Development and evaluation of a short 24-h food list as part of a blended dietary assessment strategy in large-scale cohort studies

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BACKGROUND/OBJECTIVES: The validity of dietary assessment in large-scale cohort studies has been questioned. Combining data sources for the estimation of usual intake in a blended approach may enhance the validity of dietary measurement. Our objective was to develop a web-based 24-h food list for Germany to identify foods consumed during the previous 24 h and to evaluate the performance of the new questionnaire in a feasibility study.

SUBJECTS/METHODS: Available data from the German National Nutrition Survey II were used to develop a finite list of food items. A total of 508 individuals were invited to fill in the 24-h food list via the Internet up to three times during a 3–6-month time period. In addition, participants were asked to evaluate the questionnaire using a brief online evaluation form.

RESULTS: In total, 246 food items were identified for the 24-h food list, reflecting >75% variation in intake of 27 nutrients and four major food groups. Among the individuals invited, 64% participated in the feasibility study. Of these, 100%, 85% and 68% of participants completed the 24-h food list one, two or three times, respectively. The average time needed to complete the questionnaire was 9 min, and its acceptability by participants was rated as high.

CONCLUSIONS: The 24-h food list represents a promising new dietary assessment tool that can be used as part of a blended approach combining multiple data sources for valid estimation of usual dietary intake in large-scale cohort studies.

INTRODUCTION

The valid estimation of long-term dietary intake in large-scale cohort studies represents a methodological challenge. Food frequency questionnaires (FFQs) have long been the instrument of choice. However, FFQs measure dietary intake with both systematic and random error,[1] which may affect estimates of diet–disease associations.[2–4]

Recent methodological developments to improve the assessment of usual dietary intake in cohort studies originate from research on measurement of food and nutrient intakes in surveys.[5–9] These methods presume that the usual food intake of a subject equals the probability of a food consumed on a given day times the average amount of intake of that food on a typical consumption day. The detailed 24-h dietary recall (24HDR), when applied at least twice in the same individual, provides information on both the probability of consumption and the amount consumed[5,10,11] and thus exemplifies the application of that assumption. A FFQ can add information about the frequency of dietary intake and about true non-consumption of foods (that is, foods that are not consumed at all). It has been suggested that an approach of blending instruments may provide high-quality dietary information, especially for the assessment of foods that are not consumed every day.[4,10,12,13]

Although multiple administrations of detailed 24HDRs using a blended approach with FFQs would appear optimal, this is impracticable in cohort studies due to the associated high costs and time expenditure.[14] Detailed web-based 24HDRs developed for self-administered use in cohort studies partly resolve these issues.[15,16] To further reduce demands on time, the development of abbreviated, web-based, self-administered 24HDRs has been initiated.[17,18] These instruments are typically closed-ended (that is, participants choose foods from a finite list of items) and are intended for stand-alone application only.

As the frequency of consumption contributes higher to inter-individual variation in food and nutrient intake than inter-individual variation in portion sizes,[19] and statistical methods to estimate usual intake distributions are available,[11] we propose a 24-h food list for repeated application that assesses the probability of consumption and does not inquire about portion size.

The objective of the current study was to develop a short 24-h food list based on German survey data and to evaluate the feasibility and acceptability of repeated applications of this tool by study participants of the pretest of the German National Cohort (GNC) study during a 6-month period.

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SUBJECTS AND METHODS

Development of the 24-h food list

To develop the list of food items for the 24-h food list, available data from the representative German National Nutrition Survey II (NVS II) conducted from 2005 to 2007[20] were used to identify foods characteristic of the German diet. In the NVS II, dietary intake was assessed using two applications of EPIC-SOFT, a well-established 24HDR.[21] Energy and nutrient intakes were based on the German Nutrient Database (BLS 3.01).[22] Data from 12 502 NVS II participants aged 20–80 years who reported a total of 1882 individual food items and recipes were analyzed. Food items similar in composition or usage, such as green and red peppers or different types of margarines, were combined to include 1301 food items for statistical analysis. As NVS II participants reported food consumption on two separate days, the mean values of food and nutrient intakes from those two days were used.

