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Self-Administered Food Frequency Questionnaire: The Effect of Different Designs on Food and Nutrient Intake Estimates

A WOLK,[*] R BERGSTRÖM,[*,**] H-O ADAMI,[*,†] E-M OHLANDER,[‡] Å BRUCE,[‡] L HOLMBERG[*] AND L BERGKVIST[§]

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Background. Our objective was to determine the possible influence that different designs of a food frequency questionnaire might have on food, energy and nutrient intake estimates.
Methods. A population-based survey included 6783 women, 40–70 years old, living in central Sweden. Using a factorial study design, we compared eight different types of questionnaire covering combinations of three factors: increasing/decreasing frequency categories; addition of portion sizes; and addition of non-dietary questions. All questionnaires included the same list of 60 food items. One of the eight questionnaires was mailed to each subject according to a random assignment. The overall response rate was 77%.
Results. Compared with increasing frequencies, decreasing order of frequency categories entailed 3–11% higher estimates of mean intake for 7 of 14 food groups, 4% higher estimates for energy and 3–6% higher estimates for 13 of 18 nutrients. Addition of portion sizes had heterogeneous effects, both on dietary items (e.g. from −30% decrease for eggs to +76% increase for coffee) and on calculated nutrients (from −7% for beta-carotene to +19% for vitamin C). The inclusion of some additional non-dietary questions did not influence the estimated mean intake of any food or nutrient.
Conclusions. The results of this study have implications for the design of questionnaires and for pooled analyses in nutritional epidemiology, when different food questionnaires are used.

In large epidemiological studies on diet and disease risk, cost-effective strategies often imply the mailing of simple food frequency questionnaires (FFQ), which ask only about the frequency with which foods are eaten over a given time period.[1,2] Assumptions about portion sizes then have to be made in order to assess food, nutrient and energy intakes.[3] Alternatively, FFQ may also ask about the relative portion size[4] or require the choice of an appropriate serving size from attached pictures[5] or photographs.[6] Furthermore, food questionnaires can vary by applying frequency categories in increasing (from 'never' to 'several times per day' consumption) or decreasing order. Sometimes questions about non-dietary exposures are added. These different designs of food questionnaires are currently used in epidemiological studies, but it is not known whether they give equivalent dietary estimates.

We recently reported from a population-based survey how the design and the extension of a questionnaire influenced the response rate and completeness of dietary information.[7] Using the same study the purpose of the present investigation was to determine how features of a food questionnaire design such as increasing/decreasing frequency categories, including questions about portion sizes and addition of non-dietary questions can influence food, energy and nutrient estimates.

MATERIALS AND METHODS

Subjects

The source population included all women, 40–70 years old, in two medium-sized towns in central Sweden, who where invited to a population-based mammography screening. A consecutive sample of 6783 women, who received their invitation to mammography between October 1986 and March 1987, was included in this

[*]Cancer Epidemiology Unit, University Hospital, S-751 85 Uppsala, Sweden.
[**]Department of Statistics, Uppsala University, Sweden
[†]Department of Epidemiology, Harvard School of Public Health, Boston MA, USA.
[‡]The National Food Administration, Uppsala, Sweden.
[§]The Central Hospital, Västerås, Sweden.

TABLE 1 *Description of differences in design of eight types of the food frequency questionnaires and number of analysed questionnaires in each group*

Design	Extension			
	Frequency	Frequency + portion size	Frequency + extra questions	Frequency + portion size + extra questions
Increasing frequency categories	n = 671 reference questionnaire	n = 651	n = 653	n = 651
Decreasing frequency categories	n = 687	n = 652	n = 616	n = 620

study. Each woman was randomly assigned to receive by mail one of eight differently designed FFQ. Five weeks after the first mailing, a reminder was sent to all non-responders.

Food Frequency Questionnaire

The FFQ (Table 1) were designed to categorize individuals by dietary intake over the previous 6-month period and included 60 foods and food groups. We also asked about age, marital status, education, parity, occurrence of breast cancer in first-degree relatives (mother, sister, daughter), body weight, height, and dietary supplements. Qualitative questions were asked about the usual type of diet (e.g., omnivorous, vegetarian, etc.), type of fat spread on sandwiches and type of fat used in food preparation.

