	0.004
≥70	5369	26.9	7742	30	4444	12	5444	15	7325	16	1.78	0.007	1.45	0.006	1.07	0.004
p¶			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Weight status††																
Underweight	1527	7.6	7369	55	4222	19	5008	17	7429	30	1.78	0.013	1.48	0.011	1.00	0.007
Normal	13455	67.3	8100	20	4900	8	5691	8	8245	12	1.68	0.004	1.44	0.003	0.99	0.002
Overweight	4244	21.2	8353	37	5556	15	6331	17	9050	24	1.52	0.007	1.33	0.006	0.93	0.004
Obese	760	3.8	8388	96	6249	43	6841	48	9982	70	1.36	0.015	1.24	0.013	0.85	0.009
p¶			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Smoking status																
Never	11979	59.9	7710	20	4679	8	5386	8	7898	13	1.68	0.004	1.45	0.004	0.99	0.003
Past	4387	22.0	8677	37	5514	13	6473	12	9034	19	1.59	0.006	1.35	0.005	0.97	0.004
Current	3620	18.1	8740	45	5654	15	6455	15	9402	24	1.56	0.008	1.36	0.007	0.93	0.005
p¶			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Alcohol drinking																
Nondrinker	10305	51.6	7622	21	4705	9	5447	10	7911	14	1.66	0.005	1.42	0.004	0.98	0.003
≤2 d/wk	3845	19.2	8187	38	5293	16	6001	17	8883	25	1.57	0.007	1.38	0.006	0.93	0.004
3-6 d/wk	2365	11.8	8513	49	5400	20	6237	20	8953	30	1.60	0.009	1.38	0.008	0.96	0.006
7 d/wk	3471	17.4	9190	43	5502	15	6431	14	9055	22	1.69	0.008	1.44	0.006	1.02	0.005
p¶			<0.0001		<0.0001		<0.0001		<0.0001		0.45		0.92		<0.0001	
Household size																
1	2301	11.5	8080	54	4820	22	5617	23	8063	34	1.72	0.012	1.47	0.010	1.02	0.007
2	6401	32.0	8226	29	4894	12	5739	13	8117	17	1.71	0.006	1.45	0.005	1.02	0.003
3-4	8062	40.3	8107	26	5174	11	5912	11	8679	17	1.59	0.005	1.38	0.004	0.94	0.003
≥5	3222	16.1	7900	43	5143	18	5885	18	8628	27	1.56	0.008	1.35	0.007	0.93	0.005
p¶			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	

BMR_{JPN}: basal metabolic rate (BMR) estimated using the Japanese equations; $BMR_{Schofield}$: BMR estimated using Schofield equations; EER: estimated energy requirement; EI: energy intake; se: standard error.
†Estimated using sex-specific equations developed for Japanese, based on age, body height, and body weight.[22,23]
‡Estimated using Schofield sex- and age-specific equations based on body height and weight.[24]
§Calculated using sex- and age-specific equations from the US Dietary Reference Intakes based on sex, age, and body height and weight, assuming 'low active' level of physical activity for all subjects.[25]
¶Based on analysis of variance, except for sex in which the independent *t*-test was used.
††Defined based on body mass index (kg/m^2) according to World Health Organization recommendations: <18.5 for underweight, ≥18.5 to <25 for normal, ≥25 to <30 for overweight, and ≥30 for obese subjects.[20]

Table 2. Numbers and percentages of under-reporters, plausible reporters, and over-reporters of energy intake (EI): the 2012 National Health and Nutrition Survey, Japan (n=19,986)

