Austin Journal of Nutrition & Metabolism

Open Access

Austin Publishing Group

Research Article

Validity and Reliability of Semi-Quantitative eFFQ for Hong Kong Chinese Pregnant Women

Ka Man Yip[1], Matthew Kwan Kit Fung[1], Calvin Ka Man Cheung[2], Albert Lee[3], Hung Kwan So[1], Wilfred Hing Sang Wong[1], Ruth Suk Mei Chan[4]* and Patrick Ip[1]*

[1]Department of Paediatrics and Adolescent Medicine, The University of Hong Kong, Hong Kong

[2]Centre for Health Education and Health Promotion, The Chinese University of Hong Kong, Hong Kong

[3]JC School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong

[4]Department of Applied Biology and Chemical Technology, The Hong Kong Polytechnic University

***Corresponding author:** Ruth Chan Mei Chan, Y860, Department of Applied Biology and Chemical Technology, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

Dr. Patrick Ip, Department of Paediatrics and Adolescent Medicine, LKS Faculty of Medicine, The University of Hong Kong, Hong Kong

Received: June 30, 2020; **Accepted:** July 23, 2020; **Published:** July 30, 2020

Abstract

Background: Pregnancy is an important period for delivering nutrition to the fetus and thus maternal diet remains one of the essential factors in determining the potentials of the newborn. Food Frequency Questionnaire (FFQ) is a classical tool for dietary assessment at the population scale. Instead of printed forms, several electronic FFQs (eFFQ) are being used as a cost-effective tool for data collection in large scale studies in Western countries. The present study aims to examine the validity and the reliability of an eFFQ developed for pregnant women in Hong Kong.

Methods: The previously validated version of printed FFQ among Chinese population in Hong Kong was first compared against 3-day food record in the validation phase, and was later tested against eFFQ in the reliability phase. Intra-Class Correlations (ICC) between two assessment tools were calculated. The level of agreement was evaluated using Bland-Altman method and cross-classification into quartiles of daily intakes.

Results: The mean percentages of participants being classified in the same or adjacent quantiles were 71.4% for nutrients and 72.4% for food groups in validation test, and 76.2% for nutrients and 69.6% for food groups in reliability test. Bias in Bland-Altman plots was found to be mild in higher or lower intakes in both nutrients and food groups.

Conclusions: Both cross-classification and Bland-Altman methods suggest satisfactory agreement of the eFFQ with the validated paper FFQ. It is shown to be a reliable tool to measure dietary intake of Chinese pregnant women in Hong Kong.

Keywords: Food Frequency Questionnaire; Validation; Pregnant Women

Introduction

The fetal origins of adult disease hypothesis, developed by David Barker, proposes that fetal nutrition and endocrine status affect one's developmental adaptations, leading to permanent changes in metabolism, physiology and structure, including birthweight, length, body proportions and placental weight, and hence resulting in metabolic, cardiovascular and endocrine diseases in later life [1-3].

"Programming" refers to the process in which an early stimulus or insult, during a critical or sensitive period, results in lifelong or long-term effects [4,5]. The first 1000 days of life, defined as the time starting from the initial conception up to the second year of the newborn, describes the crucial period which the establishment of optimum health and development for a human occurs [6-8]. Maternal nutrition programs during this important period have long-time impacts on the fetus [9-13]. Hence, the assessment of diet and nutrient intakes of pregnant women unquestionably becomes one of the important aspects when considering human health as it may provide insights on how maternal nutrition could possibly impact the potentials of one's life.

To capture information regarding diet and nutrient intakes, food records and multiple 24-hour (hr) recalls are usually employed as they provide relatively accurate and detailed diet information. However, these methods are considered labor intensive due to their time-consuming administration, less feasibility and difficulties in analysis in epidemiological studies [14,15]. In contrast, Food Frequency Questionnaire (FFQ) is alternative dietary assessment tool available to examine diet and nutrient intake and has been demonstrated to be a useful and valid method for ranking intakes in relative terms at the population scale at relatively low costs [16-18].