For each of 60 food items, eight intake frequency categories were defined: never/seldom; 1–3 times per month; once a week; 2–3 times a week; 4–6 times a week; once a day; 2–3 times a day; and ≥4 times a day. A factorial study design created eight different types of questionnaire covering combinations on three levels (factors): 1) the frequency categories were presented in increasing or decreasing order; 2) in four of the eight questionnaires the responder classified relative portion sizes as small, medium or large and provided responses to open-ended questions about quantities — e.g. slices of bread, glasses of milk, numbers of apples, oranges, cups of coffee—consumed during one meal, i.e. the amount attributed to one food frequency; 3) the remaining four questionnaires included one additional page, at the end, with questions on cigarette smoking, use of oral contraceptives and hormone replacement therapy during the menopause. All these questionnaires included the same list of 60 food items.

The responses were transformed into frequencies per month and assigned the following values: 0.5 (never/seldom), 2, 4, 10, 20, 30, 75, 120 (≥4 times a day). Omitted frequency responses were treated as never/seldom answers. To convert frequency data into quantitative food and nutrient intakes, frequencies were multiplied by standard serving sizes based on the National Food Administration's handbook on weights of foods and dishes.[8] These units were selected on the basis of eligible data and do not necessarily correspond to average portion sizes in the studied population. As a converting factor for small portion size we used 0.5 and for large portions 1.5–2.0, depending on kind of food. In the analyses food items were combined into 14 groups, as specified in Table 2.

Statistical Methods

Differences between the eight questionnaire types with respect to food and nutrient intake were first analysed by a one-way analysis of variance performed both on original observations and on logarithmic values. Results are given as F-values which test the hypothesis that all questionnaire types lead to the same mean values. In addition, tests based on ranks and the non-parametric Kruskall-Wallis test were also employed.

To shed further light on the reasons for the differences that were observed, multivariate linear regression analyses, which utilized the factorial design of the study, were also performed. The following model was estimated:

$$y = b_0 + b_1\,\mathrm{DECR} + b_2\,\mathrm{PORT} + b_3\,\mathrm{EXTRA} + e$$

where y denotes the intake of a certain food item or nutrient and DECR denotes decreasing order of frequency categories, PORT portion sizes included and EXTRA the occurrence of extra non-dietary questions. The constant term of the model (b_0) shows the estimate obtained for the reference questionnaire, i.e. the one with increasing order of frequency categories, without portion sizes and without extra questions. The parameter b_1 shows the difference between the estimates of intake according to the 'decreasing order' formula and the

TABLE 2 *Estimates of differences in mean monthly intake of foods (g/month; 95% confidence intervals (CI) in parentheses) due to various questionnaire designs—the effect of decreasing frequencies, addition of portion sizes and inclusion of extra non-dietary questions—as compared to the reference questionnaire (with increasing frequencies, without portion sizes, without non-dietary questions)*

Food items/groups[a]	Monthly intake (reference questionnaire)	Mean difference (95% CI) due to:[b] Decreasing frequencies	Portion size	Crude data F-value[c]
	grams per month			
1. Bread	1640	60 (5, 115)	89 (34, 144)	3.07
2. Butter/margarine	293	17 (5, 29)	−46 (−58, −34)	9.31
3. Milk	12 109	276 (−345, 897)	−316 (−937, 305)	1.25
4. Cheese	753	83 (51, 115)	−24 (−56, 8)	4.17
5 Potatoes	3462	197 (74, 320)	179 (56, 302)	2.89
6. Vegetables	3881	221 (54, 388)	−390 (−557, −223)	4 11
7. Fruit	6452	157 (−200, 514)	1946 (1587, 2305)	16.49
8. Cereal/pasta/rice	3047	179 (42, 316)	−77 (−214, 60)	1.44
9. Meat	2622	77 (9, 145)	−139 (−207, −71)	3.79
10. Fish	829	54 (22, 87)	−82 (−115, −50)	6.15
11. Egg	617	25 (−9, 59)	−187 (−221, −153)	17.70
12. Sugar/cake etc.	2934	86 (−110, 282)	614 (418, 810)	6.24
13. Coffee/tea	13 609	−117 (−907, 673)	10390 (9600, 11180)	95.15
14. Alcoholic beverages	2678	35 (−145, 215)	−230 (−410, −50)	1.23

