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Validity of a food-frequency questionnaire for elderly men in southeast China

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Abstract

Objective: To investigate the internal validity of a food-frequency questionnaire (FFQ) developed for a case–control study of prostate cancer in southeast China.
Design: A comprehensive questionnaire comprising a quantitative FFQ and a short food habit questionnaire (SFHQ) was developed and modified from previous cancer and nutritional studies. The Goldberg formula (ratio of energy intake (EI) to basal metabolic rate (BMR), EI/BMR) was used to assess the validity of the FFQ by making comparisons with physical activity levels. Physical activity levels were measured by the estimated total metabolic equivalents (MET) and the ratio of energy expenditure (EE) to BMR (EE/BMR). Correlation analyses were undertaken to compare the SFHQ variables with those of the quantitative FFQ.
Setting: Hangzhou, Zhejiang Province, China.
Subjects: A total of 404 men over 45 years old with or without prostate cancer were recruited from eight hospitals.
Results: The partial correlation coefficients, controlling for age and family history of prostate cancer, were moderate to high ($P < 0.05$) for preserved foods intake, fat consumption and tea drinking variables between the SFHQ and the quantitative FFQ. The average EI/BMR was 1.72, with 76% of subjects exceeding the Goldberg cut-off value of 1.35. Apart from weight, BMI, EE/BMR and MET, there were no significant differences in characteristics between low (<1.35) and normal EI/BMR groups.
Conclusions: The FFQ is demonstrated to be a valid instrument to measure energy and food intake for elderly men in southeast China.

Keywords
Food-frequency questionnaire
Validity
Reproducibility
Energy intake
Energy expenditure
Physical activity level
Metabolic equivalents
China

Food-frequency questionnaires (FFQs), first developed in the 1950s, have been considered the most appropriate method for dietary assessment in nutritional epidemiology studies because they measure average long-term habitual dietary intakes[1]. Validity is defined as the degree to which a study meets basic logical criteria for the absence of bias[2]. A valid FFQ should accurately reflect typical food consumption over a designated period of time, undistorted by behavioural patterns or false memory[3]. Unfortunately, there is still no 'gold standard' for directly assessing the validity of a dietary instrument[1]. A common approach is to calibrate the FFQ by comparison with another method such as 24-hour recalls, food diaries or records of varying length, or with measurements of biomarkers that reflect the intake of one or more nutrients[4–7]. Another method is to calculate total energy intake (EI) from the FFQ and then compare it with measures of energy expenditure (EE)[8,9].

Total EI deserves special consideration in nutritional epidemiology for the following reasons:

- The level of EI may be a primary determinant of disease.
- Individual differences in total EI produce variations in the intakes of specific nutrients unrelated to dietary composition, because the consumption of most nutrients is positively associated with total EI.
- When EI is associated with disease but is not a direct cause, the effects of specific nutrients may be distorted or confounded by total EI[1].

EI is an important measure because nutrients must be provided within the quantity of food consumed to fulfil the energy requirement. Therefore, reported EI may be considered a surrogate measure of the total quantity of food intake[3]. There are three methods of validation of reported EI, all of which assume that EI must equal EE when weight is stable:

1. Comparison of self-reported EI with the estimated EI required for maintaining a stable body weight;
2. Comparison of reported EI and measured EE; and
3. Comparison of reported EI with presumed energy

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requirements, both expressed as multiples of basal metabolic rate (BMR).

The Goldberg formula, the ratio of reported EI to BMR (EI/BMR), has frequently been used to assess the validity of dietary methods at the group level[10]. Meanwhile, the ratio of EE to BMR (EE/BMR) is commonly used to assess physical activity levels. EE is calculated using the doubly labelled water technique and BMR measurements. Although the doubly labelled water technique is considered to be the best method for measuring EE under free-living conditions[3], the analytical resources and cost required have limited its use as a routine tool in epidemiological studies. There have been few studies using estimated EE to assess the validity of reported EI[11,12].