With the development of technology and the rapid raise of the use of internet, online intervention has pushed the potential of FFQ to a higher ground because of its cost effectiveness, wider reach and possibility of the delivery of tailor-made dietary advice according to individual eating behavior [19-23]. Electronic FFQ (eFFQ) starts to emerge in different countries due to its great capacity to generate ample dietary data from the pool automatically [24-26]. By displacing the need to manually transfer written data in the conventional print FFQ to a computerized format, electronic version provides a more secure and efficient way for data processing [27].

However, most eFFQs developed up to date are not suitable for Chinese population due to ethnical difference in eating behaviours and food choices. Development of the existing print form of FFQ for the Hong Kong Chinese was built on extensive research regarding the food list, frequency response, portion size, and administration which is validated and suitable for large scale epidemiologic studies

Citation: Yip KM, Kit Fung MK, Man Cheung CK, Lee A, So HK, Sang Wong WH, et al. Validity and Reliability of Semi-Quantitative eFFQ for Hong Kong Chinese Pregnant Women. Austin J Nutr Metab. 2020; 7(5): 1093.

in Chinese population and thus allowing us to study the diet-disease relationship [28,29]. There has been however a lack of an online version of FFQ for Chinese population. Therefore, the aims of this study were to examine the validity of the FFQ targeting Hong Kong Chinese pregnant women and the reliability of the newly developed electronic version by comparing the estimates of intake in eFFQ and FFQ.

Materials and Methods

Study design and data collection

This study is a part of a project examining the vitamin D status of Chinese pregnant women in Hong Kong (IRB Reference Number is UW 13-055). The present study was divided into two phases, in which the printed form of the FFQ was first adapted and validated in Phase I and the reliability of the eFFQ was assessed against the FFQ in Phase II. Exclusion criteria included (1) pregnant women with chronic medical conditions, (2) pregnant women with multiple pregnancy, metabolic bone disease, calcium disorder, taking medications known to affect plasma 25-hydroxyvitamin D levels or those were treated with vitamin D supplementation within 6 months of the current pregnancy, and (3) non-Chinese subjects. From April to July 2019, pregnant women in their third trimester were recruited in the antenatal clinic of Queen Mary Hospital, a tertiary teaching hospital for both phases. All participants were invited to complete a demographic questionnaire, which collected information on age, height, pre-pregnant weight, education level, occupation, family income, marital status as well as pregnancy status, namely, gravidity and parity. Ethics approval was obtained from the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster. Written informed consent was obtained from each participating pregnant woman at the recruitment site.

Phase I: Validation of the newly developed printed form of FFQ for pregnant women against 3-day food record (3d-FR)

Development of the printed form of FFQ for pregnant women

The printed form of FFQ for pregnant women was modified and developed based on a previous validated FFQ for the general adult population [28]. Participants were guided face-to-face to report their food intake over the past month using FFQ on site. A total of 311 food items were categorized into twelve food groups, namely fishes and seafood, mushrooms, eggs, dairy beverages, beans, fruits, grains, meats, snacks, soups, vegetables and condiments and oil. Frequency options include once a month, 2-3 times per month, once to twice a week, 3-4 times per week, 5-6 times per week, and every day. Portion size was reported freely either using standardized household measurements or gram weight of food items directly. Household measurement tools like standardized bowls, plates and cups were available for reference when determining portion size. Booklet with selected pre-weighed food items was also provided to improve accuracy of portion size estimation.

Validation of the newly developed printed FFQ against 3-day food record

Three-day food record (3d-FR) was obtained from the participants in the antenatal clinic. Participants were instructed by trained research staff to record their diets for 2 weekdays and 1 weekend day in a non-consecutive manner. They were reminded to select typical days that could most resemble their usual intake and avoid festivals or days when they were unwell. To educate the participants and for the purpose of demonstration of filling in the food record, the first day of the 3d-FR was completed as 24Hr recall using multiple pass method on the spot by trained staff during the interview. The second and third day of 3d-FR were completed by the subjects themselves. Completed food records for the remaining two days were mailed back to the study site and checked by research staff for any misinformation.