[a]Composition of food groups: 1. White, whole grain, hard bread; 2. butter, margarine; 3. milk 0.5% fat, 1.5% fat, 3% fat, sour milk and yoghurt 0.5% fat, 3% fat; 5. boiled, fried and French fried potatoes; 6. carrots, beetroot, cabbage, tomatoes, iceberg/head lettuce, spinach and kale; 7. apples, pears, oranges, grapefruit, bananas, juice; 8. cooked oatmeal and other types of cooked breakfast cereal, corn flakes and other types of cold breakfast cereal, pancakes and waffles, rice, spaghetti and noodles; 9. meat and sausage—main dishes, cut meats and sausage used on sandwiches, bacon, liver and kidney, blood pudding, liver paté, chicken; 10. salmon, mackerel, herring, sardines, tuna fish and other types of fish, shrimp, lobster; 12. cake, ice cream, sweet soup, jam, carbonated beverages, sweets, chocolate, sugar; 14. beer (1.8% alcohol, 2.8% and 4.5%), wine, spirits.
[b]Regression coefficients for extra non-dietary questions were never significant and are not shown.
[c]One-way analysis of variance; values above the critical F-value = 2.01 are significant.

'increasing order' formula (e.g. 221 g/month higher estimate of the mean vegetable intake when using the 'decreasing order' formula in the food questionnaire) after adjustment for the effects of portion size and extra questions. Similarly, the parameter b_2 shows the difference between the estimates of intake when relative portion sizes are included in the questionnaire and when the questionnaire is without portion sizes (e.g. 390 g/month lower estimate of mean consumption of vegetables when portion sizes are included).

RESULTS

The overall response rate was 5245/6783 (77.3%); 44 (0.6%) of the subjects were excluded. The excluded group consisted of women not belonging to the target population, i.e. younger or older than 40–70 years (n = 8) and people with unreliable responses (n = 36). Responses were considered as unreliable when reported frequency of consumption exceeded 2–3 times per day for some food items (e.g. potatoes, rice, pasta, salmon, shrimp etc.). The number of analysed questionnaires for each of the eight types of the food frequency form is shown in Table 1. More details about total and partial response rates for each of the eight types of FFQ have been described elsewhere.[7]

The distributions by age, education and relative body weight were similar in the eight study groups, as was expected due to random assignment into groups. Mean age (± standard deviation [SD]) for the study sample was 54.5 (± 9.1) years, and mean (± SD) body mass index (weight/height^2) based on self-reports was 24.4 (± 3.6) kg/m^2.

For most foods/food groups and energy/nutrients the estimates of mean intake were statistically different when based on the eight versions of the questionnaire. Tables 2 and 3 show the results from one-way analyses of variance testing differences in mean intake. Differences were not significant for alcoholic beverages, milk and cereals, and for beta-carotene, when based on crude data. When log transformed data were analysed only estimates for cereals and alcohol were not statistically different. The same was true for the results obtained from tests based on ranks and the non-parametric Kruskall-Wallis test.

TABLE 3 *Estimates of differences in mean daily intake of energy and nutrients (95% confidence intervals (CI) in parentheses) due to various questionnaire designs—the effect of decreasing frequencies, addition of portion size and inclusion of extra non-dietary questions—as compared to estimates based on the reference questionnaire (with increasing frequencies, without portion sizes, without non-dietary questions)*