	Based on EI:BMR$_{JPN}$†							Based on EI:BMR$_{Schofield}$‡							Based on EI:EER§						
	Under-reporters		Plausible reporters		Over-reporters			Under-reporters		Plausible reporters		Over-reporters			Under-reporters		Plausible reporters		Over-reporters		
	n	%	*n*	%	*n*	%	*p*¶	*n*	%	*n*	%	*n*	%	*p*¶	*n*	%	*n*	%	*n*	%	*p*¶
All	635	3.2	18957	94.9	394	2.0	---	1254	6.3	18646	93.3	86	0.4	---	1201	6.0	18547	92.8	238	1.2	---
Mean EI (kJ/d)	4027		8148		12767		---	4503		8316		15785		---	4485		8267		14083		---
Sex							<0.0001							<0.0001							0.003
Men	308	3.5	8472	95.4	98	1.1		668	7.5	8188	92.2	22	0.2		566	6.4	8228	92.7	84	0.9	
Women	327	2.9	10485	94.4	296	2.7		586	5.3	10458	94.1	64	0.6		635	5.7	10319	92.9	154	1.4	
Age (years)							<0.0001							<0.0001							<0.0001
20-29	82	6.0	1270	93.2	11	0.8		128	9.4	1225	89.9	10	0.7		173	12.7	1180	86.6	10	0.7	
30-39	156	6.3	2313	93.4	8	0.3		244	9.9	2230	90.0	3	0.1		302	12.2	2171	87.6	4	0.2	
40-49	146	5.1	2706	94.4	15	0.5		239	8.3	2622	91.5	6	0.2		254	8.9	2603	90.8	10	0.3	
50-59	77	2.5	3026	96.4	36	1.1		182	5.8	2951	94.0	6	0.2		149	4.7	2973	94.7	17	0.5	
60-69	85	1.8	4572	95.8	114	2.4		171	3.6	4569	95.8	31	0.6		160	3.4	4547	95.3	64	1.3	
≥70	89	1.7	5070	94.4	210	3.9		290	5.4	5049	94.0	30	0.6		163	3.0	5073	94.5	133	2.5	
Weight status††							<0.0001							<0.0001							<0.0001
Underweight	40	2.6	1422	93.1	65	4.3		81	5.3	1435	94.0	11	0.7		85	5.6	1418	92.9	24	1.6	
Normal	330	2.5	12833	95.4	292	2.2		708	5.3	12678	94.2	69	0.5		684	5.1	12587	93.5	184	1.4	
Overweight	197	4.6	4015	94.6	32	0.8		360	8.5	3878	91.4	6	0.1		326	7.7	3893	91.7	25	0.6	
Obese	68	8.9	687	90.4	5	0.7		105	13.8	655	86.2	0	0.0		106	13.9	649	85.4	5	0.7	
Smoking status							<0.0001							<0.0001							<0.0001
Never	317	2.6	11376	95.0	286	2.4		627	5.2	11296	94.3	56	0.5		635	5.3	11190	93.4	154	1.3	
Past	129	2.9	4206	95.9	52	1.2		305	7.0	4070	92.8	12	0.3		243	5.5	4099	93.4	45	1.0	
Current	189	5.2	3375	93.2	56	1.5		322	8.9	3280	90.6	18	0.5		323	8.9	3258	90.0	39	1.1	
Alcohol drinking							<0.0001							0.0036							<0.0001
Nondrinker	338	3.3	9723	94.4	244	2.4		671	6.5	9584	93.0	50	0.5		633	6.1	9529	92.5	143	1.4	
≤2 d/wk	142	3.7	3656	95.1	47	1.2		265	6.9	3564	92.7	16	0.4		276	7.2	3545	92.2	24	0.6	
3-6 d/wk	78	3.3	2249	95.1	38	1.6		153	6.5	2205	93.2	7	0.3		147	6.2	2195	92.8	23	1.0	
7 d/wk	77	2.2	3329	95.9	65	1.9		165	4.8	3293	94.9	13	0.4		145	4.2	3278	94.4	48	1.4	
Household size							<0.0001							<0.0001							<0.0001
1	94	4.1	2113	91.8	94	4.1		170	7.4	2109	91.7	22	1.0		142	6.2	2103	91.4	56	2.4	
2	122	1.9	6114	95.5	165	2.6		298	4.7	6072	94.9	31	0.5		261	4.1	6046	94.5	94	1.5	
3-4	282	3.5	7682	95.3	98	1.2		532	6.6	7509	93.1	21	0.3		545	6.8	7458	92.5	59	0.7	
≥5	137	4.3	3048	94.6	37	1.1		254	7.9	2956	91.7	12	0.4		253	7.9	2940	91.2	29	0.9	

BMR$_{JPN}$: basal metabolic rate (BMR) estimated using the Japanese equations; BMR$_{Schofield}$: BMR estimated using Schofield equations; EER: estimated energy requirement.

