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Fruit and vegetable intakes in relation to plasma nutrient concentrations in women in Shanghai, China

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Abstract

Objective—To evaluate the validity of fruit and vegetable intake, using three classification schemes, as it relates to plasma carotenoid and vitamin C concentrations among Chinese women.

Design—Intakes were calculated from an interviewer-administered food frequency questionnaire. Fruits and vegetables, botanical groups, and high-nutrient groups were evaluated. These three classification schemes were compared with plasma carotenoid and vitamin C concentrations from blood drawn within one week of questionnaire completion.

Setting—Shanghai, China

Subjects—Participants (n=2031) were drawn from women who participated in a case-control study of diet and breast diseases nested within a randomized trial of breast self-examination among textile workers (n=266,064)

Results—Fruit intake was significantly ($p<0.05$) and positively associated with plasma concentrations of α-tocopherol, β-cryptoxanthin, lycopene, α-carotene, β-carotene, retinyl palmitate, and vitamin C. Fruit intake was inversely associated with γ-tocopherol and lutein +zeaxanthin concentrations. Vegetable consumption was significantly and positively associated with γ-tocopherol, and β-cryptoxanthin concentrations. Each botanical and high-nutrient group was also significantly associated with particular plasma nutrient concentrations. Fruit and vegetable intake and most plasma nutrient concentrations were significantly associated with season of interview.

Conclusions—These results suggest that the manner in which fruits and vegetables are grouped provides different plasma nutrient exposure information, which may be an important consideration when testing and generating hypotheses regarding disease risk in relation to diet. Interview season should be considered when evaluating associations of reported intake and plasma nutrients with disease outcomes.

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Keywords

fruit; vegetable; botanical; China

Introduction

Higher consumption of fruits and vegetables has been associated with lower risk of several diseases, including heart disease and several cancers[1–4]. Fruits and vegetables contain numerous phytochemicals that may reduce disease risk. High fruit and vegetable intake may also be a marker for an overall diet or for other lifestyle factors associated with reduced disease risk. Observations regarding disease risk in relation to broad and heterogeneous categories, such as “fruits” and “vegetables,” have direct implications for public health recommendations, such as “Two cups of fruit and 2 1/2 cups of vegetables per day are recommended for a reference 2,000-calorie intake” from the United States Department of Agriculture Dietary Guidelines for Americans 2005[5]. Evaluation of fruits and vegetables classified on their nutrient content, such as by particular vitamins or other phytochemicals, is useful for generating hypotheses regarding biological mechanisms of associations of fruit and vegetable intakes with disease risk.

Many studies regarding fruit and vegetable intake and disease risk have been conducted in Western populations and less is known about other population groups. Fruit and vegetable consumption amount and patterns may differ across populations. For example, fruit and vegetable intake in Southeast Asia is lower than that of Western populations[6]. Difference in amount or pattern of consumption may impact the validity and interpretation of dietary intake data.

Our primary objective was to evaluate the validity of fruit and vegetable intake obtained from a food frequency questionnaire (FFQ), by evaluating various classification schemes in relation to plasma carotenoid and vitamin C concentrations. Additional analyses were conducted to evaluate dietary intake and plasma concentrations in relation to season of interview and year of interview to evaluate potential bias that might be introduced by these variables.

Experimental Methods

Participants and Study Procedures

Participants (n=2031) were drawn from women who participated in a case-control study of diet and breast diseases nested within a randomized trial of breast self-examination among textile workers in Shanghai, China (n=266,064) (Figure 1)[7]. Figure 1 illustrates the selection of participants into the analysis for this study from the larger randomized trial. Recruitment into the trial took place between 1989 and 1991, and follow-up for breast diseases continued through July, 2000. Women born between 1925 and 1958 were eligible to participate in the trial (aged 30–64 years at enrollment). Further details regarding eligibility for the randomized trial and baseline data collection are published elsewhere[8]. Dietary data were collected from selected women in the cohort with benign or malignant breast disease diagnosed between September 1, 1995 and July 31, 2000, and from women without breast diseases who were randomly selected from the trial cohort as controls[9]. Controls were frequency-matched to cases on age. Case women were eligible for the case-control study of diet and breast diseases if they were diagnosed at one of the three hospitals serving the Shanghai Textile Industry Bureau (STIB). Non-fasting blood samples were collected for the analysis of several nutrients, including carotenoids and vitamin C. Attempts were made to schedule the diet interview and blood draw on or prior to the date of the scheduled breast

biopsy for women with benign or malignant breast disease. Women were excluded from the present analysis if their blood draw was completed and their FFQ was administered greater than one week apart or if plasma vitamin C or any of the plasma carotenoids were missing. The Institutional Review Boards at the Fred Hutchinson Cancer Research Center (FHCRC) and STIB approved the study, and informed consent by all subjects was obtained prior to their participation