Energy and nutrients	Daily intake (reference questionnaire)	Difference (95% CI) due to:[a] Decreasing frequencies	Portion size	Crude data F-value[b]
Energy (kcal)	1445.0	62.5 (38.6, 86.4)	75.7 (51.8, 99.6)	11.43
Protein (g)	58.8	2.6 (1.4, 3.8)	−0.3 (−1.5, 0.9)	4.97
Total fat (g)	50.7	2.7 (1.7, 3.7)	−1.0 (−2.0, 0)	7.12
Saturated fat (g)	23.3	1.4 (0.9, 1.9)	−0.5 (−1.0, 0)	7.31
Monounsaturated fat (g)	17.7	0.8 (0.5, 1.1)	−0.3 (0.6, 0)	5.88
Polyunsaturated fat (g)	6.1	0.3 (0.2, 0.4)	−0.1 (0.2, 0)	5.13
Carbohydrates (g)	180.7	6.8 (3.3, 10.3)	20.2 (16.7, 23.7)	22.33
Sucrose (g)	28.4	1.2 (0 1, 2.3)	4.6 (3.5, 5.7)	11.99
Dietary fibre (g)	13.3	0.6 (0.3, 0.9)	1.9 (1.6, 2 2)	22.20
Vitamin C (mg)	85.1	2.7 (−0.8, 6.2)	15.9 (12.4, 19.4)	11.56
Vitamin B_1 (mg)	0.97	0.04 (0.02, 0.06)	0.05 (0.03, 0.07)	8.00
Vitamin B_2 (mg)	1 67	0.06 (0.02, 0.10)	0.00 (−0.04, 0.04)	2.54
Vitamin B_6 (mg)	1.83	0.07 (0 03, 0.11)	0.07 (0.03, 0.11)	4.32
Retinol (mg)	0 94	0.02 (0.01, 0.05)	−0 05 (−0.08, −0.03)	3.65
Beta-carotene (mg)	4.42	0.17 (−0.05, 0.39)	−0.32 (−0.54, −0.10)	1.71
Vitamin E (mg)	4.94	0.24 (0.14, 0.34)	0.16 (0.06, 0.26)	5.36
Calcium (mg)	921.0	41.7 (15 8, 67.6)	0.4 (−25.5, 26.3)	2.53
Alcohol (g)	3.77	0.1 (−0.2, 0.4)	0.5 (0.2, 0.8)	3.02

[a]Regression coefficients for extra non-dietary questions were never significant and are not shown
[b]One-way analysis of variance; values above the critical F-value = 2.01 are significant.

In regression analyses we obtained estimates of differences due separately to three factors in the design of the questionnaires: decreasing frequencies; portion sizes; and non-dietary questions.

Foods

Compared with the reference questionnaire, a feature of the questionnaire design such as decreasing order of frequency categories entailed slightly or moderately higher estimates of mean intakes for several food items/groups (Table 2). The largest relative increases caused by decreasing frequencies were observed for cheese (+11%), fish (+7%), potatoes, vegetables, and fat used on sandwiches (+6%), bread (+4%) and meat (+3%); estimates for other foods were not influenced.

The effect of the addition of relative portion sizes was more heterogeneous (Table 2). The highest relative decrease in the estimated mean intake was observed for eggs (−30%), followed by fat used on sandwiches (−16%), vegetables and fish (−10%), alcoholic beverages (−9%) and meat (−5%). Milk, cheese and cereal/pasta/rice were not appreciably influenced. Significantly higher estimates were seen for bread and potatoes (+5%), sugar/sweet foods (+21%), fruit (+30%) and coffee/tea (+76%).

Adding extra non-dietary questions to the FFQ did not significantly influence the estimated mean intake for any of the food items and food groups (parameters not shown).

Energy and Nutrients

Only minor differences were found between questionnaires based on increasing or decreasing frequency categories (Table 3). For decreasing frequencies estimated mean energy intake was 4% higher; mean intakes of nutrients differed by +4% for protein, carbohydrates, vitamin B_1, B_2, B_6, +5% for total fat, monounsaturated and polyunsaturated fatty acids, dietary fibre, vitamin E, calcium and +6% for saturated fat.

At the nutrient level the information on relative portion sizes influenced intake estimates to a lesser extent than at the food level (Table 3). Mean estimated intakes of beta-carotene (−7%) and retinol (−5%) were lower. Mean estimated intakes of protein, total fat, saturated, mono- and polyunsaturated fatty acids, vitamin B_2 and calcium were not influenced when relative portion sizes were added. Significantly higher estimates were observed for vitamin E (+3%), vitamin B_6 (+4%), energy and vitamin B_1 (+5%), carbohydrates (+11%), alcohol (+13%), dietary fibre (+14%), sucrose (+16%), and vitamin C (+19%).