†Under-reporters were defined as participants with an EI:BMR <0.87; plausible reporters as participants with an EI:BMR 0.87-2.75; over-reporters as participants with an EI:BMR >2.75. BMR was estimated using sex-specific equations developed for Japanese, based on age, body height, and body weight.[22,23]

‡Under-reporters were defined as participants with an EI:BMR <0.87; plausible reporters as participants with an EI:BMR 0.87-2.75; over-reporters as participants with an EI:BMR >2.75. BMR was estimated using Schofield sex- and age-specific equations based on body height and weight.[24]

§Under-reporters were defined as participants with an EI:EER <0.59; plausible reporters as participants with an EI:EER 0.59-1.71; over-reporters as participants with an EI:EER >1.71. EER was calculated using sex- and age-specific equations for use in populations with a range of weight statuses from the US Dietary Reference Intakes based on sex, age, and body height and weight, assuming 'low active' level of physical activity for all subjects.[25]

¶Based on chi-square test.

††Defined based on body mass index (kg/m^2) according to World Health Organization recommendations: <18.5 for underweight, ≥18.5 to <25 for normal, ≥25 to <30 for overweight, and ≥30 for obese subjects.[20]

Table 3. Risk of being an under-reporter of energy intake (EI) compared to being a plausible reporter of EI: the 2012 National Health and Nutrition Survey, Japan†

	Based on EI:BMR$_{JPN}$‡				Based on EI:BMR$_{Schofield}$§				Based on EI:EER¶			
	Under-reporters/ plausible reporters (*n*)	OR	Lower 99% CI	Upper 99% CI	Under-reporters/ plausible reporters (*n*)	OR	Lower 99% CI	Upper 99% CI	Under-reporters/ plausible reporters (*n*)	OR	Lower 99% CI	Upper 99% CI
Sex												
Men	308/8472	1	Reference		668/8188	1	Reference		566/8228	1	Reference	
Women	327/10485	1.09	0.85	1.40	586/10458	0.77	0.64	0.93	635/10319	1.06	0.88	1.28
Age (years)												
20-29	82/1270	1	Reference		128/1225	1	Reference		173/1180	1	Reference	
30-39	156/2313	0.97	0.67	1.41	244/2230	1.01	0.74	1.36	302/2171	0.89	0.68	1.17
40-49	146/2706	0.76	0.52	1.11	239/2622	0.83	0.61	1.13	254/2603	0.61	0.46	0.81
50-59	77/3026	0.37	0.24	0.57	182/2951	0.60	0.43	0.83	149/2973	0.33	0.24	0.45
60-69	85/4572	0.28	0.18	0.43	171/4569	0.37	0.26	0.51	160/4547	0.23	0.17	0.32
≥70	89/5070	0.26	0.17	0.40	290/5049	0.55	0.41	0.75	163/5073	0.21	0.15	0.29
Weight status††												
Underweight	40/1422	0.91	0.58	1.41	81/1435	0.94	0.69	1.29	85/1418	0.90	0.66	1.24
Normal	330/12833	1	Reference		708/12678	1	Reference		684/12587	1	Reference	
Overweight	197/4015	2.14	1.67	2.73	360/3878	1.70	1.42	2.02	326/3893	1.77	1.47	2.13
Obese	68/687	3.32	2.30	4.79	105/655	2.55	1.90	3.42	106/649	2.64	1.96	3.55
Smoking status												
Never	317/11376	1	Reference		627/11296	1	Reference		635/11190	1	Reference	
Past	129/4206	1.35	0.99	1.83	305/4070	1.39	1.13	1.73	243/4099	1.28	1.02	1.60
Current	189/3375	1.82	1.38	2.41	322/3280	1.55	1.25	1.92	323/3258	1.57	1.27	1.94
Alcohol drinking												
Nondrinker	338/9723	1	Reference		671/9584	1	Reference		633/9529	1	Reference	
≤2 d/wk	142/3656	0.78	0.59	1.02	265/3564	0.80	0.65	0.98	276/3545	0.81	0.66	0.99
3-6 d/wk	78/2249	0.81	0.57	1.14	153/2205	0.77	0.60	0.98	147/2195	0.83	0.64	1.07
7 d/wk	77/3329	0.59	0.41	0.84	165/3293	0.55	0.43	0.71	145/3278	0.61	0.47	0.79
Household size												
1	94/2113	1	Reference		170/2109	1	Reference		142/2103	1	Reference	
2	122/6114	0.51	0.36	0.74	298/6072	0.67	0.52	0.87	261/6046	0.74	0.56	0.99
3-4	282/7682	0.63	0.45	0.87	532/7509	0.77	0.60	0.98	545/7458	0.80	0.62	1.04
≥5	137/3048	0.74	0.51	1.07	254/2956	0.91	0.69	1.20	253/2940	0.93	0.69	1.24