The item list was composed using a hierarchy of statistical methods. First, stepwise linear regression analysis was used to identify food items that most discriminated between individuals.[23] Total nutrient intake from foods was defined as the dependent variable and nutrient intakes from individual food items were defined as the independent variables. Food items were chosen that reflected at least 75% of variation in nutrient intake for each of the 27 nutrients (energy, protein, carbohydrate, fat, saturated fatty acids (FA), monounsaturated FA, polyunsaturated FA, cholesterol, omega-3 and omega-6 FA, fibre, alcohol, vitamins A, C, B_6, B_{12}, E, D, K, thiamine, riboflavin, ß-carotene, folate, sodium, calcium, magnesium and iron).[24] Calculations were performed for all NVS II participants and NVS II participants stratified by sex (women, men) and age (20–24, 25–34, 35–50, 51–64 and 65–80 years of age). Second, to ensure that important food items had not been missed, items reflecting variation in intakes of four major food groups (fruits, vegetables, meat and meat products and milk and dairy products) were identified. All regression models were run using the SAS procedure PROC REG with the model option SELECTION = STEPWISE (version 9.3, 2008, SAS Institute Inc., Cary, NC, USA). Third, contribution analysis according to Block was applied.[25,26] That analysis identified food items that contributed at least 50% to the absolute intake of the 27 nutrients. Informative food items were combined to create suitable items for the final list of items used in the 24-h food list.

The 24-h food list was implemented as a web-based questionnaire hosted by an online platform for questionnaires and study management (https://sms.dife.de), developed and maintained by the Department of Epidemiology of the German Institute of Human Nutrition Potsdam-Rehbruecke (DIfE). The questionnaire was designed to assess information on the consumption (yes vs no) of selected food items during the previous 24 h according to the food groups. Specifically, participants were asked whether a particular food group had been consumed. If the answer was yes, a drop-down menu appeared that contained a list of individual food items related to that particular food group. From that list, the participant could then indicate the specific food consumed. The questionnaire can be viewed at https://sms.dife.de/tool/vs24hr/de. The study management system also recorded the time needed to complete each 24-h food list.

Feasibility and evaluation study of the 24-h food list

Study centres and population. The feasibility and evaluation study of the web-based 24-h food list was embedded in pretest studies for the GNC, which took place from August 2011 to February 2012 in Germany. Participating study centres were located in Augsburg, Berlin—North, Berlin—South, Freiburg, Kiel and Regensburg. Potential GNC study participants were recruited based on address lists obtained from municipal population registries and comprised a sample of men and women aged 20–70 years. Augsburg and Regensburg included samples with larger proportions of individuals in older age groups, whereas the other centres used simple random samples.

The baseline assessment was conducted during a visit at the corresponding study centre. Socioeconomic variables were assessed in a face-to-face interview by trained interviewers. Anthropometric measurements followed a standardized protocol. In total, 508 GNC participants (Augsburg $n = 76$, Berlin—North $n = 27$, Berlin—South $n = 45$, Freiburg $n = 157$, Kiel $n = 102$ and Regensburg $n = 101$) were invited to complete the online 24-h food list and to evaluate the questionnaire. In Berlin—North, only individuals with Internet access were asked to participate, whereas the other study centres invited all GNC pilot study subjects to participate. Participants with missing values on age and sex were excluded from the analysis ($n = 3$).

Approvals for all study procedures were provided by the Ethics Committees of the corresponding study centres, and written informed consent was obtained from all participants.

Design of dietary assessment and evaluation

The feasibility study covered a period of 3–6 months, depending on the organizational flow within study centres. Participants were randomly prompted to complete the online 24-h food list three times. Time intervals between administrations ranged from 10 days to 4 weeks due to the different workflows in the study centres. In Augsburg, participants were asked to complete the first 24-h food list during their visit at the study centre. In Berlin—North, Berlin—South, Freiburg and Kiel, participants were asked to complete the 24-h food list online at home when prompted on an unannounced day after their visit to the study centre. In Regensburg, participants were asked to complete the first 24-h food list online at home any time after their visit to the study centre. Repetitions of 24-h food lists were prompted via e-mail or phone calls on unannounced days.