Phase II: Reliability of the newly developed eFFQ

Development of the eFFQ from the printed form of the FFQ

An electronic version of the semi-quantitative FFQ (eFFQ) was developed with interface similar to the original FFQ where the food groups and frequency options provided were identical. Standardized portion was provided on eFFQ as reference serving for each food item. Participants reported their average food consumption in the past month using fraction or multiples of the reference serving (i.e. one reference serving of full fat milk is 250ml, and serving size options range from 0.5 to 5). After filling in printed form of FFQ in the antenatal clinic, participants received individual login name and password for access to the eFFQ platform to complete the eFFQ within one month. Participants could fill in the eFFQ on all common electronic devices (e.g. laptop, mobile phone). They could temporarily save the initial input and continue to fill in the remaining parts at their convenience. Unfinished eFFQ was checked regularly and reminder phone calls were given to the participants by research staff.

Dietary data analysis and statistical analysis

Mean daily intake of nutrients from printed form of FFQ, 3d-FR and eFFQ were calculated using Nutrition Analysis and Fitness software Food Processor (Version 11.6.1, ESHA Research, US) based on USDA food composition table [30] and food composition tables with traditional Chinese and local Hong Kong foods. Energy intake below 500 kcal/d were excluded.

Mean, SD, median and interquartile range of nutrient intakes were computed from 3d-FR, FFQ and eFFQ. Intra-Class Coefficient (ICC) was calculated to assess the reliability and Bland-Altman method was used to evaluate the agreement of food groups and nutrient intakes [31] between various dietary assessment methods graphically. Log-transformed nutrient values were used to calculate the Limit of Agreement (LOA), which obtained by overlaying the plot of difference of 3d-FR and FFQ *versus* mean. Instead of reviewing whether the agreement is sufficient for the tools to be used, Bland-Altman plot function as a simple visual method to quantify the bias and the range of the agreement between the mean differences of the two measuring tools wished to be compared and only priori criteria based on biological or clinical significance could deduce if the resulting agreement is appropriate [32]. Cross classification by quantiles were used to compute the number of subjects classified into same, adjacent, disagree and extreme groups. All analyses were performed using environment R (R Development Core Team 2018). A p-value <0.5 was considered to be statistically significant.

Results

Baseline characteristics of the study population

A total of 80 and 63 participants were recruited in Phase I and

Table 1: Demographic characteristics of participants.

	Phase I (n=80)		Phase II (n=63)	
	Mean	SD	Mean	SD
Age, year	34.7	4.3	34.2	4.2
Height, cm	160.2	5.5	161.3	5.2
Pre-pregnant weight, kg	56.4	9.3	55.6	9.1
Pre-pregnant BMI	21.7	4.3	21.3	3.1
Pregnancy status				
Gravidity				
One, %	61.8		65.6	
Two, %	32.9		29.5	
Three, %	5.3		4.9	
Parity				
Zero, %	54.8		60	
One, %	42.5		38.3	
Two, %	2.7		1.7	
Education				
Primary education, %	0		0	
Lower secondary education, %	1.3		0	
Upper secondary education, %	9.3		11.7	
Higher certificate or diploma, %	14.7		15	
Bachelor's degree, %	45.3		43.3	
Postgraduate degree, %	29.3		30	
Occupation				
Full-time employed, %	79.7		78.2	
Part-time employed, %	4.3		1.8	
Housewife, %	8.7		10.9	
Student, %	1.4		1.8	
Unemployed, %	4.3		5.5	
Retried, %	0		0	
Others, %	1.4		1.8	
Family income				
< $7,999, %	1.3		0	
$8,000- $29,999, %	26.3		31.7	
$30,000- $79,999, %	40		38.1	
>$80,000, %	22.5		22.2	
Preferred not to tell, %	10		7.9	

Phase II respectively. Participants in both phases showed similar demographic characteristics (Table 1). Participants in Phase I and Phase II had a mean age of 34.7 (SD 4.3) and 34.2 (SD 4.2) years and mean pre-pregnant BMI of 21.7 (SD 4.3) and 21.3 (SD3.1) kg/m^2 respectively. Nearly 75% of the participants in both phases received tertiary education or above and the majority (80%) of them were currently full-time employed. Over 60% of the participants reported to have a monthly family income higher than HKD 30,000 (~3871USD). For pregnancy status, around two-third of the participants of both phases had been pregnant at least once; while 54.8% in Phase I and 60.0% in Phase II has never been in labour before.

