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A brief dietary assessment instrument for assessing target foods, nutrients and eating patterns

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Abstract

Objective: To develop and validate a new dietary assessment tool, the focused recall, and to use this to measure co-consumption of carotenoid-containing fruits and vegetables with savory snacks.

Design: Participants completed a telephone-administered focused recall and a 24-hour recall on the same day. We compared mean estimates of fruit, vegetable, savory snack and carotenoid consumption from both instruments. We also assessed the ability of each method to measure co-consumption of carotenoids with full-fat, reduced/non-fat and olestra-containing savory snacks.

Setting and subjects: Data are from 245 male and 244 female adult participants in the Olestra Post-Marketing Surveillance Study (OPMSS).

Results: The mean (± SD) intake of fruit was 1.8 (1.1) servings day^{-1} from the focused recall and 1.6 (1.4) servings day^{-1} from the 24-hour recall (r=0.56). The mean vegetable intake was 2.1 (1.3) and 2.2 (1.7) servings day^{-1} (r=0.42), respectively, from each instrument. Estimates of total carotenoid and β-carotene intake were within 5% of each other (r=0.63 for total carotenoids and r=0.70 for β-carotene). Both instruments estimated that approximately 14% of total daily carotenoids were co-consumed with savory snacks (r=0.63).

Conclusions: The focused recall provides valid information about fruit, vegetable and savory snack consumption and allows researchers to examine associated eating patterns more easily.

Keywords
Diet
Nutrition assessment
Carotenoids
Fat substitutes
Fruit
Vegetables
Questionnaires

Measuring dietary intake of fruits and vegetables is an important aspect of public health research. Fruits and vegetables have been consistently associated with decreased risk of many diseases, including cancers of the colon and lung[1–3] and cardiovascular disease[4]. The most common method for assessing usual fruit and vegetable intake in epidemiological studies is based on a food frequency-type approach[5]. Study participants report their usual frequency of consuming fruit juices, potatoes, salads, fruits and vegetables, and these are then summed to yield an estimate of total servings per day. While this approach gives information on dietary exposure over a defined period of time, there are limitations to the types of data obtained from food frequency questionnaires. For example, there are no data on either meal patterns involving fruits and vegetables, consumption of mixed dishes that contain substantial amounts of fruits and vegetables, or food preparation methods. This type of information can be very important for aetiological studies of diet and disease, for designing intervention strategies to increase consumption of fruits and vegetables, and for evaluation of dietary interventions to increase consumption of fruits and vegetables[6]. Other limitations of food frequency questionnaires include the restrictions imposed by a fixed list of foods and the cognitive challenge of reporting foods consumed over a broad timeframe, such as the past 3 months. Twenty-four-hour dietary recalls can provide this information, but for many reasons they are not optimally designed to do so. First, 24-hour recalls collect far more information than is needed to measure fruit and vegetable intake, and thus a very high price is paid to collect extra data that may not be useful for a study. Second, dietary recalls rely on participant memory for foods eaten and for quantification of portion size. Small portions of vegetables eaten as part of mixed dishes such as soups or casseroles are not likely to be reported unless the interviewer engages in lengthy and detailed probing, which could be burdensome to both study staff and participants. Finally, most researchers use computer software to both collect and analyse 24-hour recalls, and

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it is extremely difficult to manipulate data files from these systems to extract details on preparation methods, meal patterns or even simply numbers of servings of fruits and vegetables. These problems motivated our development of a 'focused recall' to measure fruit and vegetable intake. Cognitively, this approach combines the short-term recall used in a 24-hour recall with some simple categorization of responses used in food frequency-type instruments. The data obtained yield very detailed information that is focused on a specific group of foods eaten during the previous day. In the application described here, the target foods are fruits and vegetables, however the method may be generalized to measure intake of any specific class of foods.

This report describes the development, analysis and validity of a focused recall used in the OPMSS, a large, population-based investigation designed to assess olestra intake and its association with serum concentrations of fat-soluble vitamins and carotenoids[7]. Olestra is a Food and Drug Administration (FDA) approved energy-free, non-absorbable fat substitute available only in savory snacks (potato and tortilla chips, extruded snacks and crackers)[8]. When consumed with carotenoid-containing foods, olestra can sequester carotenoids and reduce their absorption[9–11]. It was therefore necessary to develop a detailed measure of fruits and vegetables, because they are the primary source of dietary carotenoids, along with the extent to which carotenoids are co-consumed with olestra-containing snacks that could affect their absorption. Here we give results from a validity substudy on the performance of the focused recall in comparison with a criterion measure, a complete 24-hour dietary recall. We also give the proportion of total carotenoids consumed with savory snacks (i.e. 'at-risk' carotenoids). Finally, we estimate the potential for olestra to reduce serum carotenoid levels in the population based on the degree of co-consumption that we observed.