Metabolic equivalent (MET) is the ratio of the work metabolic rate to the resting metabolic rate. One MET is defined as 1 $kcal\,kg^{-1}\,h^{-1}$ and is roughly equivalent to the energy cost of sitting quietly. MET is also defined as oxygen uptake in $ml\,kg^{-1}\,min^{-1}$ with 1 MET equal to the oxygen cost of sitting quietly, equivalent to 3.5 $ml\,O_2\,kg^{-1}\,min^{-1}$. The concept of MET was proposed in 1993 and subsequently recommended by the National Centre for Chronic Disease Prevention and Health Promotion as a measurement for physical activity[13,14]. However, there has been no reported validity study that has specifically used MET to measure physical activity levels. In the present study, both EE/BMR and MET were used to quantify EE. The objective was to assess the validity of an FFQ used in a case–control study of prostate cancer.

Subjects and methods

Study population

Subjects were men residing in Zhejiang Province for at least 10 years and over 45 years of age. They were recruited during 2001 and 2002 through daily reviews of medical records, laboratory and pathology reports at eight public hospitals in Hangzhou, the capital of Zhejiang Province located in southeast China. Potential participants with a history of stroke or Alzheimer's disease were excluded to avoid memory error. Cases were confirmed by histopathological reports of prostate adenocarcinoma. Controls, recruited in the same hospitals during the same period, had no previous diagnosis of malignancies. Among the 143 cases recruited, 133 (93%) were interviewed and 10 (7%) declined to participate in the study, including one with Alzheimer's disease. Three patients were later excluded because their date of diagnosis was more than 3 years previously. Of the 284 eligible controls identified, 274 (96.5%) participated in the study and seven declined to be interviewed. Two men (0.7%) with Alzheimer's disease and one with a history of stroke were also excluded.

Data collection

Subjects were interviewed using a structured questionnaire which included a quantitative FFQ component. The FFQ was modified from the Hangzhou ovarian cancer study[15], the Shanghai stomach cancer study[16], the Hawaii Cancer Research Survey[17], the Australian Health Survey 1995[18] and the US food survey[19]. Information on demographic characteristics, family history of prostate cancer, height, weight and physical activity (5 years ago) and medical history were also collected. Interviews were usually conducted in the presence of the next-of-kin to assist in recall. The study was approved by the human research ethics committee of the researchers' institution, the Zhejiang hospital administration and the doctors in charge of the relevant wards. Confidentiality and anonymity issues were explained to each participant. Formal consent was sought prior to the interview.

Dietary assessment

The FFQ contained questions on 130 food items which included all foods in the usual diet of Zhejiang residents. To ascertain consumption pattern, the frequencies of food intakes were categorised into 0–2 times a year, 3–11 times a year, once a month, 2–3 times a month, once a week, 2–3 times a week, 4–6 times a week, once a day and ≥ 2 times a day. The habitual quantities of foods consumed per meal were also recorded. To help quantify the portion intake of each food item, a series of standard containers and photographs were shown to the respondents. A reference recall period (5 years before diagnosis for cases and 5 years before interview for controls) was adopted to avoid possible change in dietary and lifestyle habits after the onset of the disease.

To assess reproducibility of the FFQ, a short food habit questionnaire (SFHQ) soliciting categorical information on food habits was also administered. The SFHQ contained items on total preserved food (cured food) intake which was classified into four levels: never or seldom, once a month, once a week and every day. Fat consumption was described as never or seldom, sometimes and often. Information on tea drinking habit was sought by questions on the concentration of tea per brew (low, medium, high) and the number of new batches of tea per day (≤ 1, 1.5–2 and >2).

Physical activity assessment

Information on habitual physical activity was assessed in terms of type, intensity and duration. The same reference recall period (5 years before diagnosis for cases and 5 years before interview for controls) was adopted. Type referred to occupational, household and leisure-time activities. Intensity was categorised as rest (sleeping or lying down), light (e.g. sitting in car or bus, sitting at work, watching television or a movie, listening to radio, reading, playing cards, sewing), moderate (e.g. cycling on level ground, gardening, housework, cooking, walking, Taichi) and vigorous (e.g. moving heavy furniture, weight lifting, loading or unloading trucks, jogging, cycling up hill, swimming, aerobics, badminton). Based on the amount of energy or effort a person expends in performing the activity, MET scores of 0.9, 1.0, 1.5, 3 and 6 were assigned respectively to sleeping, lying, light, moderate and vigorous activities. To measure duration, the daily average time (hours) spent in each activity was recorded. The daily MET scores, independent of body weight, were calculated by multiplying the reported duration of any activity by the respective intensity score and then summing over all activities. The overall physical activity level was then quantified in terms of weekly MET. Finally, 24-hour EE was obtained from multiplying daily MET score by body weight (kg) five years ago.