Food Frequency Questionnaire and Classification of Food Groups

The FFQ consisted of 107 food items and was administered during an in-person interview. Women were asked "During most of your adult life how often did you usually eat…" for each of the FFQ food items. Women responded as number of times per day, week, month, or year, or they indicated that they have never consumed the item. Foods were classified using a three grouping system: traditional groups, botanical groups, and high-nutrient groups (containing foods high in the nutrient). Botanical groups were included because certain phytochemical may aggregate within botanical groups distinct from the high-nutrient groupings. Traditional groups were mutually exclusive, and consisted of fruits, vegetables, red meat, poultry, seafood, eggs, milk and milk products, soy foods, legumes excluding soy, and grains excluding corn. Fruits included were: apples, pears, oranges/tangerines, lychee, bananas, peaches, persimmon, pineapple, grapes, apricots, and watermelon. Vegetables included: salted mustard greens, other salted vegetables, bok choy, spinach, cabbage, Chinese cabbage, watercress, broccoli, Chinese broccoli, green asparagus, cauliflower, celery, eggplant, wild rice stem, winter squash, lettuce, yellow sweet potatoes or yams, other potatoes, wax gourd, gherkin, carrots, pumpkin, mushrooms, red or green pepper, tomato, bamboo shoots, radish/turnips, lotus rhizomes, taro root, corn, onions and chives, garlic stalk, and seaweed. Table 1 provides examples of foods included in each of botanical groups. Foods included in the botanical and high-nutrient groups are published in detail elsewhere[10]. High-nutrient groups were not mutually exclusive with respect to included foods, and included groups for alpha-carotene (carrots, pumpkin, string beans, winter squash), beta-carotene (apricots, bok choy, broccoli, carrots, Chinese broccoli, Chinese cabbage, persimmon, pumpkin, salted mustard greens, spinach, string beans, watercress, winter squash, yellow sweet potatos or yams), high beta-cryptoxanthin (corn, oranges/tangerines, persimmon, watermelon), high lutein+zeaxanthin (broccoli, Chinese broccoli, corn, hyacinth beans, salted mustard greens, seaweed, spinach, watercress), high lycopene (persimmon, tomato, watermelon), and high total carotenoids (apricots, bok choy, broccoli, carrots, Chinese broccoli, Chinese cabbage, persimmon, pumpkin, salted mustard greens, red or green peppers??, seaweed, spinach, tomato, watercress, watermelon, yellow sweat potatoes or yams). Botanical groups were mutually exclusive with respect to included foods, and included araliaceae (fresh ginseng, white ginseng powder or extract, red ginseng powder or extract), compositae (sunflower seeds, lettuce), convolvulaceae/dioscoreaceae (yellow sweet potatoes, yams), cruciferae (bok choy broccoli, cabbage, cabbage, cauliflower, Chinese broccoli, Chinese cabbage, radish or turnips, watercress), cucurbitaceae (gherkin, pumpkin, watermelon, wax gourd, winter squash), ebenaceae (persimmon), laminariaceae (seaweed), leguminosae (fresh fava beans, fried bean curd, fried bean curd puff, green or kidney beans, hyacinth beans, mung bean sprouts, mung beans, other dried beans, other soybean foods, pea or cow peas, peanuts, peanut butter, red pea or green bean groups, soybean milk, soybeans, string beans, szuki beans), liliaceae (asparagus, Chinese chives, chives, garlic, garlic stalk, onions, scallions), rosaceae (apples, apricots, peaches, pears), rutaceae (oranges, tangerines), sapindaceae (lychee), solanceae (eggplant, hot pepper, other potato, red or green pepper, tomato), umbelliferae (carrots, celery), vitaceae (grapes), and zingiberaceae (ginger root). Servings per week were calculated for each food group. The average serving size from the Chinese population was used to estimate a serving from the reported frequency for each food item. Each reported frequency was assigned the average

serving size for that food item. Average serving sizes were obtained from the 1992 China Health and Nutrition Survey[11].

Plasma Collection and Nutrient Analysis

Blood was collected into foil-covered EDTA 10-ml vacutainer and centrifuged within 45 minutes of collection or refrigerated and centrifuged within two hours of collection. The sample was centrifuged for 15 minutes at 1300 × *g*. Plasma was transferred into 2 ml cryovials and frozen at −20°C for 1 month or at −70°C for longer periods, until being shipped to Seattle. Specimens were shipped to Seattle on dry ice and immediately stored at −70°C.

Ascorbic acid concentrations measurements are described in detail elsewhere[12]. The intra-assay percent coefficients of variation (%CV) were 6.3 and 1.3 at 0.83 and 1.65 mg/dl. The inter-assay percent coefficients of variation were 8.1 and 5.0 at 0.78 and 1.65 mg/dl. The extraction of analytes from plasma, the quality control parameters, and the HPLC methods for measurements of plasma carotenoids and tocopherols were previously published[13, 14]. The HPLC method in this study included a profile of carotenoids, carotenes, retinols and tocopherols in a single HPLC run, and is described elsewhere[12]. The %CV for the pooled quality control samples for all analytes were 10% or less.