Methods

Study sample and design

Details of the OPMSS design are already published[7,12]. For this substudy, participants were a randomly selected age- and sex-stratified sample of 500 adult OPMSS participants from the sentinel study site in Indianapolis. Data for this report are from 245 male and 244 female participants who completed unannounced telephone interviews between June and September 1997, after olestra-containing snacks were introduced in Indianapolis. The dietary assessment instruments used in these analyses are described below.

Focused recall

The focused recall questionnaire was divided into six sections that corresponded to typical food consumption occasions. For each period during the day (breakfast, mid-morning, lunch, afternoon, dinner, evening) interviewers asked participants whether they had eaten a fruit, vegetable or any of five categories of savory snacks (potato chips, tortilla/corn chips, extruded snacks such as cheese curls, crackers and pretzels). If a participant reported eating a savory snack, interviewers probed for portion size and fat classification (regular fat, reduced/non-fat or olestra-containing). If a participant consumed juice or fruit, the interviewer recorded the type on a list of 21 carotenoid-containing fruits (e.g. grapefruit, cantaloupe) or recorded 'other fruit'. For mixed fruit dishes, interviewers recorded up to five different fruits, and we used the corresponding fraction of each fruit in the mix for analysis. If a participant ate a vegetable or mixed dish containing a vegetable, the interviewer recorded the type on a list of 27 carotenoid-containing vegetables (e.g. carrots, spinach) and 14 mixed foods (e.g. pizza), or recorded 'other vegetable'. For lunch and dinner, interviewers probed for more detailed information on the use of tomato products (e.g. ketchup, salsa, tomato sauce) and vegetables in mixed dishes (e.g. soups, casseroles). For nutrient analysis, we assigned medium portion sizes[13] to fruits, vegetables and mixed foods, and fractional portion sizes to vegetables consumed primarily as condiments such as onions and green peppers. We applied the carotenoid values from the United States Department of Agriculture–National Cancer Institute (USDA-NCI) carotenoid database for foods to each portion consumed[14]. No carotenoid values were assigned to 'other fruits' or 'other vegetables'. Analysis yielded number of fruit, vegetable and savory snack servings and micrograms of total and individual carotenoids per eating occasion, and these values were summed to obtain total daily intake of fruits, vegetables, savory snacks and carotenoids.

Twenty-four-hour dietary recalls

After completion of the focused recall and a larder inventory questionnaire, we administered the 24-hour recalls. We administered the focused recall first because the detailed probing of the 24-hour recall would have biased our ability to measure the validity of the focused recall. Trained interviewers conducted the 24-hour dietary recalls using the Nutrition Data System (version 2.9, Nutrition Coordinating Center, University of Minnesota, Minneapolis). Interviewers used a standardized script for data collection, which included probes for frequently forgotten foods such as beverages, snacks and condiments.

Fruit and vegetable consumption from the 24-hour recall was calculated using an automated food grouping system previously developed for cancer prevention studies[15]. Fruits included fresh, canned, frozen and dried fruit and 100% fruit juice. A medium serving of fruit was defined as: 8 oz of juice, one medium piece of fruit or its equivalent in grams, 0.5 cup of cut fruit pieces or 0.25 cup of dried fruit. The vegetable group contained juice, fresh, canned, frozen and dried vegetables. A serving of vegetables was defined as: 8 oz of vegetable

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juice, 0.5 cup cooked, 1 cup raw, 2 cups raw leafy or one medium (e.g. tomato, potato) vegetable. We included fruits and vegetables consumed as part of mixed dishes. For example, we counted vegetables in stew, tomatoes on sandwiches, tomato sauce on pasta and peaches in peach pie. Foods with extremely high fat or sugar content such as fruit drinks, French fries, Poptarts®, jams and jellies were excluded. Computer algorithms converted the portion sizes of each fruit and vegetable into servings and summed servings of each by meal type (breakfast, lunch, dinner and snacks). A parallel system was used for measuring savory snack consumption from 24-hour recall data. This system tabulated intakes of five categories of snacks (potato chips, tortilla/corn chips, extruded products, crackers and pretzels), with three fat classifications (regular fat, reduced/non-fat and olestra-containing) and defined a medium serving size as 2 oz.