Statistical analysis

Statistical analysis was undertaken using the SPSS package (version 11; SPSS Inc., Chicago, IL, USA). In addition to descriptive statistics, independent-samples *t*, Mann–Whitney and chi-square tests were used to compare the demographic characteristics and potential risk factors between cases and controls. Whenever univariate statistics showed no significant differences in EI, EE and MET between them, the two groups were combined together for further analysis.

Partial correlation coefficients between the continuous variables in the quantitative FFQ and the categorical variables in the SFHQ were compared separately for case and control groups, controlling for age and family history of prostate cancer.

Average daily energy and fat intakes from the 130 food items were calculated using data from the Chinese nutrient database established by the Institute of Nutrition and Food Health, Chinese Academy of Preventive Medicine[20]. EI was expressed in terms of kcal day^{-1}. BMR was calculated based on the following equations[21], accounting for age and weight of the subjects[22]:

$$\text{BMR} = 3.67 + 0.0485 \times \text{weight}, \text{ for men 30–59 years;}$$

$$\text{BMR} = 2.04 + 0.0565 \times \text{weight}, \text{ for men 60 years and over.}$$

The Goldberg equation was used to evaluate the overall bias for underreporting at the group level[10]. In this technique, mean reported EI is expressed as a multiple of the mean BMR estimated from the above equations, with a cut-off value of 1.35 for EI/BMR to classify underreporting and normal groups[23]. EE/BMR and MET were divided into quartiles according to the distribution of all participants. One-way analysis of variance was conducted to compare the reported EI between various physical activity levels.

Results

Demographic characteristics

There were no significant differences between cancer cases and controls in mean age at interview, height, weight, locality of residence, education, family income and marital status. All participants were married and only one man lived separately from his wife. Cases tended to have a family history of prostate cancer and their average body mass index (BMI) was higher than that of controls ($P < 0.05$). Information on medical history indicated that no participant suffered any malignant illness or disease that could have affected their body weight during the 5-year reference recall period. Therefore, it can be assumed that the subjects have stable weight.

Participation rate of next-of-kin

Seventy-five per cent of the interviews were conducted in the presence of the participant's next-of-kin. Of the 101 (25%) participants who neither shopped for food nor cooked meals, 98 (97%) of them were interviewed with their next-of-kin who shopped and cooked for the family. In this way, the usual quantities and frequencies of foods consumed by the participants were properly recorded.

Correlations of food intakes between FFQ and SFHQ

Table 1 presents the average quantities of preserved food intake, fat consumption and tea drinking from the quantitative FFQ with respect to the SFHQ categories. As expected, significant differences were observed between cases and controls in these variables. The partial correlation coefficients were: 0.556 (cases) and 0.416 (controls) for total preserved foods versus cured foods; 0.301 (cases) and 0.328 (controls) for fat intake versus fat consumption; 0.761 (cases) and 0.852 (controls) for tea intake (g day^{-1}) versus tea concentration per brew; 0.642 (cases) and 0.433 (controls) for tea intake (g day^{-1}) versus batches of tea per day. The correlations were moderate to high ($P < 0.05$), confirming the reproducibility of the questionnaire in both case and control groups.

Comparison between low and normal EI/BMR groups

Table 2 compares the characteristics between the low energy reporters (EI/BMR < 1.35) and the normal group. There were few differences in age, height, locality of residence, education, income and marital status. The proportions of prostate cancer and family cancer history were also similar between the two groups. However, significant differences were found in terms of weight, BMI, EE/BMR and MET, suggesting that BMI and physical activity levels could affect reported EI.