In addition, participants were asked to fill in an online evaluation form directly after they had completed the first 24-h food list. They were requested to rate the understandability of the 24-h food list (introduction section, questions, food groups), the perceived completeness of the list of food items, the usability of the questionnaire and the effectiveness of the visual presentation. Participants were queried about whether the 24-h food list represented their diet over the past 24 h, whether they experienced difficulties in locating foods or matching them to the item list, whether the number of legends was sufficient and whether they would consider repeating the online 24-h food list.

Statistical analysis

Descriptive statistics of the study population, including sex (men vs women), age (20–49 vs 50–70 years), body mass index (<25 vs $\geqslant 25\,kg/m^2$), education (secondary school vs high school), smoking status (ever vs never) and marital status (married vs single or divorced) are presented as absolute numbers and percentages according to study centre. Response proportions were calculated taking into account the reasons for non-participation except for Berlin—North, because at that study centre, participant recruitment was restricted to individuals with Internet access and the reasons for non-participation were not inquired about. In the current project, a positive response was defined as completion of at least one 24-h food list. In addition, response proportions were calculated for study centres that used comparable recruitment approaches (that is, Berlin—South, Freiburg, Kiel and Regensburg) to account for differences in recruitment and prompting procedures across study centres.

The median time needed to complete each 24-h food list was recorded by the study management system. To evaluate the extent to which participants were prone to reactivity, agreement was assessed between the day on which a 24-h food list was prompted and the day on which it was completed.

Evaluation forms corresponding to the first 24-h food list completed were analyzed by calculating the percentages of each possible response option.

All statistical analyses were performed using the Statistical Analysis Software (version 9.3, 2008, SAS Institute Inc.).

RESULTS

The 24-h food list consisted of a total of 246 food items. The number of food items selected for individual nutrients ranged from three food items explaining 75% of the variation in vitamin A intake to 78 food items explaining 75% of the variation in protein intake. On top of this, five items were selected to explain the variation in intakes of four major food groups and another four items were selected based on their contribution to the absolute intake of the 27 nutrients. All but five food items were chosen by at least one study participant.

Among all GNC study subjects, 36% of individuals did not participate in the feasibility and evaluation study. About 28% refused or were unable to participate, primarily because of lack of access to the Internet (Table 1). Non-participation was higher for women than men, and it was higher for older than younger individuals. Another 8% of individuals who initially agreed to participate did not respond to the first online invitation. Overall, at

least one 24-h food list was obtained from 323 study participants, corresponding to an overall response proportion of 64%. Response proportions were largest in Berlin—South (86%), Berlin—North (74%) and Kiel (72%). The response proportion in study centres using comparable recruitment and prompting procedures was 63%.

Of the study population, 52% were female and 51% were younger than 50 years of age (Table 1). Differences between study centres with respect to sex were marginal except for the study centre in Berlin—South, which recruited a greater proportion of women (79%). Differences between study centres regarding age resulted from different approaches of selecting the study sample, as described previously. Compliance was highest for the first application of the 24-h food list and lower for the second and third applications. Among all participants, 100, 85 and 68% completed the 24-h food list one, two or three times, respectively.

Considering each administration separately, a total of 817 24-h food lists were completed (Table 2). The median completion time was 9 min, and this was very similar across study centres. On average, women required 2 min more to complete the questionnaire than men. Older individuals required 4 min more than younger participants. Of all the 24-h food lists, 57% were completed on the day the participant was prompted. The lowest number of 24-h food lists completed on time was found in Berlin—North and Regensburg.

The evaluation form was completed by 78% of participants (Figure 1). Over 90% of participants rated the understandability, usability and visual presentation of the 24-h food list as good or very good. At least 80% reported good or very good perceived completeness of the list of food items and confirmed that the questionnaire reflected their diet of the previous 24 h. Approximately 90% had no difficulties in finding the foods they had consumed and matching them to the item list. Only few food items were declared missing on the 24-h food list. Missing food items predominantly included regional specialities or were foods assignable to existing food items. Also, no difficulties were reported in recalling what was consumed the day before. Additional assistance in navigating the questionnaire in terms of the need for supplementary legends and so on was stated as not being necessary. About 95% of participants indicated that they would be willing to repeat the web-based version of the 24-h food list.