Lastly, computer algorithms tabulated the extent to which carotenoids were consumed at the same time as olestra-containing snacks. Based on experimental research[10,11], we defined co-consumption as consumption of a carotenoid-containing fruit or vegetable within 2 hours (either before or after) of eating an olestra-containing savory snack.

Statistical analysis

We measured agreement between the focused recall and the 24-hour recall by comparing the proportion of participants who reported consumption of fruits, vegetables and savory snacks at each eating occasion from each assessment instrument. For statistical analysis, we log-transformed servings of fruits, vegetables, savory snacks and micrograms of carotenoids to approximate normality, but we present geometric means calculated as the antilog of the mean of the log-transformed nutrient estimates for ease of interpretation. We assessed bias by comparing the mean servings of fruits, vegetables and savory snacks, and mean carotenoid intake estimates from the focused recall with the 24-hour recall. We used Spearman correlation coefficients to assess precision of intake estimates from the focused recall compared to the 24-hour recall. We assessed the ability of the instruments to assess co-consumption of olestra and carotenoids by comparing the proportion of the day's total carotenoids that were eaten with each type of savory snack from each dietary assessment method. All statistical analyses were performed with SAS (version 6.12; SAS Institute Inc., Cary, NC).

Results

The mean age of study participants was 41.6 years, 80.6% were Caucasian, 16.8% were African-American and 2.7% were other minorities. Participants were well educated; 62.2% had at least some college education. The mean length of time to complete the focused recall was 6 min while it was 25 min for the 24-hour recall.

In general, there was good agreement between the focused recall and the 24-hour recall on whether or not fruits, vegetables and savory snacks were consumed at each eating occasion (Table 1). However, compared to the 24-hour recall, the focused recall captured fewer instances of vegetable consumption at each eating occasion. The consumption of savory snacks with a fruit or vegetable was rare. At lunch and between meals, 6–11% of participants reported co-consuming a fruit or vegetable with a savory snack on the focused recall compared with about 12% on the 24-hour recall.

Table 2 gives servings of fruits, vegetables and savory snacks per day as assessed from the focused recall and the 24-hour recall. Estimates of servings of fruits, vegetables and savory snacks were similar for both instruments. The correlations between instruments were approximately 0.6

Table 1 Per cent of participants reporting consumption of fruits, vegetables and savory snacks on a focused dietary recall (FR) and a 24-hour dietary recall (24-H) administered on the same day ($n=489$)

	Breakfast*			Lunch			Dinner			Snacks		
	FR	24-H	Agree†	FR	24-H	Agree†	FR	24-H	Agree†	FR	24-H	Agree†
Meal type	70.4	73.8	90.0	84.3	84.7	94.3	93.5	91.4	94.3	70.4	86.3	79.5
Food consumption												
Fruit and vegetables	41.9	44.4	86.9	65.4	69.1	88.5	79.5	82.2	86.3	28.2	33.7	78.5
Fruits	40.7	41.9	88.1	20.7	24.7	86.5	20.9	23.9	85.1	24.5	25.1	82.6
Vegetables	2.7	4.5	96.1	58.5	63.4	88.1	76.1	79.3	85.3	6.3	14.9	87.7
Any savory snacks‡	–	1.0	99.0	15.9	17.8	94.1	10.4	9.8	94.1	21.1	23.1	91.4
Regular fat snacks	–	1.0	99.0	9.4	9.8	95.9	6.3	5.3	96.1	12.3	12.5	95.3
Reduced and non-fat snacks§	–	0.0	100.0	6.5	7.8	93.1	4.1	4.3	96.5	9.8	11.0	94.7
Co-consumption												
Savory snack with fruit or vegetable‡	–	0.4	–	10.8	12.9	93.9	8.8	8.2	94.5	6.3	11.7	90.6
Regular fat snack with fruit or vegetable	–	0.4	–	5.9	6.5	96.5	4.9	4.1	96.7	3.5	5.5	93.9
Reduced/non-fat snack with fruit or vegetable	–	0.0	–	4.9	6.1	94.7	3.9	3.9	96.3	3.1	6.1	96.5

* Participants were not asked about savory snack consumption at breakfast.
† Per cent of sample in agreement (yes/yes or no/no).
‡ There were only nine occasions of eating savory snacks made with olestra, only one of which occurred in the presence of a fruit or vegetable.
§ Includes all types of reduced fat and non-fat snacks including olestra-containing snacks.