Phase I: Comparison of estimated intake using printed form of FFQ against 3d-FR

Results of the agreement of estimated daily intake of nutrients and food groups between FFQ and 3d-FR were shown in Table 2. ICC ranged from 0.02 for manganese to 0.46 for total fibre in nutrient groups, and from 0.02 for grains to 0.08 for fruit groups. Classifications of nutrient and food groups into quartiles of intake for the two methods are also shown. Overall, 31% of the pregnant women were classified in the same quartile for nutrients (ranging from 22.5% for polyunsaturated fats and folate, to 43.8% for copper and iodine) and 27% for core food groups (ranging from 24.8% for meat and alternatives to 29.1 for dairy and alternatives).

The Bland-Altman plots for the estimate of nutrients reveal an obvious trend of overestimation or underestimation with increasing intake. Regression coefficients were positive for energy and protein, and negative for vitamin D and folate. An average of 5.38% individual differences of energy and macronutrients, and 5.21% of minerals and vitamins were beyond the 95% LOA (Figure 1). Spearman correlation coefficients were positive for all nutrients which were found to be significant for energy, protein, fat, vitamin D and vitamin B12.

Phase II: Comparison of estimated intake using eFFQ against printed form of FFQ

Table 3 shows the estimated daily intake of nutrients and food groups using eFFQ and FFQ in terms of mean, standard deviation, median, interquartile range and intraclass correlation, as well as the cross-classification of the intake between the two methods. ICC

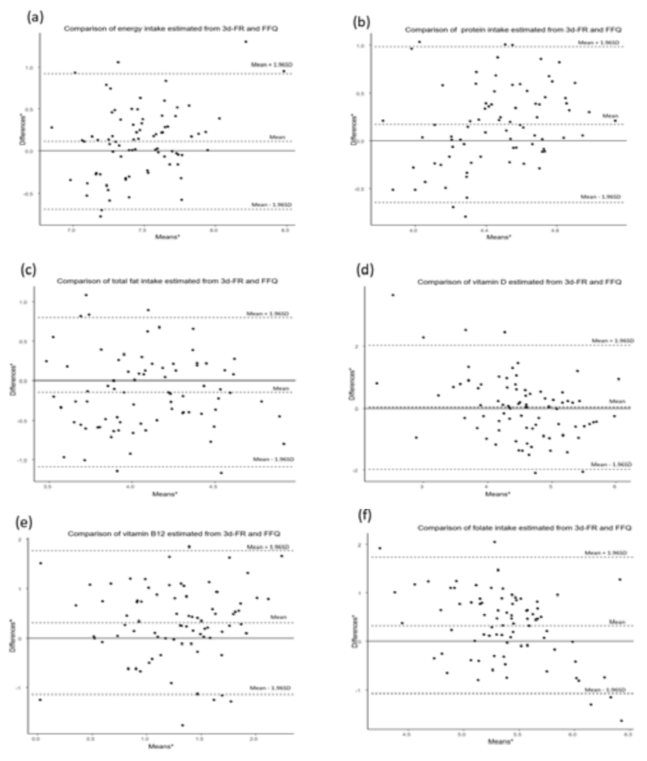

Figure 1: Bland and Altman plots comparisons of nutrients in Phase I (n=80).
*Nutrients data are log-transformed.
(a) energy, (b) protein, (c) total fat, (d) vitamin D, (e) vitamin B12, (f) folate