Table 1. Characteristics of participants and non-participants of the feasibility study[a]

		Study centre					
	Total	*Augsburg*	*Berlin—North*	*Berlin—South*	*Freiburg*	*Kiel*	*Regensburg*
n (%)							
Individuals invited to 24-h food list	505	74	27	44	157	102	101
Non-participants	140 (28)	27 (36)	0 (0)	3 (7)	40 (25)	21 (21)	49 (49)
Female	85 (61)	19 (70)	—	0 (0)	24 (60)	11 (52)	31 (63)
Age < 50 years[b]	44 (31)	9 (33)	—	1 (33)	13 (33)	7 (33)	14 (29)
Reason: no web access	97 (69)	15 (56)	—	3 (100)	30 (75)	18 (86)	31 (63)
No reaction after online invitation	42 (8)	0 (0)	7 (26)	3 (7)	24 (15)	8 (8)	0 (0)
Participants	323 (64)	47 (64)	20 (74)	38 (86)	93 (59)	73 (72)	52 (51)
Female	169 (52)	22 (47)	8 (40)	30 (79)	44 (47)	40 (55)	25 (48)
Age < 50 years[b]	164 (51)	25 (53)	8 (40)	22 (58)	46 (49)	44 (60)	19 (37)
BMI ⩾ 25 kg/m^2	171 (53)	28 (60)	10 (50)	17 (45)	50 (54)	33 (45)	33 (63)
High school[c]	185 (57)	19 (40)	10 (50)	24 (63)	63 (68)	43 (59)	26 (50)
Never smoker[d]	221 (68)	28 (60)	16 (80)	26 (68)	71 (76)	40 (55)	40 (77)
Married[e]	212 (66)	37 (79)	11 (55)	21 (55)	63 (68)	41 (56)	39 (75)
Number of 24-h food lists completed							
1 24-h food list	323 (100)	47 (100)	20 (100)	38 (100)	93 (100)	73 (100)	52 (100)
2 24-h food lists	275 (85)	42 (89)	17 (85)	36 (95)	77 (83)	67 (92)	36 (69)
3 24-h food lists	219 (68)	26 (55)	14 (70)	35 (92)	53 (57)	64 (88)	27 (52)

Abbreviation: BMI, body mass index. [a]$n = 505$. [b]Age categories: 20–49 vs 50–70 years. [c]Education categories: secondary school vs high school. [d]Smoking categories: never smoker vs ever smoker. [e]Family categories: married vs single, divorced.

Table 2. Duration and timeliness of 24-h food lists completed[a]

		Study centre					
	Total	*Augsburg*	*Berlin—North*	*Berlin—South*	*Freiburg*	*Kiel*	*Regensburg*
Total 24-h food lists completed, *n* (%)	817 (100)	115 (14)	51 (6)	109 (13)	223 (27)	204 (25)	115 (14)
Duration per 24-h food list (min), median (IQR)	9 (7–13)	9 (7–12)	8 (7–14)	9 (7–14)	9 (7–12)	9 (7–12)	9 (7–15)
Female	10 (7–13)	9 (8–12)	9 (7–14)	9 (6–14)	10 (8–12)	10 (7–12)	10 (8–15)
Male	8 (7–13)	8 (6–13)	8 (7–14)	8 (7–12)	8 (7–12)	8 (7–18)	9 (7–11)
Age 20–49 years	8 (6–10)	8 (6–10)	7 (7–8)	8 (6–9)	7 (6–10)	8 (6–10)	8 (7–9)
Age 50–70 years	12 (8–16)	11 (8–34)	12 (8–16)	13 (9–16)	12 (8–15)	12 (8–19)	11 (8–15)
24-h food list on time[b], *n* (%)	467 (57)	72 (63)	5 (10)	65 (60)	160 (72)	146 (72)	19 (17)
24-h food list not on time[c], *n* (%)	350 (43)	43 (37)	46 (90)	44 (40)	63 (28)	58 (28)	96 (83)

Abbreviation: IQR, interquartile range. [a]$n = 817$. [b]24-h food list completion on the day of prompting the study participant. [c]24-h food list completion not on the day of prompting the study participant.