Statistical Methods

Means and standard deviations (SD) were calculated as summary statistics. Because distributions were not normally distributed, data were log-transformed prior to analyses for plasma concentrations of β-cryptoxanthin, lycopene, α-carotene, β-carotene, retinyl palmitate, and vitamin C. Exponentiations of the mean value of the log-transformed nutrient to obtain the geometric mean were performed for presentation of the data in the results. Dietary intake was divided into quartiles for analysis. Linear regression was also used to evaluate differences in mean plasma nutrient concentrations across quartiles of intake, adjusted for woman's age, case-control classification, season of interview, and year of interview. Quartile of intake was calculated using the median and 25th and 75th percentiles of each food grouping (Table 1) and included as a single categorical term in the linear regression models. Season was defined as four three-month categories (December-February, March-May, June-August, and September-November). Year of recruitment was divided into three categories: 1995–1996, 1997–1998, and 1999–2001. Case-control classification was divided into three groups: controls, women with benign breast disease, and women with breast cancer. In order to quantify the differences across seasons and year of interview, dietary intake and plasma nutrients were evaluated in relation to season of interview and year of interview using ANOVA and regression analyses, respectively, adjusted for woman's age, case-control classification, and, for dietary nutrients, also adjusted for total kilocalorie intake. Analyses using controls only were evaluated, and differences in overall interpretation of the results were unremarkable, so results for analyses of all participants are presented. A sampling of plots of predicted values vs. standardized residuals was evaluated for heteroscedasticity; plots were consistent with meeting the assumptions of homoscedasicity. Statistical significance was considered at $p<0.05$. Analyses were conducted using Stata 11.0 (Stata Corp, College Station, TX).

Results

Women reported consuming an average of approximately six servings of fruit and sixteen servings of vegetable per week (Table 1). Fresh vegetables contributed to the majority of vegetable intake. The correlation between fruit and vegetable intake was r=0.39. Cruciferae, cucurbitaceae, liliaceae, rosaceae, and solanaceae were the most frequently consumed fruit

and vegetable botanical groups. High β-carotene, total carotenoid, lycopene and β-cryptoxanthin foods were the most frequently consumed high-nutrient groups. Weekly servings of high β-carotene and high total carotenoid foods were highly correlated (r=0.91), so further analyses were conducted with high total carotenoid foods only. Although similar foods were in the high lycopene and high β-cryptoxanthin groups, weekly servings of these foods were not strongly correlated enough to be considered collinear (r=0.58).

Distribution of plasma nutrients is presented in Table 2. Wide variation in plasma concentrations of the nutrients was observed in the women.

Fruit intake was significantly and positively associated with plasma concentrations of α-tocopherol, β-cryptoxanthin, retinyl palmitate, lycopene, α-carotene, β-carotene, and vitamin C (Table 3). Inverse associations with γ-tocopherol and lutein+zeaxanthin with fruit intake were observed. Vegetable consumption was significantly and positively associated with γ-tocopherol and β-cryptoxanthin. Botanical and high-nutrient groups were associated with plasma nutrients in a manner distinct from association with the fruit and vegetable groups. Almost all of the groups were positively associated with vitamin C concentrations. Some groups, e.g. rosaceae, were associated with most nutrient concentrations, whereas other groups, e.g. solanceae, were associated with few nutrient concentrations.

Season and year of interview were significantly associated with diet and most plasma nutrients (Table 4). Women reported lower lifetime fruit consumption when interviewed during the summer and autumn months, and lower vegetable consumption when interviewed in the autumn months. Fruit and vegetable intakes and mean plasma concentrations of lutein +zeaxanthin, γ-tocopherol and β-cryptoxanthin decreased over the course of the study. To evaluate whether decreased fruit and vegetable consumption over time was balanced by increased consumption of other foods, we examined mean intake of other main food groups in relation to year of interview, adjusted for total kilocalories, case-control classification, season of interview and age at interview. Consumption of red meat (mean intake for 1995–96, 1997–98, 1999–2001 was 5.6 servings/wk, 5.3, and 4.8 servings/wk, respectively) and legumes excluding soy (3.5, 3.2, 2.9 servings/wk for the respective corresponding time periods) also decreased significantly in relation to year of interview ($p \leq 0.001$). Consumption of poultry (0.8, 1.0, 1.0, servings/wk), eggs (3.2, 3.2, 3.7 servings/wk), milk and milk products (3.2, 3.1, 4.1 servings/wk), and grains excluding corn (5.5, 5.2, 6.9 servings/wk) increased significantly ($p \leq 0.001$). No change in consumption of seafood (3.4, 3.3, 3.3 servings/wk) or soy foods (5.6, 5.2, 5.4 servings/wk) was observed ($p > 0.3$).

Discussion

Serum and plasma carotenoids and vitamin C are proposed biomarkers of fruit and vegetable intake[15–17]. Carotenoids are stored in the liver and blood concentrations provide a marker of long-term exposure, and blood concentration of vitamin C, which is not stored, serves as short-term marker of exposure[18]. In this study, we observed that fruit intake was associated with most plasma carotenoids and vitamin C. Inverse associations with γ-tocopherol and lutein+zeaxanthin with fruit intake were observed; it is not unremarkable that there was not positive associations because γ-tocopherol is found in high amounts in vegetable oils and lutein+zeaxanthin are found in eggs and corn, as well as green and yellow fruits and vegetables. However, the inverse association may have been observed by chance or may reflect a higher consumption of other foods, such as vegetables, that replaces fruit consumption. Vegetable intake was associated with two of the ten plasma nutrients evaluated, β-cryptoxanthin and γ-tocopherol. These observations suggest that the fruit group provides a broad classification of exposure to carotenoids and the vegetable group provides an index of exposure to select nutrients.