BMRJPN: basal metabolic rate (BMR) estimated using the Japanese equations; BMR$_{Schofield}$: BMR estimated using Schofield equations; EER: estimated energy requirement, OR: odds ratio; CI: confidence interval.

†Multivariate logistic regression analysis was conducted to calculate OR (99% CI). All the variables listed were entered into the model simultaneously.

‡Under-reporters were defined as participants with an EI:BMR <0.87; plausible reporters as participants with an EI:BMR 0.87-2.75. Over-reporters (participants with an EI:BMR >2.75; n=394) were excluded from the analysis. BMR was estimated using sex-specific equations developed for Japanese, based on age, body height, and body weight.[22,23]

§Under-reporters were defined as participants with an EI:BMR <0.87; plausible reporters as participants with an EI:BMR 0.87-2.75. Over-reporters (participants with an EI:BMR >2.75; *n*=86) were excluded from the analysis. BMR was estimated using Schofield sex- and age-specific equations based on body height and weight.[24]

¶Under-reporters were defined as participants with an EI:EER <0.59; plausible reporters as participants with an EI:EER 0.59-1.71. Over-reporters (participants with an EI:EER >1.71; *n*=238) were excluded from the analysis. EER was calculated using sex- and age-specific equations for use in populations with a range of weight statuses from the US Dietary Reference Intakes based on sex, age, and body height and weight, assuming 'low active' level of physical activity for all subjects.[25]

††Defined based on body mass index (kg/m^2) according to World Health Organization recommendations: <18.5 for underweight, ≥18.5 to <25 for normal, ≥25 to <30 for overweight, and ≥30 for obese subjects.[20]

Table 4. Risk of being an over-reporter of energy intake (EI) compared to being a plausible reporter of EI: the 2012 National Health and Nutrition Survey, Japan†