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Table 2 Consumption of fruits, vegetables, savory snacks and carotenoids estimated from a focused dietary recall and a 24-hour dietary recall administered on the same day ($n=489$)

	Focused recall		24-hour recall		
	Participants consuming (%)	Mean* (SD) among consumers	Participants consuming (%)	Mean* (SD) among consumers	Correlation coefficient†
Food (servings day^{-1})					
Fruit and vegetables	96.1	3.2 (2.0)	98.2	3.3 (2.5)	0.56
Fruits	65.4	1.8 (1.1)	69.5	1.6 (1.4)	0.56
Vegetables	90.8	2.1 (1.3)	95.3	2.2 (1.7)	0.42
All savory snacks‡	41.5	1.2 (1.0)	44.4	1.3 (1.0)	0.59
Regular fat snacks	25.2	1.2 (0.9)	26.4	1.3 (1.0)	0.52
Reduced/non-fat snacks	18.8	1.0 (0.9)	21.9	0.9 (0.8)	0.49
Carotenoids (μg day^{-1})					
Total carotenoids§	94.4	7531 (9777)	96.3	7195 (9905)	0.63
β-carotene	94.4	1132 (1593)	96.1	1141 (1760)	0.70
Lycopene	71.8	6804 (8568)	73.4	5284 (6641)	0.67
Lutein/zeaxanthin	89.6	677 (494)	93.5	871 (1380)	0.70

* Geometric means.
† Spearman correlation coefficients (all $P<0.001$).
‡ There were only nine occasions of eating savory snacks made with olestra, only one of which occurred in the presence of carotenoids.
§ α-carotene and β-cryptoxanthin were not included in individual carotenoid assessment.

for total fruit and vegetables, fruits and all savory snacks, and was about 0.4 for vegetables. Estimates of carotenoid intakes were similar from the two instruments; total carotenoids and β-carotene were within 5% of each other, while lycopene was about 22% higher and lutein/zeaxanthin was about 22% lower from the focused recall. The correlation between instruments was 0.6 for total carotenoids and 0.7 for the individual carotenoids.

Table 3 gives data comparing the proportion of carotenoids consumed at the same meal as savory snacks from the focused recall and the 24-hour recall. The instruments yielded similar results, indicating that on any one day, 13–14% of carotenoids were consumed at the same meal as a savory snack. These records contained only nine occasions of eating olestra-containing savory snacks and only one instance of olestra consumption in the presence of carotenoids. Therefore, we combined all reduced fat, non-fat and olestra-containing snacks for analysis. Only 5–6% of carotenoids were co-consumed with any type of fat-modified snack. There was good agreement between the instruments on the percentages of carotenoids eaten in the presence of all savory snacks ($r=0.6$), regular fat snacks ($r=0.6$) and reduced/fat-free snacks ($r=0.5$).

Discussion

This study demonstrates the utility of a simple, brief instrument in providing valid estimates of fruit, vegetable, carotenoid and savory snack consumption and eating pattern information (i.e. co-consumption). Reports of the previous day's intake of fruit and savory snacks were similar when assessed by either the standard 24-hour dietary recall or the focused recall. However, the proportion of participants reporting vegetable consumption was slightly higher from the 24-hour recall compared to the focused recall. This finding probably resulted because the

Table 3 Per cent of dietary carotenoids co-consumed with savory snacks* estimated from a focused recall and a 24-hour dietary recall administered on the same day ($n=489$)

	Focused recall		24-hour recall		
	Participants co-consuming† (%)	Carotenoids co-consumed‡ (%)	Participants co-consuming† (%)	Carotenoids co-consumed‡ (%)	Correlation coefficient§
Per cent of total carotenoids consumed at same meal as a savory snack	23.9	13.8	27.6	13.5	0.63
Per cent of total carotenoids consumed at same occasion as regular fat snack	13.3	8.8	14.3	7.1	0.60
Per cent of total carotenoids consumed at same occcasion as reduced/non-fat snack	11.7	5.2	14.5	6.3	0.55

* There were only nine occasions of eating savory snacks made with olestra, only one of which occurred in the presence of carotenoids.
† Per cent of participants that consume any carotenoids in the presence of a savory snack on a single day.
‡ Per cent of carotenoids consumed at the same eating occasion as a savory snack on a single day.
§ Spearman correlation coefficients between the two estimates of per cent of carotenoids co-consumed (all $P<0.001$).