We observed that the high total carotenoid group was positively associated with plasma concentrations of α-carotene, β-cryptoxanthin, lutein+zeathanin, γ-tocopherol, and vitamin C. This pattern was distinct from the high lycopene and high β-cryptoxanthin food groups. Among other plasma nutrients, the high lycopene group was positively associated with plasma lycopene concentrations and the high β-cryptoxanthin group was positively associated with plasma β-cryptoxanthin concentrations. These observations suggest that the high total carotenoid group provides a valid assessment of several plasma carotenoids and that the specific carotenoid food groups adequately reflect their specific plasma nutrients. A strength of using these high-nutrient classifications is that, while they are a finer stratification than fruits and vegetables, there is adequate variation in intake. A limitation of using these classifications is that it may be more difficult to provide public health recommendations regarding consumption of high nutrient groupings compared to public health recommendations for increased consumption of fruits and vegetables in general.

Fruits and vegetables can be classified based on their botanical family groups, such as Cruciferae, or on their high specific phytochemical content, such as isoflavones in soy or glucosinolates in cruciferous vegetables. Evaluating associations of these groups and disease risk is useful for generating and evaluating hypotheses regarding risk associated with particular phytochemicals found in high amounts in these botanical families. We observed patterns of association, distinct from the other classifications, with plasma carotenoids for the five categories of botanical groups evaluated. In general, the patterns of association were consistent with what might be expected. For example, cruciferae was positively associated with β-carotene, lutein and zeaxanthin, γ-tocopherol, and vitamin C, and solanceae, which includes eggplant and peppers, was positively associated with lycopene and vitamin C. This observation suggests that these groups are useful for evaluating particular botanical families of interest. However, rosaceae (apples, pears, peaches, and apricots) was associated with most plasma nutrients, suggesting that this botanical family may be serving as a marker of consumption of other foods.

Season of interview was associated with fruit and vegetable intake and plasma nutrient concentrations. Consumption of overall and particular fruits and vegetables is usually seasonal, based on availability and pricing, so changes in plasma nutrients likely reflect changes in consumption. For example, plasma lycopene was higher in summer months and lutein+zeaxanthin was lower in autumn months, which may reflect seasonal changes in consumption of high lycopene foods (e.g. persimmon, tomato, watermelon) or high lutein +zeaxanthin foods (e.g. perishable greens). The FFQ queried participants about their usual intake of particular foods during their adult life. Association of season of interview with fruit and vegetable intake likely reflects a source of error in dietary exposure measurement, in which participants extrapolate current exposure to lifetime exposure. As a result, season of interview is associated with exposure (diet) and could introduce non-differential or differential bias, depending on the relationship of season of interview with outcome, when evaluating an exposure-outcome association[19].

Year of interview was also associated with fruit and vegetable intake and plasma nutrient concentrations. Plasma β-cryptoxanthin, γ-tocopherol and vitamin C were associated with vegetable intake. B-cryptoxanthin and γ-tocopherol, which are stored in the liver and reflect a longer period of exposure, were also inversely associated with year of interview, whereas vitamin C, which reflects a shorter exposure period, was not associated. Red meat and legume consumption also decreased over the course of the study, while poultry, milk and milk product, and grain consumption increased. Overall, these observations suggest that reported decreased fruit and vegetable intake may represent a real trend of changing consumption patterns. There are many possible reasons for a decrease in fruit and vegetable consumption with time, including increased urbanization, although this is not predicted to

have a remarkable influence in China's vegetable and fruit consumption[20], or changing availability and cost of fruits and vegetables in response to shifts in import and export practices during the 1999–2001 time period[21]. However, it is also possible the lower fruit and vegetable consumption in later years was observed by chance.

There are several potential limitations in this study. One limitation was that average serving size for the population was used to calculate dietary intake for all participants. Willett summarized results from several studies that indicate that individuals are relatively inaccurate in recalling portion sizes and that the majority of intake variability is from frequency of consumption rather than serving size[19]. Thus, not collecting serving size information likely reduced the intake values but did not markedly alter the overall ranking of individuals by intake. This would be expected to be a minor source of bias across quartiles of intake. However, if reduction in the variability in dietary intake did occur, this would represent a source of non-differential bias and would have reduced the ability to detect an association between dietary intake and plasma nutrient concentrations. In this circumstance, our results would be conservative. Because a single plasma sample was collected rather than multiple samples over time and that single plasma sample was compared with usual adult intake, we would expect decreased ability to detect an association. Overall, these sources of potential non-differential bias in our study suggest that the associations between plasma nutrients and dietary fruit and vegetable intakes we observed may be conservative.