	Based on EI:BMR$_{JPN}$‡				Based on EI:BMR$_{Schofield}$§				Based on EI:EER¶			
	Over-reporters/ plausible reporters (n)	OR	Lower 99% CI	Upper 99% CI	Over-reporters/ plausible reporters (n)	OR	Lower 99% CI	Upper 99% CI	Over- reporters/ plausible reporters (n)	OR	Lower 99% CI	Upper 99% CI
Sex												
Men	98/8472	1	Reference		22/8188	1	Reference		84/8228	1	Reference	
Women	296/10485	2.46	1.65	3.66	64/10458	2.76	1.26	6.06	154/10319	1.65	1.02	2.66
Age (years)												
20-29	11/1270	1	Reference		10/1225	1	Reference		10/1180	1	Reference	
30-39	8/2313	0.43	0.13	1.45	3/2230	0.18	0.03	1.01	4/2171	0.21	0.05	0.99
40-49	15/2706	0.70	0.25	1.97	6/2622	0.32	0.08	1.22	10/2603	0.44	0.14	1.42
50-59	36/3026	1.40	0.57	3.47	6/2951	0.27	0.07	1.05	17/2973	0.62	0.22	1.76
60-69	114/4572	3.01	1.30	6.95	31/4569	0.93	0.34	2.55	64/4547	1.53	0.62	3.79
≥70	210/5070	4.80	2.10	10.97	30/5049	0.76	0.27	2.13	133/5073	2.78	1.15	6.72
Weight status††												
Underweight	65/1422	1.95	1.35	2.82	11/1435	1.22	0.52	2.87	24/1418	1.12	0.63	1.99
Normal	292/12833	1	Reference		69/12678	1	Reference		184/12587	1	Reference	
Overweight	32/4015	0.34	0.21	0.55	6/3878	0.30	0.10	0.89	25/3893	0.42	0.24	0.73
Obese	5/687	0.35	0.11	1.12	0/655	---	---	---	5/649	0.60	0.18	1.93
Smoking status												
Never	286/11376	1	Reference		56/11296	1	Reference		154/11190	1	Reference	
Past	52/4206	0.81	0.51	1.28	12/4070	1.18	0.47	2.99	45/4099	1.05	0.61	1.79
Current	56/3375	1.36	0.87	2.13	18/3280	2.18	0.96	4.93	39/3258	1.51	0.87	2.64
Alcohol drinking												
Nondrinker	244/9723	1	Reference		50/9584	1	Reference		143/9529	1	Reference	
≤2 d/wk	47/3656	0.92	0.60	1.42	16/3564	1.11	0.51	2.42	24/3545	0.72	0.40	1.29
3-6 d/wk	38/2249	1.24	0.77	1.99	7/2205	0.89	0.31	2.63	23/2195	1.04	0.56	1.91
7 d/wk	65/3329	1.46	0.96	2.21	13/3293	1.14	0.46	2.82	48/3278	1.39	0.84	2.29
Household size												
1	94/2113	1	Reference		22/2109	1	Reference		56/2103	1	Reference	
2	165/6114	0.68	0.48	0.96	31/6072	0.54	0.26	1.13	94/6046	0.63	0.40	0.99
3-4	98/7682	0.50	0.34	0.75	21/7509	0.37	0.16	0.84	59/7458	0.50	0.31	0.83
≥5	37/3048	0.46	0.27	0.77	12/2956	0.54	0.21	1.39	29/2940	0.59	0.32	1.08

BMR$_{JPN}$: basal metabolic rate (BMR) estimated using the Japanese equations; BMR$_{Schofield}$: BMR estimated using Schofield equations; EER: estimated energy requirement; OR: odds ratio; CI: confidence interval.
†Multivariate logistic regression analysis was conducted to calculate OR (99% CI). All the variables listed were entered into the model simultaneously
‡Over-reporters were defined as participants with an EI:BMR >2.75; plausible reporters as participants with an EI:BMR 0.87-2.75. Under-reporters (participants with an EI:BMR <0.87; n=635) were excluded from the analysis. BMR was estimated using sex-specific equations developed for Japanese, based on age, body height, and body weight.[22,23]
§Over-reporters were defined as participants with an EI:BMR >2.75; plausible reporters as participants with an EI:BMR 0.87-2.75. Under-reporters (participants with an EI:BMR <0.87; n=1254) were excluded from the analysis. BMR was estimated using Schofield sex- and age-specific equations based on body height and weight.[24]
¶Over-reporters were defined as participants with an EI:EER >1.71; plausible reporters as participants with an EI:EER 0.59-1.71. Under-reporters (participants with an EI:EER <0.59; n=1201) were excluded from the analysis. EER was calculated using sex- and age-specific equations for use in populations with a range of weight statuses from the US Dietary Reference Intakes based on sex, age, and body height and weight, assuming 'low active' level of physical activity for all subjects.[25]
†† Defined based on body mass index (kg/m^2) according to World Health Organization recommendations: <18.5 for underweight, ≥18.5 to <25 for normal, ≥25 to <30 for overweight, and ≥30 for obese subjects.[20]

Irrespective of the methods applied, a higher likelihood of being an over-reporter was associated with female sex, while a lower likelihood of being an over-reporter was associated with overweight and household consisting of 3-4 persons. In some analyses, a higher likelihood of being an over-reporter was associated with ages 60-69 y ($EI:BMR_{JPN}$ only) and ≥70 y (except for $EI:BMR_{Schofield}$), and underweight ($EI:BMR_{JPN}$ only), while a lower likelihood of being an over-reporter was associated with age 30-39 y (EI:EER only) and household consisting of 2 persons and ≥5 persons (except for $EI:BMR_{Schofield}$).