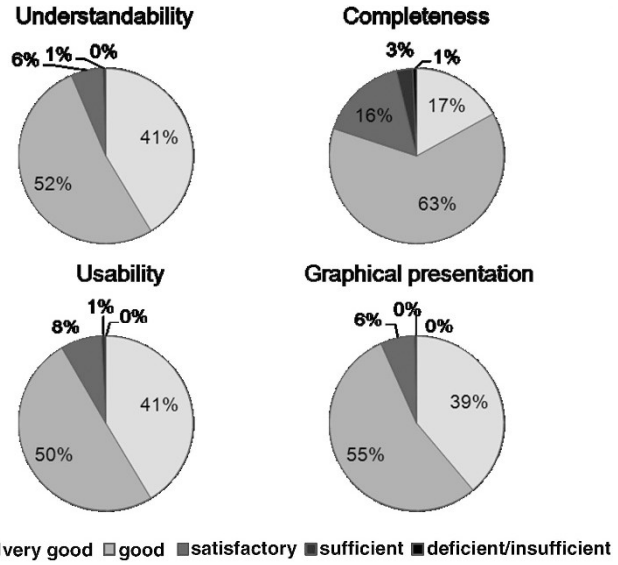

Figure 1. Acceptance of the 24-h food list among 252 participants who completed the evaluation form.

DISCUSSION

Our 24-h food list included 246 food items and took participants on average 9 min to complete. The overall response proportion was 64%. Acceptance by study participants was high as shown by the results of the evaluation form. However, compliance declined with increasing administrations of the questionnaire.

Various innovative approaches are currently addressing the challenges in dietary assessment in epidemiological studies. Some focus on new methodologies, such as combining different assessment instruments, while others address new technologies, such as dietary assessment using mobile phones[27] or web-based 24HDR applications.[15,16] In general, available instruments differ with respect to the number of foods assessed, the collection of information on portion size and the inclusion of probes, but all are stand-alone instruments. For example, the ASA24 represents a detailed automated self-administered 24HDR. It collects and codes dietary intake data and includes detailed questions about portion sizes and food preparation methods.[16,28] Likewise, the web-based 24HDR DietDay contains 9349 foods, assesses information on portion sizes and preparation methods and was designed for repeated administrations.[15] The Oxford WebQ is a low-cost, web-based method for assessing previous 24-h dietary intakes. It obtains information on the quantities consumed of 21 food groups, and the median time for self-completion is 12.5 min.[18] Thus, with a finite food list and brief application time, the Oxford WebQ is similar to our 24-h food list. However, our questionnaire assesses the probability of consumption of 246 food items without requesting information on the quantity consumed. This approach is backed by the notion that the frequency of food intake represents a larger contribution to inter-individual variation in food and nutrient intake than inter-individual variation in portion sizes.[19] Our 24-h food list is by definition intended for use in a blended approach and not as a stand-alone instrument.

Of the various methods for estimating usual dietary intake, three deserve particular consideration: the National Cancer Institute Method (NCI),[7] the Multiple Source Method (MSM),[10] and the Statistical Program to Assess Dietary Exposure (SPADE).[29] All three methods rely on repeated 24HDR information and follow a two-step approach. The first step includes an estimation of the probability of consumption and the second step entails an estimation of the quantity consumed. NCI and SPADE directly estimate usual intake distributions of the study population. In contrast, MSM first estimates usual intake data for each individual and uses that information to calculate usual intake distributions of the population. Covariates such as age and body mass index can be included in the model for NCI and MSM. In contrast, SPADE allows adjustment for age only. For NCI and MSM, frequency information from a FFQ can be used as a covariate in the model. For MSM, the FFQ can further be used to identify true consumers among those considered non-consumers according to the 24HDR. Because our 24-h food list lends itself to quick and potentially frequent applications for a given study participant, it may represent a superior tool for estimating the probability of consumption in large-scale cohort studies than a conventional detailed 24HDR. The 24-h food list is intended to represent the first of the three entities to estimate usual dietary intake of a subject: (1) repeated application of the 24-h food list assesses the probability of consumption; (2) a single application of a FFQ assesses true non-consumption and provides further information on frequency of consumption as covariate information; and (3) survey data are used to calculate the amount consumed on a consumption day depending on further covariate information (Table 3).