TABLE 4 *Different estimates of mean intake of cheese, fruits and coffee/tea (g/month) caused by differences between questionnaires (without portion sizes versus with portion sizes)*

	Without portion size				With portion size			
Foods	Increasing frequencies	Increasing frequencies + extra questions	Decreasing frequencies	Decreasing frequencies + extra questions	Increasing frequencies	Increasing frequencies + extra questions	Decreasing frequencies	Decreasing frequencies + extra questions
Cheese, g/month	749	749	825	844	746	709	808	807
Cheese, frequency/ month	37.5	37.4	41.3	42.2	35.3	33.2	38.7	38.5
Cheese,[a] slice/ frequency	1	1	1	1	1 05 (1–3)	1.05 (1–2)	1.05 (1–3)	1.05 (1–2)
Total fruit, g/month	6347	6549	6575	6765	8479	8436	8621	8470
Banana, frequency/ month	9.7	9.8	9.9	10.7	10.85	10.02	10.32	10.80
Banana,[a] pieces/ frequency	1	1	1	1	1.09 (1–5)	1.05 (1–4)	1 10 (1–4)	1.10 (1–4)
Apple, frequency/ month	16 8	16.2	17.9	18.0	17 07	17 62	17.55	16.60
Apple,[a] pieces/ frequency	1	1	1	1	1.21 (1–6)	1.18 (1–6)	1.21 (1–8)	1.23 (1–7)
Citrus, frequency/ month	17.2	18.0	17.4	19.1	19.40	19.02	17.74	18.94
Citrus,[a] pieces/ frequency	1	1	1	1	1.29 (1–6)	1.20 (1–6)	1.27 (1–9)	1.28 (1–6)
Juice, frequency/ month	6.7	7.4	7.0	6 4	7.53	7.25	8 11	6.74
Juice,[a] glass/ frequency	1	1	1·	1	1.09 (1–4)	1.08 (1–4)	1.11 (1–4)	1.12 (1–9)
Drinks, g/month	13 527	13 571	13 568	13 472	24 425	23 647	23 473	24 191
Coffee, frequency/ month	68.3	67.3	67.2	65.0	66.60	66.34	66.36	66.80
Coffee,[a] cups/ frequency	1	1	1	1	1.89 (1–8)	1.82 (1–9)	1.82 (1–8)	1.86 (1–8)
Tea, frequency/ month	16.4	17.4	17.5	18.6	16.24	16 23	16.59	17 05
Tea,[a] cups/ frequency	1	1	1	1	1.20 (1–5)	1.16 (1–4)	1.18 (1–8)	1.23 (1–5)

[a]Mean number of slices/pieces/cups per meal (one frequency), i.e. on the same occasion (ranges in brackets).

Adding extra non-dietary questions to the FFQ did not significantly influence the estimated mean intake for energy or any of the nutrients (parameters not shown).

Standard Portions

We examined in more detail the reasons for the large discrepancy between the mean intake of some foods as estimated by different questionnaires (Table 4). For those foods for which there was relatively good agreement between the results using different types of questionnaire (e.g. cheese), the mean number of self-reported slices/pieces/glasses/cups per meal was near to the standard which was used for calculations based on the reference questionnaire. The difference between the standard number (1 piece) and the mean of the self-reported numbers of bananas, apples, citrus fruits and glasses of juice per meal—i.e. on the same occasion—was large, with the highest mean values reported for citrus fruits 1.20–1.29 (range 1–9 pieces per meal). The largest discrepancy was observed between our standard (1 cup) and self-reported cups of coffee per meal (mean number of cups 1.82–1.89, range 1–9).

A discrepancy was observed between the effect of portion sizes on estimates of the mean intake of alcoholic beverages (−7.7 g/day, Table 2) and estimates of the mean intake of pure alcohol (+0.50 g/day, Table 3). The lower estimate for alcoholic beverages was caused by the smaller mean portion of light beer based on self-reports (298.2–305.2 g) than our standard portion (330 g) for this most frequently consumed alcoholic beverage. The higher estimated intake of pure alcohol was caused by the larger mean portions of alcohol beverages with higher alcohol content, i.e. wine (178–184 g) and spirits (47.7–53.8 g) based on self-reports than standard portions (167 g and 40 g, respectively). This kind of discrepancy between alcoholic drinks and pure alcohol estimated from different types of questionnaire was caused by inappropriate standard portions.

DISCUSSION

When interpreting the results of our study, the general limitations of FFQ in quantifying nutrient intake should be kept in mind. As recently debated, nutrient calculations based on FFQ lead to very approximate estimates of the normal nutrient intake for an individual. The method relies on a number of assumptions including those involved in the grouping of foods into broad categories, the definition of typical portion sizes and the creation of average nutrient composition for grouped food items. Therefore the resulting estimates are far from exact.[9] Our study further reveals that food and nutrient estimates based on FFQ depend heavily on the questionnaire design.