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food grouping algorithms applied to the 24-hour recalls capture minute quantities of vegetables in mixed dishes (e.g. onions, celery), while participants are likely to report only substantial quantities of vegetables (e.g. vegetables in stew). Despite this bias in the estimates of vegetable servings from the focused recall, the estimates of carotenoid intakes were comparable between the two instruments (r=0.6–0.7). This level of precision is similar to or better than results from other dietary assessment validity studies[16,17]. Advantages of the focused recall are that it can be completed in 5–7 min by staff with minimal training, requires no special coding prior to data analysis and provides good estimates of intake of the foods, nutrients and dietary patterns of interest.

Of particular interest to the OPMSS is that our results indicate that about 14% of carotenoids were co-consumed with savory snacks on any one day. The potential for olestra to decrease absorption of carotenoids depends on the proportion of co-consumed snacks that are made with olestra. According to Information Resources Inc. (Chicago, IL), olestra-containing snacks comprise about 6% of the current total market share of savory snacks. Thus, less than 1% of carotenoids should be at risk of impaired absorption, and the resulting impact on serum carotenoids in the population will probably be minimal. Results of the full-scale OPMSS in 2001 will provide data on the associations of olestra consumption with serum carotenoids.

There are limitations to our study. First, in comparing two methods of dietary assessment in validation studies, it is important that the errors associated with the criterion measure are independent of the errors in the instrument being tested. For example, sources of error in 24-hour recalls include participant memory, coding errors, interviewer bias and difficulties in portion size estimation. Because the focused recall used a combination of characteristics from food frequency questionnaires (e.g. close-ended responses and a fixed food list) together with features of dietary recalls (e.g. recall of diet over the previous day), some of the errors are probably correlated. These correlated errors have the potential to bias our estimates of precision of the focused recall. Second, the focused recall contains a fixed list of fruits and vegetables, which was defined by the available data in the USDA-NCI carotenoids database for foods. Such restricted food lists can be a source of error by yielding estimates of nutrient intake that do not allow adequate discrimination between study participants[13]. Finally, there may be social desirability to overreport fruits and vegetables and underreport savory snacks, which could bias our estimates of co-consumption[18]; and there may have been social desirability to give consistent answers to both instruments. Nevertheless, the focused recall described here can serve as an example or template for the development of brief instruments that can assess consumption of target foods, eating patterns or other types of co-consumption. For example, this approach could be useful when assessing biological markers of nutrients (e.g. carotenoids) that are found in specific classes of foods (e.g. fruits and vegetables)[19,20], or when assessing compliance to feeding study protocols where a comprehensive dietary assessment is neither necessary nor desirable. A focused recall could also be used in the NCI 5-A-Day projects when adoption of a particular eating pattern (fruit and vegetable intake) is an endpoint[21]. However, scientists designing similar tools must remember that abbreviated instruments must be thorough enough to capture the foods that are the major sources of the nutrient(s) of interest[22] as well as foods that are part of mixed dishes such as vegetables in soups and casseroles. In conclusion, the focused recall offers a new approach for quickly, easily and accurately assessing intake of target foods, nutrients and specific eating patterns.