The simple structure of the 24-h food list with its rapid completion time has been designed to decrease participant burden and thereby increase the willingness to participate. Ease of use is important because multiple applications of the questionnaire are required, which itself bears a risk of affecting participant compliance and thus of reducing the applicability for repeated self-administration in large-scale cohort studies. Indeed, the median completion time of our questionnaire was 9 min, which we consider an acceptable duration. However, we already noted that compliance declined with an increasing number of 24-h food lists completed. There appears to be a point in time at which the gain in accuracy due to multiple administrations of a 24HDR is offset by loss of participants due to the high burden.[13] According to the authors, the number of 24HDRs required varies depending on the typical frequency of consumption of foods, which lead them to suggest the combined use of 24HDR and FFQ in cohort studies.

The food item selection for our 24-h food list was conducted using stepwise linear regression analysis, a method that identifies foods that most discriminate between individuals and is typically used for FFQ development.[23] In addition, we applied contribution analysis, which yielded only four additional items for the item list. Thomas and Mark[30] proposed an alternative strategy for the selection of subsets of foods for the development of short questionnaires. By maximizing the correlation coefficient, Max_r selects a subset of foods that best preserves the between-person variance in nutrient intake. However, it has been shown that this method produces results similar to the stepwise procedure.[23,31] In addition, we did not intend to obtain the shortest item list possible, as evidenced by our decision to include a large number of nutrients ($n = 27$) and four major food groups. Food items selected for each nutrient overlapped considerably, reducing the possibility that we may have missed a particular food item. To assess whether we had included all relevant food items, we asked participants to declare missing items. This resulted in the addition of two items to a revised item list created subsequent to the feasibility study. Further, all but five food items were chosen by at least one study participant, suggesting that our item list was appropriate.

The strengths and limitations of our study warrant consideration. One limitation is that the strategies used for prompting and reminding participants differed between study centres. This may explain the observed differences in the timeliness and number of 24-h food lists completed between study centres. Further, the time frame for repeated assessments varied between 3 and 6 months, limiting our ability to directly compare participant

Table 3. Proposed blend of dietary assessment instruments for statistical derivation of usual dietary intake distributions in large-scale cohort studies

Information	*Instrument*	*Study participants*
Probability of consumption	24-h food list	All
True non-consumption, frequency	FFQ	All
Quantity of food consumed	Detailed 24HDR	Subgroup or survey data

Abbreviations: FFQ, food frequency questionnaire; 24HDR, 24-h dietary recall.

compliance between study centres. Thus, one of the implications of our feasibility study was to develop an automated system for prompting and reminding study participants. Our study tested a web-based application of the 24-h food list; a paper-based version was not available. This may limit the generalizability of our findings to persons with Internet access. We found that non-participants tended to be older and of female sex while the main reason for non-participation was lack of Internet access. These findings are in line with previous studies of web-based questionnaires,[32] although Internet access is rapidly increasing in Germany.[33] Therefore, a further implication of our feasibility study was to develop a paper-based version of the 24-h food list. Participants may have been prone to reactivity, because the questionnaire was accessible throughout the entire duration of the study. To minimize the potential for reactivity, participants were asked to complete the 24-h food list the day they were prompted. However, because we were unable to monitor the date participants actually checked their e-mail, the proportion of participants who failed to complete their 24-h food list on time (43%) should be interpreted with caution.

Strengths of the present study are that the 24-h food list represents a novel tool that assesses the probability of consumption of 246 food items. The list of food items was based on representative contemporary German dietary survey data and is thus suitable for application in different study regions throughout Germany. Further, formal statistical procedures were used for food item selection.