EI/BMR across physical activity levels

Since there was no difference in EI and total weekly MET between the cases and controls ($P > 0.05$), the two groups

Table 1 Preserved foods, fat and tea intakes reported in the quantitative FFQ and the SFHQ

		Total preserved foods (g day^{-1})*	
		Cases ($n = 130$)	Controls ($n = 274$)
Cured food†	Never or seldom	6.50 (6.43)‡	8.61 (12.21)
	Once a month	19.04 (16.22)	14.74 (18.60)
	Once a week	41.80 (27.30)	26.28 (24.32)
	Every day	81.52 (54.08)	65.74 (64.02)
		Fat intake (g day^{-1})*	
		Cases ($n = 130$)	Controls ($n = 274$)
Fat consumption†	Never or seldom	47.11 (10.79)§	42.27 (11.05)
	Sometimes	48.84 (16.72)	52.02 (17.77)
	Often	64.77 (26.08)	61.72 (22.58)
		Tea (g day^{-1})*	
		Cases ($n = 72$)	Controls ($n = 219$)
Tea concentration per brew†	Low	1.76 (1.32)§	1.77 (1.56)
	Medium	2.48 (1.37)	3.85 (3.12)
	High	4.75 (3.79)	6.75 (3.91)
New batches of tea per day†	≤1	2.29 (1.69)§	3.46 (3.15)
	1.5–2	3.60 (1.17)	6.24 (3.35)
	>2	12.33 (4.94)	8.82 (5.17)

FFQ – food-frequency questionnaire; SFHQ – short food habit questionnaire.
* Quantitative variable from FFQ.
† Categorical variable from SFHQ.
‡ Median (interquartile range).
§ Mean (standard deviation).

were combined for further analysis of the energy-related variables. Table 3 shows the mean EI/BMR of the 404 participants across different levels of physical activity in terms of both EE/BMR and total weekly MET. The EI/BMR exceeded 1.35 for 76% of subjects (77% of cases and 75% of controls).

No significant change in mean EI/BMR values was found across the four EE/BMR levels ($F = 1.748$, $P = 0.157$). However, EI/BMR appeared to be significantly different across physical activity levels in terms of weekly MET ($F = 3.327$, $P = 0.020$).

Discussion

It is often difficult to assess the validity of FFQs due to the lack of a 'gold standard' for comparison. In this study, several methods were used to assess the validity of an FFQ used in a case–control study of prostate cancer. The findings confirmed that the questionnaire is valid and can measure habitual food intake accurately for elderly Chinese men.

The target population was elderly men in southeast China. The majority of them hold the traditional role, i.e. their wives were responsible for cooking and purchasing foods. To ensure accuracy of the information obtained, interviews were conducted in the presence of the participant's next-of-kin. Photographs of food quantities and containers of different sizes were shown during interviews to reduce recall and measurement errors. A reference recall period of 5 years was adopted to avoid possible changes in food consumption patterns since the onset of the disease.

The partial correlation coefficients were moderate to high when the SFHQ items in preserved foods, fat intake and tea drinking were compared with the corresponding quantitative FFQ variables, thus confirming agreement and reproducibility between the two methods.

Reported EI is an important benchmark of validity in nutritional epidemiology. However, the likelihood of underreporting in dietary surveys is pervasive[3]. An EI/BMR ratio of 1.35 and above has been considered as the maintenance requirement for energy[23]. In this study, the average EI/BMR for all participants was indeed 1.72, indicating sufficient intake of energy by the elderly men. Similarities in demographics between low and normal EI/BMR groups provided additional evidence of homogeneity of the study population.

In order to assess the validity of dietary reports based on the Goldberg cut-off value for EI/BMR, information is needed on the physical activity level, weight and BMI of each individual. Results from Table 3 demonstrate that the Goldberg index (EI/BMR) increased with physical activity levels in terms of weekly MET. Therefore, a single cut-off value of 1.35 for EI/BMR to classify underreporting is insufficient.