Our primary objective was to evaluate the validity of fruit and vegetable intake obtained from a food frequency questionnaire (FFQ), by evaluating various classification schemes in relation to plasma carotenoid and vitamin C concentrations. From this evaluation, we observed several outcomes relevant to study design and analysis. First, various classifications of fruit and vegetable intake were associated with plasma carotenoids and vitamin C, suggesting that intake estimated from the FFQ provides a valid assessment of exposure. Second, fruit and vegetable, high-nutrient and botanical groups were distinctly associated with plasma nutrients. Third, season of interview should be considered as a potential confounder or cases and controls should be matched on season of interview. We also observed a significant decrease in that fruit and vegetable consumption over time in this population of Chinese women and, given positive associations of fruit and vegetable intakes with health, this should be evaluated in additional studies.

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Abbreviations

FFQ food frequency questionnaire

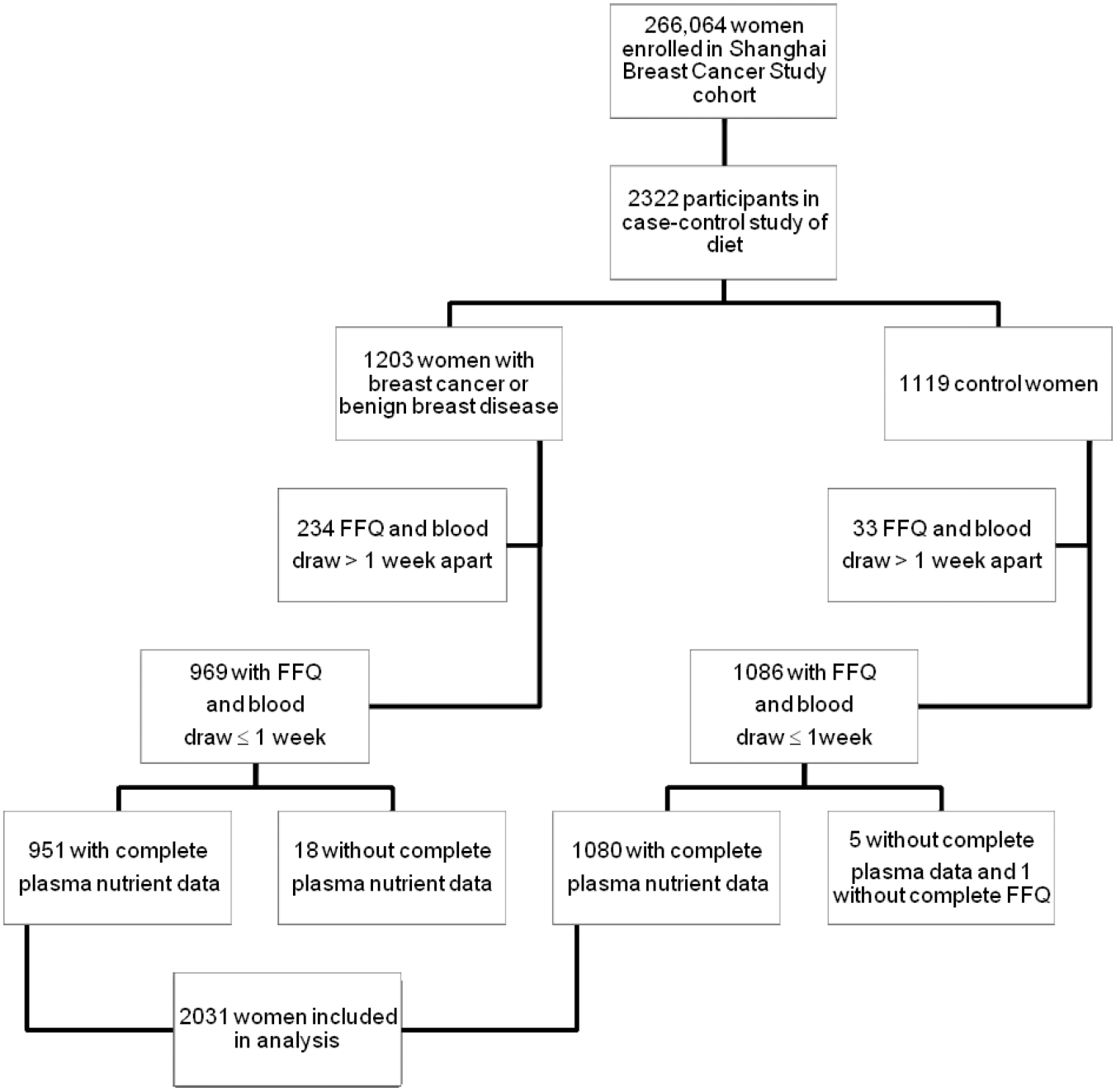

Figure 1.
Female Shanghai textile workers enrolled in a randomized trial of breast self-examination who participated in nested dietary study.