Taking into account the short completion time of 9 min on average, the 24-h food list represents a potentially promising tool to estimate the probability of consumption of a finite number of food items in future large-scale cohort studies. However, an increasing number of repeated administrations of the 24-h food list may lower participant compliance. In combination with a FFQ and information on standard consumption quantities, the 24-h food list can be used as part of a blended approach combining multiple data sources for the estimation of usual dietary intake in prospective epidemiological settings. The application of our proposed blended approach needs to be tested in future research.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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REFERENCES

1 Rosner B, Willett WC, Spiegelman D. Correction of logistic regression relative risk estimates and confidence intervals for systematic within-person measurement error. *Stat Med* 1989; **8**: 1051–1069, discussion 1071–1073.
2 Willett WC, Hu FB. Not the time to abandon the food frequency questionnaire: point. *Cancer Epidemiol Biomarkers Prev* 2006; **15**: 1757–1758.
3 Kristal AR, Potter JD. Not the time to abandon the food frequency questionnaire: counterpoint. *Cancer Epidemiol Biomarkers Prev* 2006; **15**: 1759–1760.
4 Kipnis V, Midthune D, Buckman DW, Dodd KW, Guenther PM, Krebs-Smith SM *et al.* Modeling data with excess zeros and measurement error: application to evaluating relationships between episodically consumed foods and health outcomes. *Biometrics* 2009; **65**: 1003–1010.
5 Tooze JA, Midthune D, Dodd KW, Freedman LS, Krebs-Smith SM, Subar AF *et al.* A new statistical method for estimating the usual intake of episodically consumed foods with application to their distribution. *J Am Diet Assoc* 2006; **106**: 1575–1587.
6 Dodd KW, Guenther PM, Freedman LS, Subar AF, Kipnis V, Midthune D *et al.* Statistical methods for estimating usual intake of nutrients and foods: a review of the theory. *J Am Diet Assoc* 2006; **106**: 1640–1650.
7 Tooze JA, Kipnis V, Buckman DW, Carroll RJ, Freedman LS, Guenther PM *et al.* A mixed-effects model approach for estimating the distribution of usual intake of nutrients: the NCI method. *Stat Med* 2010; **29**: 2857–2868.
8 Illner AK, Nothlings U, Wagner K, Ward H, Boeing H. The assessment of individual usual food intake in large-scale prospective studies. *Ann Nutr Metab* 2010; **56**: 99–105.
9 de Boer EJ, Slimani N, van 't Veer P, Boeing H, Feinberg M, Leclercq C *et al.* The European Food Consumption Validation Project: conclusions and recommendations. *Eur J Clin Nutr* 2011; **65**(Suppl 1): S102–S107.
10 Haubrock J, Nothlings U, Volatier JL, Dekkers A, Ocke M, Harttig U *et al.* Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam Calibration Study. *J Nutr* 2011; **141**: 914–920.
11 Souverein OW, Dekkers AL, Geelen A, Haubrock J, de Vries JH, Ocke MC *et al.* Comparing four methods to estimate usual intake distributions. *Eur J Clin Nutr* 2011; **65**(Suppl 1): S92–S101.
12 Subar AF, Dodd KW, Guenther PM, Kipnis V, Midthune D, McDowell M *et al.* The food propensity questionnaire: concept, development, and validation for use as a covariate in a model to estimate usual food intake. *J Am Diet Assoc* 2006; **106**: 1556–1563.
13 Carroll RJ, Midthune D, Subar AF, Shumakovich M, Freedman LS, Thompson FE *et al.* Taking advantage of the strengths of 2 different dietary assessment instruments to improve intake estimates for nutritional epidemiology. *Am J Epidemiol* 2012; **175**: 340–347.
14 Schatzkin A, Subar AF, Moore S, Park Y, Potischman N, Thompson FE *et al.* Observational epidemiologic studies of nutrition and cancer: the next generation (with better observation). *Cancer Epidemiol Biomarkers Prev* 2009; **18**: 1026–1032.
15 Arab L, Wesseling-Perry K, Jardack P, Henry J, Winter A. Eight self-administered 24-hour dietary recalls using the Internet are feasible in African Americans and Whites: the energetics study. *J Am Diet Assoc* 2010; **110**: 857–864.
16 Subar AF, Kirkpatrick SI, Mittl B, Zimmerman TP, Thompson FE, Bingley C *et al.* The automated self-administered 24-hour dietary recall (ASA24): a resource for researchers, clinicians, and educators from the National Cancer Institute. *J Acad Nutr Diet* 2012; **112**: 1134–1137.
17 Apovian CM, Murphy MC, Cullum-Dugan D, Lin PH, Gilbert KM, Coffman G *et al.* Validation of a web-based dietary questionnaire designed for the DASH (dietary approaches to stop hypertension) diet: the DASH online questionnaire. *Public Health Nutr* 2010; **13**: 615–622.
18 Liu B, Young H, Crowe FL, Benson VS, Spencer EA, Key TJ *et al.* Development and evaluation of the Oxford WebQ, a low-cost, web-based method for assessment of previous 24 h dietary intakes in large-scale prospective studies. *Public Health Nutr* 2011; **14**: 1998–2005.
19 Noethlings U, Hoffmann K, Bergmann MM, Boeing H. Portion size adds limited information on variance in food intake of participants in the EPIC-Potsdam study. *J Nutr* 2003; **133**: 510–515.
20 Max Rubner-Institut. Nationale Verzehrsstudie II, Ergebnisbericht Teil 1 [in German: National Nutrition Survey II, first report]. Max Rubner-Institut, Federal Research Institute of Nutrition and Food. Karlsruhe. 2008 [cited 11 December 2012]; Available from http://www.mri.bund.de/fileadmin/Institute/EV/NVS_II_Abschlussbericht_Teil_1_mit_Ergaenzungsbericht.pdf.
21 Slimani N, Deharveng G, Charrondiere RU, van Kappel AL, Ocke MC, Welch A *et al.* Structure of the standardized computerized 24-h diet recall interview used as reference method in the 22 centers participating in the EPIC project. European Prospective Investigation into Cancer and Nutrition. *Comput Methods Programs Biomed* 1999; **58**: 251–266.
22 Max Rubner-Institut (Federal Research Institute of Nutrition and Food). German Nutrient Database - Bundeslebensmittelschlüssel (BLS) Version 3.01. 2010 [cited 11 December 2012]; Available from http://www.blsdb.de.