DISCUSSION

Using data from NHNSJ, we evaluated EI reporting in a nationwide sample of Japanese adults aged ≥20 y. To the best of our knowledge, this is the first study to evaluate misreporting of EI among Japanese, based on data from a national nutrition survey, using a series of different strategies to identify misreporters. Misreporting of EI was, on average, ≤10% and prevalence of under- and over-reporters of EI was ≤6.3% and ≤2.0%, respectively, indicating plausible estimate of mean EI (and possibly mean intakes of foods and nutrients) in NHNSJ. Nevertheless, misreporting was associated with several characteristics. Under-reporting was associated with younger age, overweight and obesity (compared with normal weight), current smoking (compared with never smoking), no drinking (compared with drinking everyday), and household consisting of a single person (compared with that consisting of two persons), while over-reporting was associated with female sex, normal weight (compared with overweight), and household consisting of a single person. These results suggest that caution should be exercised when assessing the plausibility of EI in specific subgroups.

A limited number of national studies have consistently shown that misreporting of EI is pervasive in adults. The prevalence of under-reporting was 63% (men) and 55% (women) in Great Britain (based on a 7-d weighed dietary record);[9] 24% (men) and 21% (women) in France (based on a 7-d estimated dietary record);[10] 21% (men) and 25% (women) in New Zealand (based on a 24-h dietary recall);[11] 14% (men) and 23% (women) in South Korea (based on a 24-h dietary recall);[12] 33% (both sex combined) in Ireland (based on a semi-quantitative food frequency questionnaire);[7] 20% (men) and 25% (women) in Norway (based on a semi-quantitative food frequency questionnaire);[8] and 18% (men) and 24% (women) in the US (based on a 24-h dietary recall);[13] while the prevalence of over-reporting was 0.4% (men) and 0% (women) in Great Britain;[9] 12% (both sex combined) in Ireland;[7] 7% (men) and 5% (women) in Norway;[8] and 4% (men) and 2% (women) in the US[13] (over-reporters not defined in other countries). The much lower prevalence of under- and over-reporters in the present Japanese study (≤6.3% and ≤2.0%, respectively) compared with previous studies is encouraging. The reasons for this are unclear, but the use of a 1-day (rather than multiple-day) and household-based (rather than individual-based) dietary assessment method places less burden on the participant and this may have contributed to obtaining an acceptable mean estimate. Additionally, the much lower prevalence of overweight and obese subjects, who tend to under-report EI more than normal weight subjects,[1] may, at least partly, contribute to the smaller degree of under-reporting observed in the present study. Also, wide confidence limits for EI:BMR and EI:EER because of the only 1-d dietary assessment may again at least partly explain the small numbers of under- and over-reporters.

However, the extent of EI misreporting (i.e., EI:EER values) and the prevalence of under- and over-reporters observed in the present study should be interpreted with caution, because, due to a lack of information on physical activity, we assumed ‘low active’ level of physical activity for all subjects during the calculation of EER (as well as using the PAL for sedentary lifestyle for all subjects when using the Goldberg principles). Given the generally inactive lifestyle in Japanese,[14] this seems appropriate for most subjects. It should also be noted that the exactly same procedure has been applied in a number of investigations based on national representative dietary surveys, including the US,[13] France,[10] New Zealand,[11] Korea,[12] and Norway.[8] Nevertheless, in some very active individuals, EER would be underestimated, having the effect of overestimating EI:EER, thus tending to retain those individuals in acceptable or over-reporters. However, repeated analyses with the use of the PAL for active lifestyle (1.75)[19] also showed lower prevalence of under- and over-reporters (5.9% and 0.7% based on $EI:BMR_{JPN}$, 11.8% and 0.1% based on $EI:BMR_{Schofield}$, and 10.5% and 0.4% based on EI:EER, respectively) compared with that observed in other countries. In any case, it would be advisable that future NHNSJ should include an assessment of physical activity (favorably objective measurement such as doubly labeled water or accelerometer) at least among a subgroup of the study sample so that misreporting of EI can be evaluated more rigorously.