Table 1

Summary statistics for intake of fruits and vegetables in 2031 Chinese women in Shanghai, 1995–2001

Dietary intake (servings per week)	Mean	Standard deviation	Range	25th percentile	Median	75th percentile	Kurtosis	Skewness
Fruit[†]	6.4	3.7	0–60	3.8	5.7	8.2	2.43	25.8
Vegetables[§]	15.7	6.8	3–56	10.8	14.8	19.5	1.01	4.87
Unsalted vegetables	14.6	6.6	2–49	9.7	13.6	18.4	1.01	4.70
Salted and cured vegetables	1.4	2.2	0–18	0.3	0.6	2.0	2.32	9.66
Araceae (*e.g.* taro root)	0.1	0.4	0–7	0.06	0.1	0.3	7.27	122
Bromeliaceae (*e.g.* pineapple)	0.0	0.2	0–3	0.04	0.06	0.08	5.95	63.2
Chenopodiaeceae (*e.g.* spinach)	0.3	0.6	0–14	0.1	0.3	0.6	14.1	389
Compositae (*e.g.* lettuce)	0.8	1.3	0–8	0.2	0.4	1.1	3.05	13.7
Convolvulaceae/Dioscoreaeceae (*e.g.* yellow sweet potato)	0.0	0.2	0–4	0.02	0.06	0.08	8.29	122
Cruciferae (*e.g.* bok choy)	5.0	2.8	0–36	3.0	4.6	6.8	1.89	14.6
Cucurbitaceae (*e.g.* squash)	3.7	1.6	0–14	2.7	3.5	4.6	1.23	7.01
Ebenaceae (*e.g.* persimmon)	0.1	0.3	0–4	0.04	0.06	0.2	4.58	34.8
Graminae (*e.g.* bamboo shoots)	0.6	0.7	0–8	0.3	0.5	0.9	3.21	26.1
Laminariaeceae (*e.g.* seaweed)	0.2	0.4	0–4	0.04	0.2	0.3	3.76	25.3
Liliaceae (*e.g.* onions)	3.4	3.5	0–30	0.5	2.1	7.0	1.28	6.10
Musaceae (*e.g.* bananas)	0.7	1.0	0–7	0.2	0.5	1.2	3.24	18.0
Nymphaeaceae (*e.g.* lotus rhizomes)	0.0	0.2	0–2	0.04	0.08	0.1	5.05	52.2
Rosaceae (*e.g.* apples)	2.5	2.3	0–51	1.0	2.0	3.6	5.37	98.2
Rutaceae (*e.g.* oranges)	0.9	0.9	0–7	0.25	0.67	1.2	2.10	11.2
Sapindaceae (*e.g.* litchis)	0.0	0.2	0–2	0.04	0.06	0.08	6.73	69.0
Solanaceae (*e.g.* peppers)	2.7	1.9	0–23	1.5	2.3	3.4	2.32	14.6
Umbelliferae (*e.g.* celery)	0.6	0.9	0–9	0.3	0.4	0.8	4.37	33.9
Vitaceae (*e.g.* grapes)	0.3	0.6	0–4	0.08	0.2	0.6	2.43	10.1
High β-carotene	6.3	3.2	0–37	4.0	5.8	8.2	1.79	12.6
High lutein+zeathanin	1.3	1.1	0–18	0.67	1.0	1.6	4.36	46.6
High lycopene	2.9	1.3	0–21	2.2	2.8	3.6	2.44	26.9
High α-carotene	1.7	1.1	0–11	0.94	1.5	2.2	2.13	12.3
High β-cryptoxanthin	2.8	1.4	0–15	2.0	2.6	3.5	1.75	11.9

Dietary intake (servings per week)	Mean	Standard deviation	Range	25th percentile	Median	75th percentile	Kurtosis	Skewness
High total carotenoid	8.5	3.7	0–40	5.9	8.0	11	1.64	10.3

† Fruits included: apples, apricots, bananas, grapes, lychee, oranges or tangerines, peaches, pears, persimmon, pineapple, watermelon

§ Vegetables included: unsalted vegetables (asparagus, bok choy, broccoli, cabbage, Chinese broccoli, Chinese cabbage, spinach, watercress) and salted and cured vegetables (fermented bean curd, salted mustard greens, other salted vegetables)

Table 2

Summary statistics for plasma nutrient concentrations in 2031 Chinese women in Shanghai, 1995–2001

Plasma nutrient concentrations	Mean	Standard deviation	Range	Kurtosis	Skewness
β-carotene (μg/dl)	31.8	21.9	3.00–399	71.6	5.64
α-carotene (μg/dl)	2.62	2.06	0.60–42.9	121	8.48
Lycopene (μg/dl)	7.40	7.20	0.80–78.1	11.7	2.42
β-cryptoxanthin (μg/dl)	14.0	14.1	1.40–160	2.95	0.02
Lutein+zeaxanthin (μg/dl)	37.0	16.5	7.90–184	11.1	1.91
Retinol (μg/dl)	41.5	11.2	6.70–107	5.36	0.96
Retinyl palmitate (μg/dl)	3.60	2.78	0.40–85.5	414	16.5
α-tocopherol (μg/ml)	9.28	3.12	0.10–35.8	12.3	2.34
γ-tocopherol (μg/ml)	2.14	0.99	0.30–9.35	8.05	1.91
Vitamin C (μg/ml)	8.12	8.37	<LOQ[†]–12.1	68.8	6.61

[†]LOQ: limit of quantitation

Table 3

Mean[†] plasma nutrient in 2031 Chinese women in Shanghai, 1995–2001, in relation to quartiles of fruit and vegetable intake, adjusted for age at interview, year and season of interview and case-control classification.