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References

1 Ziegler RG. A review of epidemiological evidence that carotenoids reduce the risk of cancer. *J. Nutr.* 1989; **119**: 116–22.
2 Verhoeven DT, Goldbohm RA, van Poppel G, Verhagen H, van den Brandt PA. Epidemiological studies on brassica vegetables and cancer risk. *Cancer Epidemiol. Biomark. Prev.* 1996; **5**: 733–48.
3 Slattery ML, Potter JD, Coates A, *et al.* Plant foods and colon cancer: an assessment of specific foods and their related nutrients (United States). *Cancer Causes Control* 1997; **8**: 575–90.
4 Klipstein-Grobusch K, Geleijnse JM, den Breeijen JH, *et al.* Dietary antioxidants and risk of myocardial infarction in the elderly: the Rotterdam Study. *Am. J. Clin. Nutr.* 1999; **69**: 261–6.
5 Tucker KL, Chen H, Vogel S, Wilson PW, Schaefer EJ, Lammi-Keefe CJ. Carotenoid intakes, assessed by dietary questionnaire, are associated with plasma carotenoid concentrations in an elderly population. *J. Nutr.* 1999; **129**: 438–45.
6 Slattery ML, Boucher KM, Caan BJ, Potter JD, Ma KN. Eating patterns and risk of colon cancer. *Am. J. Epidemiol.* 1998; **148**: 4–16.
7 Kristal AR, Patterson RE, Neuhouser ML, *et al.* Olestra Postmarketing Surveillance Study: design and baseline results from the sentinel site. *J. Am. Diet. Assoc.* 1998; **98**: 1290–6.
8 US Department of Health and Human Services, Food and Drug Administration. Food additives permitted for direct addition to food for human consumption: olestra; final rule. In: *Federal Register, Part III, 21 CFR Part 172*, Vol. 61. US DHHS/FDA, 1996; 3118–73.
9 Weststrate JA, van het Hof KH. Sucrose polyester and plasma carotenoid concentrations in healthy subjects. *Am. J. Clin. Nutr.* 1995; **62**: 591–7.

10 Daher GC, Cooper DA, Peters JC. Physical or temporal separation of olestra and vitamins A, E, and D intake decreases the effect of olestra on the status of the vitamins in the pig. *J. Nutr.* 1997; **127**: S1566–72.
11 Cooper DA, Webb DR, Peters JC. Evaluation of the potential for olestra to affect the availability of dietary phytochemicals. *J. Nutr.* 1997; **127**: S1699–709.
12 Rock CL, Thornquist MD, Kristal AR, *et al.* Demographic, dietary and lifestyle factors differentially explain variability in serum carotenoids and fat-soluble vitamins: baseline results from the sentinel site of the Olestra Post-Marketing Surveillance Study. *J. Nutr.* 1999; **129**: 855–64.
13 Willett W. *Nutritional Epidemiology*, 2nd edn. New York: Oxford University Press, 1998.
14 Mangels AR, Holden JM, Beecher GR, Forman MR, Lanza E. Carotenoid content of fruits and vegetables: an evaluation of analytic data. *J. Am. Diet. Assoc.* 1993; **93**: 284–96.
15 Kristal AR, Patterson RE, Simmons NC, Shattuck AS, Beresford SAA. Precision and bias of food frequency questionnaire measures of fruit and vegetable intakes. *Eur. J. Clin. Nutr.* 1998; **52**: S46.
16 Kristal AR, Feng Z, Coates RJ, Oberman A, George V. Associations of race/ethnicity, education, and dietary intervention with the validity and reliability of food frequency questionnaire: the Women's Health Trial feasibility study in minority populations. *Am. J. Epidemiol.* 1997; **146**: 856–69.
17 Patterson RE, Kristal AR, Carter RA, Tinker LF, Bolton MP, Agurs-Collins T. Measurement characteristics of the Women's Health Initiative food frequency questionnaire. *Ann. Epidemiol.* 1999; **9**: 178–87.
18 Nestle M, Wing R, Birch L, *et al.* Behavioral and social influences on food choice. *Nutr. Rev.* 1998; **56**: S50–74.
19 Campbell DR, Gross MD, Martini MC, Grandits GA, Slavin JL, Potter JD. Plasma carotenoids as biomarkers of vegetable and fruit intake. *Cancer Epidemiol. Biomark. Prev.* 1994; **3**: 493–500.
20 McEligot AJ, Rock CL, Shanks TG, *et al.* Comparison of serum carotenoid responses between women consuming vegetable juice and women consuming raw or cooked vegetables. *Cancer Epidemiol. Biomark. Prev.* 1999; **8**: 227–31.
21 Thompson B, Shannon J, Beresford SAA, Jacobson PE, Ewings JA. Implementation aspects of the Seattle '5 a Day' intervention project: strategies to help employees make dietary changes. *Top. Clin. Nutr.* 1995; **11**: 58–75.
22 Neuhouser ML, Kristal AR, McLerran DL, Patterson RE, Atkinson J. Validity of short food frequency questionnaires used in cancer chemoprevention trials: results from the Prostate Cancer Prevention Trial. *Cancer Epidemiol. Biomark. Prev.* 1999; **8**: 721–5.