Although the present Japanese population was of normal weight overall, overweight and obese subjects were more likely to under-report their EI, which has also been widely observed in many Western studies.[1-11,13] Additionally, younger age was associated with under-reporting of EI, although the association of age with under-reporting is not consistent in the literature.[1,6,7,10,13] For other correlates of misreporting, research is limited or the results are generally inconsistent,[1,13] while we observed the associations of under-reporting with current smoking and no alcohol drinking. Interestingly, under-reporting (as well as over-reporting) was associated with household consisting of a single person, although the reasons for this are unknown. While we found that over-reporting was associated with several characteristics, including female sex and normal weight, characteristics associated with over-reporting of EI are less understood.[1,7,8,13] Although these variables may not always be associated with EI misreporting, and the association should be dependent on the population characteristics, dietary assessment methods, and the procedure for identifying misreporters, accumulating literature clearly indicates that misreporting occurs non-randomly in adult populations.

Several limitations of the present study warrant mention. Although NHNSJ intends to represent a national representative sample of the non-institutionalized population of Japan, only 52% of households sampled took part in the survey. Moreover, the exact response rate is not known. Thus selection bias cannot be ruled out.

At present, the only way to obtain unbiased information on energy requirements in free-living settings is to use doubly labeled water.[1] This technique is expensive and impractical for the application to large-scale epidemiologic studies, and thus alternative procedures are used.[3,5,9,13,20] In the present study, EER was calculated using US Dietary Reference Intakes equations. Although these equations have been developed based on a large number of measurements of total energy expenditure by the doubly labeled water method and are highly accurate, these were predominantly conducted in Caucasians,[25] and might therefore be inappropriate for the present Japanese population. The utility of these equations for the Japanese and other non-Caucasian populations merits investigation in future research. Further, we do not know the sensitivity and specificity of the procedures for identifying under- and over-reporters of EI used. Additionally, there is currently not enough information on relative merits of the different methods for detecting misreporters (i.e., EI:BMR and EI:EER), although EI:EER may be better given that the magnitude of misreporting can be estimated without information on the exact PAL value. Thus, we are unable to determine whether the associations found between misreporting of EI and several characteristics are true, or were artifacts caused by the procedure used to identify misreporters. For example, EI:BMR and EI:EER ultimately reflect both actual EI and estimation errors in EI, and factors such as age and smoking habits may affect actual EI and errors in EI.[1] Thus, it is unclear whether the differences of EI:BMR and EI:EER among age or smoking status groups were caused by low EI or estimation errors in EI. Furthermore, although the within-subject variation in EI was taken into account when calculating the confidence limits for identifying misreporters, it is not possible to deny that mere “under-eaters” and “over-eaters” were included in under-reporting and over-reporting groups, respectively.

EI was assessed using a 1-d semi-weight household dietary record, with a combination of the approximate proportions by which each dish was divided among the family members. Thus, the present findings might be specific to this dietary assessment method and should be interpreted in this context. Moreover, the days of the week were not proportionately selected for dietary assessment and Sundays were intentionally excluded as a survey day (based on the survey protocol), which should produce some bias to estimate an average intake.

Height and weight were measured by trained fieldworkers in only 70% of the subjects, while for the remaining these were measured by a member of household or self-reported. However, a repeated analysis including only subjects with body height and weight measured by trained fieldworkers (n=13,926) provided essentially same results (data not shown), suggesting that the bias associated with this survey procedure should be negligible at least for the present analysis. Finally, the cross-sectional nature of the study does not permit the assessment of causality, owing to the uncertain temporality of the association.

In conclusion, based on data from NHNSJ, misreporting of EI was on average ≤10% among Japanese adults, and almost all subjects (≥92.8%) were classified as plausible reporters of EI. These results suggest that NHNSJ can provide a reasonable estimate of mean EI (and possibly mean intakes of foods and nutrients). However, under-reporting was associated with younger age, overweight and obesity (compared with normal weight), current smoking (compared with never smoking), no drinking (compared with drinking everyday), and household consisting of a single person (compared with that consisting of two persons). Additionally, over-reporting was associated with female sex, normal weight (compared with overweight), and household consisting of a single person. Thus, caution should be exercised when assessing the plausibility of EI data for such subgroups.

AUTHOR DISCLOSURES

None of the authors have any conflicts of interest to declare. This study was supported in part by the Grants-in-Aid for Young Scientists (B) from the Ministry of Education, Culture, Sports, Science and Technology of Japan (KM, grant number 15K16213). The Ministry of Education, Culture, Sports, Science and Technology of Japan had no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

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