In this study, the two surrogate measures of physical activity, namely estimated EE and MET, are found to be economical, feasible and reliable indices. They can

Table 2 Characteristics of participants with low (<1.35) and normal EI/BMR ratio

	EI/BMR	
Characteristic	<1.35 ($n = 100$)	≥1.35 ($n = 304$)
Prostate cancer, *n* (%)		
Cases	30 (30.0)	100 (32.9)
Controls	70 (70.0)	204 (67.1)
Prostate cancer in first-degree relatives, *n* (%)		
No	83 (83.0)	269 (88.5)
Yes	1 (1.0)	2 (0.7)
Unclear	16 (16.0)	33 (10.9)
Age at interview (years), *n* (%)		
< 65	10 (10.0)	45 (14.8)
65–75	55 (55.0)	173 (56.9)
> 75	35 (35.0)	86 (28.3)
Height (cm), mean (SD)	168 (5.7)	168 (5.5)
Weight* (kg), mean (SD)	67 (10.7)	64 (9.7)
BMI* (kg m^{-2}), *n* (%)		
< 18.5	7 (7.0)	22 (7.2)
18.5–22.9	36 (36.0)	146 (48.0)
23.0–24.9	21 (21.0)	68 (22.4)
≥ 25	36 (36.0)	68 (22.4)
Locality of residence, *n* (%)		
Urban	82 (82.0)	222 (73.0)
Rural	18 (18.0)	82 (27.0)
Education, *n* (%)		
No formal education	8 (8.0)	39 (12.8)
Primary	26 (26.0)	89 (29.8)
Secondary	39 (39.0)	115 (37.8)
Tertiary	27 (27.0)	61 (20.1)
Personal monthly income in 2000 (RMB), *n* (%)		
≤ 500	20 (20.0)	54 (17.8)
501–1000	42 (42.0)	126 (41.4)
1001–2000	30 (30.0)	112 (36.8)
≥ 2001	8 (8.0)	12 (3.9)
Marital status, *n* (%)		
Married	89 (89.0)	270 (88.8)
Widowed, divorced, separated	11 (11.0)	34 (11.2)
EE/BMR*		
≤ 1.51	35 (35.0)	66 (21.7)
1.52–1.70	24 (24.0)	77 (25.3)
1.71–1.91	24 (24.0)	77 (25.3)
> 1.91	17 (17.0)	84 (27.6)
Weekly MET*		
≤ 194	38 (38.0)	64 (21.1)
195–215	23 (23.0)	77 (25.3)
216–245	21 (21.0)	81 (26.6)
> 245	18 (18.0)	82 (27.0)

EI – energy intake; BMR – basal metabolic rate; SD – standard deviation; BMI – body mass index; RMB – Chinese yuan; EE – energy intake; MET – metabolic equivalent.
* Significant differences ($P < 0.05$) between low and normal EI/BMR groups.

provide additional information when assessing FFQs by the Goldberg technique. Moreover, the estimated EE of each individual can readily be obtained from a properly designed questionnaire.

To the best of our knowledge, this is the first study investigating the internal validity of an FFQ based on EI/BMR, MET and EE/BMR for Chinese men. The results show that EI/BMR is positively correlated with physical activity levels expressed in terms of MET. Although the doubly labelled water technique may precisely measure EE, it is too expensive and complex for routine validation of EI[24]. We recommend the use of estimated EE/BMR and MET as surrogate measures of physical activity levels to assess the validity of reported energy intakes.

Table 3 EI/BMR ratio of participants across physical activity levels in terms of EE/BMR and weekly MET

	EI/BMR			
Physical activity level	*n*	Mean	SD	95% CI
EE/BMR				
≤ 1.52	101	1.64	0.51	1.54–1.74
1.53–1.71	101	1.68	0.52	1.58–1.79
1.72–1.91	101	1.77	0.49	1.67–1.86
> 1.91	101	1.78	0.47	1.68–1.87
Weekly MET*				
≤ 194	102	1.62	0.50	1.52–1.72
195–215	100	1.66	0.44	1.58–1.75
216–245	102	1.78	0.54	1.67–1.89
> 245	100	1.81	0.50	1.71–1.91
Total	404	1.72	0.50	1.67–1.77

EI – energy intake; BMR – basal metabolic rate; EE – energy intake; MET – metabolic equivalent; SD – standard deviation; CI – confidence interval.
* Significant differences ($P = 0.02$) in EI/BMR across weekly MET levels.

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