23 Willett W. *Nutritional Epidemiology*. Oxford University Press: New York, NY, USA, 1998.
24 Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witschi J *et al.* Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol* 1985; **122**: 51–65.
25 Block G, Hartman AM, Dresser CM, Carroll MD, Gannon J, Gardner L. A data-based approach to diet questionnaire design and testing. *Am J Epidemiol* 1986; **124**: 453–469.
26 Nothlings U, Hoffmann K, Bergmann MM, Boeing H. Fitting portion sizes in a self-administered food frequency questionnaire. *J Nutr* 2007; **137**: 2781–2786.
27 Khanna N, Boushey CJ, Kerr D, Okos M, Ebert DS, Delp EJ. An overview of The Technology Assisted Dietary Assessment Project at Purdue University. *ISM* 2010 290–295.
28 Zimmerman TP, Hull SG, McNutt S, Mittl B, Islam N, Guenther PM *et al.* Challenges in converting an interviewer-administered food probe database to self-administration in the National Cancer Institute Automated Self-administered 24-Hour Recall (ASA24). *J Food Compost Anal* 2009; **22**(Supplement 1): S48–S51.
29 Waijers PM, Dekkers AL, Boer JM, Boshuizen HC, van Rossum CT. The potential of AGE MODE, an age-dependent model, to estimate usual intakes and prevalences of inadequate intakes in a population. *J Nutr* 2006; **136**: 2916–2920.
30 Thomas DG, Mark SD. Max_r: an optimal method for the selection of subsets of foods for the measurement of specific nutrient exposures. *Comput Methods Programs Biomed* 1997; **54**: 151–156.
31 Mark SD, Thomas DG, Decarli A. Measurement of exposure to nutrients: an approach to the selection of informative foods. *Am J Epidemiol* 1996; **143**: 514–521.
32 Smith B, Smith TC, Gray GC, Ryan MA. When epidemiology meets the Internet: web-based surveys in the Millennium Cohort Study. *Am J Epidemiol* 2007; **166**: 1345–1354.
33 Statistisches Bundesamt. [data-base on the Internet] 2012 [cited 21 November 2012]; Available from https://www.destatis.de/DE/ZahlenFakten/GesellschaftStaat/EinkommenKonsumLebensbedingungen/ITNutzung/Tabellen/ZeitvergleichComputernutzung_IKT.html.