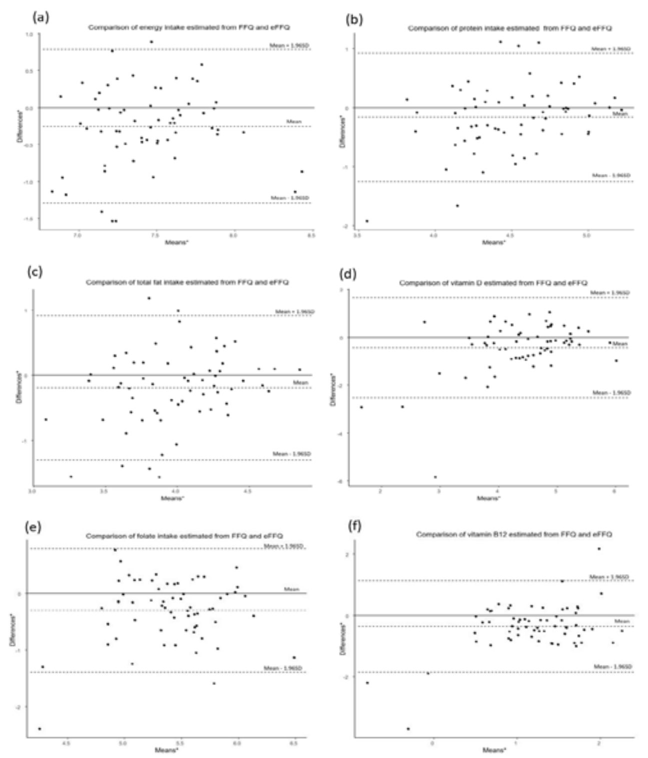

Figure 2: Bland and Altman plots comparisons of nutrients in Phase II (n=62).
*Nutrients data are log-transformed.
(a) energy, (b) protein, (c) total fat, (d) vitamin D, (e) vitamin B12, (f) folate

ranged from 0.01 for added sugar to 0.58 for vitamin C in nutrient groups, and from 0.01 for vegetables to 0.12 for dairy and alternatives. Classifications of nutrient and food groups into quartiles of intake for the two methods are also shown. Overall, 35% of the pregnant women were classified in the same quartile for nutrients (ranging from 22.2% for carbohydrate, to 50.8% for vitamin D) and 25% for core food groups (ranging from 24.3% for vegetables to 27.0% for fruit).

The Bland-Altman plots for the estimate of nutrients of FFQ and eFFQ shows an obvious trend with increasing intake. Regression coefficients were positive for almost nutrients, except added sugar. An average of 6.83% individual differences of energy and macronutrients, and 5.80% of minerals and vitamins were beyond the 95% LOA (Figure 2). Spearman correlation coefficients were positive for all nutrients.

Discussion

The main purpose of the study was to develop a reliable eFFQ for use in future nutritional studies among Chinese pregnant women. Satisfactory agreements and correlations were observed in both the validity of the adapted FFQ and the reliability of eFFQ as a replacement of its print form. We had successfully provided evidence in the suitability in its application on future pregnant women-nutritional projects in the Chinese population.

Validation of FFQ usually involves comparison with a reference instrument which the latter has less systematic bias than the measuring instrument being validated. In this study, we have chosen a 3 day food record as it is considered to be relatively less burdensome to the participants compared to other methods such as weighed diet records or multiple 24Hrs recalls. While an increase in the number of days for food record could lead to a higher accuracy in capturing real individual average intake, the use of 3 days was suggested to show similar estimation with 7 days for diet records [33]. In the present study, there is a tendency of overestimation in intake by FFQ compared to 3d-FR, which is a phenomenon commonly observed in the literature [34,35]. Better to state which parameters were overestimate by FFQ *vs* 3d-FR in your study, and quote some similar findings in previous studies. Possible cause include inaccurate estimation of self-intake due to biased memory when given a comprehensive food list with multiple options. This systematic difference is suggested not to be an issue in epidemiological studies if the ranking of individuals according to the intake is valid [36].