To our knowledge an effect of the order of frequency response categories on food and/or nutrient estimates has not been reported earlier. A decreasing order of frequency response categories entailed significantly (3–11%) higher estimates of mean intake for seven out of 14 food groups. Accordingly, the estimated intakes of energy and of most nutrients (13 of 18) were also higher by 3–6%. These data indicated that respondents in our study marked the first reasonably appropriate frequency category. Which of the estimated mean values for food and nutrient intakes is closest to the truth is impossible to say without a validation study.

In this study examination of the effect of adding portion size to the FFQ was mostly limited to those foods which come in natural units (e.g. slices, pieces, cups). When we added portion sizes, mean estimates of some food and nutrient intakes increased, whereas others did not change or even decreased. The magnitude of the differences we observed for foods ranged from −30% for eggs to +76% for coffee/tea; for nutrients the differences were less pronounced, from −7% for beta-carotene to +19% for vitamin C. The differences mainly depended on an inappropriate standard portion size used for calculations—a portion which was not equal to the reported mean portion size (mean number of natural units per frequency) in the population. The distribution of portion sizes was skewed for some foods, e.g. coffee and tea. For those foods which had a negatively skewed distribution of portions (small portions more frequent) addition of portion sizes decreased mean intake; those foods with positively skewed distribution (large portions more frequent e.g. coffee) showed an increased mean intake. The choice of coefficients for small and large portions in our study was arbitrary, without the underlying observational data, and might also influence the results in this study.

Our results are generally in agreement with other studies on dietary questionnaires in which subjects could indicate the usual amount consumed of specific foods as small, medium, or large. The estimated mean intakes of nutrients changed when all portion sizes values were recorded as 'medium',[4] or when portion size values from external sources were inferred.[3,10]

We observed a special phenomenon for foods eaten daily when a separate column for portion sizes was added. The best example is coffee. The self-reported number of cups of coffee on one occasion (one frequency) ranged up to nine! It seems that the question about number of coffee cups drunk on one occasion was misunderstood by some subjects who might have reported the total number of cups per day. The same people probably also reported frequencies higher than once per day. This speculation is confirmed by the fact that the average frequency of coffee consumption was similar for both types of questionnaire, with and without portion sizes. Such misunderstanding of the question about portions might be present for all foods which were consumed more than once daily, and might exaggerate some dietary estimates.

In a recent study we observed that the addition of portion sizes significantly reduced frequencies for several foods[7] but this effect was small in comparison to the effect of inappropriate standard portion sizes on estimated mean food intakes, as observed in the present study.

It should be remembered that our study could not address the problem which questionnaire design (with or without portion sizes) measured the true intake better. The study only indicates that food and nutrient estimates based on questionnaires without portion sizes differ from those based on FFQ including portion sizes. This statement can be generalized to situations where an inappropriate standard was used and to those foods which come in natural units.

Our statistical analyses include methods requiring normally distributed variables in small samples. However, the large sample sizes in this study mean that deviation from normality should not cause any problem as we can rely on asymptotic results. In general, the conclusions obtained from analyses based on original observations and logarithmic observations with regression type methods and non-parametric methods were similar. The different results obtained for pure alcohol when using original data versus logarithmic data, were presumably due to the original variable which, for certain questionnaire types, was considerably more skewed than for the other types. Use of logarithms rather than the original variable reduced the impact of extreme observations and led to smaller differences between the mean values obtained from different questionnaires.

In the analyses of nutritional factors in epidemiological studies the data are often used in such a form that the ranking of individuals is important and not the absolute values of a given nutritional variable. Thus it would be important to test the effect of questionnaire design with this aspect in mind. With the present set of data this was possible only to a limited extent in the analyses based on ranks. However, these give a very partial answer to the problem. A more complete analysis would require a study design where the same individual answered questionnaires of all the types under study.

The results of this study have implications for multicentre studies and pooled analyses in nutritional epidemiology. Relatively small differences between FFQ designs can markedly influence certain dietary estimates within a population. Even larger differences are likely to occur between populations with varying sociocultural backgrounds. Thus, differences between countries in the design of food questionnaires can result in more pronounced differences in the outcome of dietary assessment. Therefore, analyses of dietary data from multicentre studies require some kind of calibration for each centre before data can be used for pooled analysis.

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