Food groups in servings per week	β-carotene (μg/dl)	α-carotene (μg/dl)	Lycopene (μg/dl)	β-cryptoxanthin (μg/dl)	Lutein + zeaxanthin (μg/ml)	Retinol (μg/dl)	Retinyl palmitate (μg/dl)	α-tocopherol (μg/ml)	γ-tocopherol (μg/ml)	Vitamin C (μg/ml)
Fruit										
Q1	25.8	2.12	4.88	8.34	37.9	40.9	3.20	9.04	2.20	7.65
Q2	26.7	2.23	5.13	9.33	37.3	41.3	3.25	9.20	2.16	8.03
Q3	27.7	2.35	5.40	10.4	36.7	41.7	3.31	9.36	2.12	8.40
Q4	28.7	2.47	5.68	11.7	36.0	42.1	3.36	9.53	2.08	8.81
p-trend	0.002	<0.001	<0.001	<0.001	0.049	0.084	0.034	0.009	0.037	<0.001
Vegetables										
Q1	27.1	2.26	5.20	9.44	36.8	41.1	3.31	9.20	2.08	7.97
Q2	27.2	2.28	5.24	9.72	36.9	41.4	3.29	9.26	2.12	8.13
Q3	27.3	2.30	5.29	10.0	37.0	41.6	3.27	9.31	2.16	8.30
Q4	27.3	2.33	5.33	10.3	37.1	41.9	3.24	9.37	2.20	8.47
p-trend	0.790	0.255	0.520	0.046	0.724	0.216	0.371	0.360	0.039	0.091
Cruciferae										
Q1	25.8	2.26	5.40	9.51	35.5	41.6	3.22	9.19	2.06	7.58
Q2	26.7	2.28	5.31	9.74	36.5	41.5	3.26	9.25	2.12	7.99
Q3	27.7	2.30	5.22	9.98	37.5	41.5	3.29	9.31	2.17	8.44
Q4	28.7	2.33	5.12	10.2	38.4	41.5	3.33	9.38	2.21	8.91
p-trend	0.001	0.260	0.178	0.098	0.003	0.903	0.156	0.312	0.012	<0.001
Cucurbitaceae										
Q1	25.9	2.22	5.10	9.23	36.9	41.1	3.26	9.13	2.16	7.57
Q2	26.8	2.27	5.21	9.65	37.0	41.4	3.27	9.23	2.15	7.99
Q3	27.7	2.32	5.32	10.1	37.0	41.7	3.28	9.34	2.14	8.44
Q4	28.6	2.36	5.43	10.5	37.0	42.0	3.30	9.44	2.13	8.92
p-trend	0.003	0.036	0.111	0.003	0.965	0.165	0.616	0.093	0.595	<0.001
Liliaceae										
Q1	28.1	2.32	5.19	10.3	38.3	40.8	3.32	9.29	2.06	8.50
Q2	27.5	2.30	5.24	10.0	37.4	41.3	3.29	9.29	2.11	8.31

Food groups in servings per week	β-carotene (μg/dl)	α-carotene (μg/dl)	Lycopene (μg/dl)	β-cryptoxanthin (μg/dl)	Lutein + zeaxanthin (μg/ml)	Retinol (μg/dl)	Retinyl palmitate (μg/dl)	α-tocopherol (μg/ml)	γ-tocopherol (μg/ml)	Vitamin C (μg/ml)
Q3	26.9	2.28	5.29	9.72	36.5	41.8	3.26	9.28	2.17	8.11
Q4	26.4	2.27	5.34	9.45	35.6	42.2	3.23	9.27	2.23	7.93
p-trend	0.080	0.486	0.453	0.066	0.005	0.035	0.282	0.913	0.005	0.065
Rosaceae										
Q1	25.8	2.21	5.00	8.78	37.4	41.1	3.20	9.13	2.20	7.73
Q2	26.7	2.26	5.18	9.49	37.1	41.4	3.25	9.23	2.16	8.05
Q3	27.7	2.32	5.35	10.3	36.8	41.6	3.30	9.34	2.12	8.39
Q4	28.8	2.37	5.54	11.1	36.6	41.9	3.36	9.44	2.0	8.74
p-trend	0.001	0.013	0.008	<0.001	0.382	0.247	0.038	0.086	0.044	0.001
Solanaceae										
Q1	27.2	2.26	5.06	9.48	36.9	41.6	3.31	9.34	2.11	7.92
Q2	27.2	2.28	5.20	9.73	37.0	41.6	3.29	9.30	2.13	8.11
Q3	27.2	2.30	5.33	10.0	37.0	41.5	3.27	9.26	2.15	8.32
Q4	27.2	2.33	5.48	10.3	37.0	41.4	3.24	9.23	2.17	8.52
p-trend	0.980	0.280	0.042	0.072	0.962	0.704	0.378	0.516	0.334	0.043
High-total carotenoid fruits and vegetables										
Q1	26.4	2.22	5.34	9.38	36.0	41.4	3.26	9.20	2.07	7.65
Q2	27.0	2.27	5.29	9.70	36.6	41.5	3.27	9.26	2.12	8.02
Q3	27.5	2.32	5.24	10.0	37.3	41.5	3.28	9.31	2.16	8.41
Q4	28.1	2.36	5.20	10.4	38.0	41.6	3.29	9.37	2.21	8.83
p-trend	0.072	0.035	0.491	0.025	0.038	0.738	0.636	0.365	0.016	<0.001
High-lycopene fruits and vegetables										
Q1	26.5	21.6	4.91	8.93	37.8	41.3	3.29	9.14	2.12	7.65
Q2	27.0	2.25	5.14	9.54	37.2	41.4	3.28	9.24	2.13	8.02
Q3	27.5	2.34	5.38	10.2	36.7	41.6	3.27	9.33	2.15	8.41
Q4	27.9	2.43	5.64	10.9	36.1	41.7	3.26	9.43	2.16	8.82
p-trend	0.136	<0.001	<0.001	<0.001	0.088	0.473	0.719	0.119	0.520	<0.001
High-β-cryptoxanthin fruits and vegetables										
Q1	26.9	2.15	4.77	7.81	39.0	41.1	3.23	9.08	2.17	7.76

Food groups in servings per week	β-carotene (μg/dl)	α-carotene (μg/dl)	Lycopene (μg/dl)	β-cryptoxanthin (μg/dl)	Lutein + zeaxanthin (μg/ml)	Retinol (μg/dl)	Retinyl palmitate (μg/dl)	α-tocopherol (μg/ml)	γ-tocopherol (μg/ml)	Vitamin C (μg/ml)
Q2	27.1	2.24	5.06	9.00	37.8	41.3	3.26	9.20	2.15	8.03
Q3	27.3	2.32	5.37	10.4	36.5	41.6	3.29	9.33	2.14	8.31
Q4	27.5	2.41	5.70	11.9	35.2	41.9	3.31	9.45	2.12	8.60
p-trend	0.580	<0.001	<0.001	<0.001	0.001	0.248	0.336	0.065	0.461	0.013

†Geometric means for β-cryptoxanthin, lycopene, α-carotene, β-carotene, retinyl palmitate, vitamin C

Table 4

Mean[†] of weekly fruit and vegetable intake and of plasma nutrients in 2031 Chinese women in Shanghai, 1995–2001, in relation to season and to year of interview, adjusted for age at interview, case-control classification, and for fruit and vegetable groups, total kilocalorie intake.

	Season of Interview[§]					Year of Interview			
	Winter (n=601)	Spring (n=600)	Summer (n=373)	Autumn (n=457)	p-value[//]	1995, 1996 (n=442)	1997, 1998 (n=494)	1999, 2000, 2001 (n=1095)	p-trend[¶]
Intake (servings per week)									
Fruit	6.4	6.7	6.0	6.2	<0.001	7.5	7.2	5.5	<0.001
Vegetables	16	16	16	15	0.003	18	17	14	<0.001
Plasma concentrations									
β-carotene (μg/dl)	31.0	31.1	31.2	28.9	0.132	31.9	28.3	31.1	0.562
α-carotene (μg/dl)	2.76	2.33	2.36	2.99	<0.001	2.61	2.58	2.62	0.934
Lycopene (μg/dl)	8.97	13.2	26.6	13.3	<0.001	14.4	14.6	14.1	0.542
β-cryptoxanthin (μg/dl)	19.2	13.4	6.39	11.2	<0.001	14.3	15.6	11.8	<0.001
Lutein+zeaxanthin (μg/dl)	38.9	40.8	35.5	30.6	<0.001	41.5	37.0	35.2	<0.001
Retinol (μg/dl)	40.7	41.4	41.6	42.6	0.044	40.3	42.1	41.7	0.042
Retinyl palmitate (μg/dl)	3.55	3.53	3.75	3.50	0.433	3.70	3.53	3.53	0.306
α-tocopherol (μg/ml)	9.35	9.17	9.05	9.54	0.081	9.18	9.04	9.44	0.162
γ-tocopherol (μg/ml)	2.14	2.19	2.17	2.06	0.188	2.22	2.18	2.09	0.037
Vitamin C (μg/ml)	7.92	7.41	6.68	6.19	<0.001	7.56	5.90	7.56	0.902

[†]Geometric means for β-cryptoxanthin, lycopene, α-carotene, β-carotene, retinyl palmitate, vitamin C

[§]Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Autumn: September, October, November

[//]p-value for difference between categories calculated from ANOVA

[¶]p-value for linear trend across categories calculated from linear regression