Cross-classification is a common method to examine agreements. By sorting subjects into quantiles or quintiles, participants with same agreement level are classified into the same groups, and thus the percentage in particular groups between the two tools can be compared. In our study, the median percentages of participants being classified in the same or adjacent quantiles for nutrients and food groups in validation phase are 71.4% and 72.4%, and that in reliability phase are 76.2% and 69.6% respectively. These results were comparable to findings in Asian and Western pregnant women studies where nutrients have around 70% and food groups were shown to have 67% to 75% in the same or adjacent quantiles [37,38]. In fact, if selecting only nutrients of interest during pregnancy such as energy, protein, total fat, folate, vitamin B12 and D, the percentages classified in same or adjacent quantiles will raise to 72.7% and 78.9% in the two phases, which the results demonstrates further on its suitability in the pregnant women population.

On the other hand, Bland-Altman plot, instead of reviewing whether the agreement is sufficient for the tools to be used, functions as a simple visual method to quantify the bias and the range of the agreement between the mean differences of the two measuring tools wished to be compared and only priori criteria based on biological or clinical significance could deduce if the resulting agreement is appropriate [39]. FIn our present study several underestimations or overestimations appear in energy and nutrient estimation with increasing intake, which is also commonly seen in FFQ validation studies [40,41]. We consider such biases to be reasonable and acceptable and in fact our agreement intervals in the validation phase is comparable to a similar study in rural China which the FFQ targeting pregnant women was validated using six 24 Hr recalls [41].

While correlation is one of the commonly used method in validation studies, its use to assess agreement remains debatable [42]. Regardless, ICC was tested in an attempt to compare the results with other studies in the literature. Statistically significant ICC in validation phase ranged from 0.19 for iodine to 0.46 for total fibre and that in reliability phase ranged 0.22 for Cobalamins (B12) to 0.58 for Vitamin C. As a rule of thumb, a reasonable correlation requires the coefficient to be 0.3 to 0.49, and a good correlation to be 0.5 or higher [43]. Nearly half of the nutrients presented in our study reach the criteria of reasonable or good correlation in the reliability in form of online version FFQ.

We acknowledged a few limitations in our study. Our sample

Table 2: Agreement of estimated daily intake of nutrients and food groups between FFQ and 3d-FR.

	FFQ		3D-FR		Mean Difference (FFQ - 3D-FR)		ICC	Cross-classification		
	Mean	SD	Mean	SD	Mean	%		Same (%)	Same or adjacent (%)	Extreme (%)
Energy and Nutrients										
Energy, kcal	2031.54	1058.95	1727.93	495.02	303.6	22.31	0.29**	32.5	73.8	3.8
Protein, g	101.48	37.86	83	23.29	18.48	28.9	0.31**	30	72.5	5
Total fat, g	60.31	23.59	70.38	32.05	-10.07	-2.58	0.37**	30	76.2	3.8
Cholesterol, mg	435.26	199.61	409.47	136.32	25.78	17.35	0.12	25	70	8.8
Saturated fat, g	17.58	7.19	21.04	12.47	-3.45	-1.58	0.32**	37.5	80	6.2
Monounsaturated fat, g	18.87	8.19	19.31	10	-0.44	14.45	0.27**	27.5	72.5	6.2
Polyunsaturated fat, g	10.56	4.24	11.97	10.99	-1.41	24.21	0.13	22.5	70	5
Carbohydrate, g	275.04	210.54	192.47	67.23	82.57	56.39	0.08	28.7	72.5	7.5
Added sugar, g	34.59	190.44	2.06	8.02	32.53	174.23	0	25	63.7	7.5
Total fibre, g	16.43	6.3	13.08	5.26	3.35	39.53	0.46**	35	80	1.2
Sodium, mg	2123.03	1640.71	2092.85	1053.56	30.18	19.6	0.15	32.5	67.5	5
Potassium, mg	2546.65	974.38	1960.89	661.1	585.76	40.16	0.29**	32.5	72.5	7.5
Calcium, mg	774.32	332.1	647.93	416.02	126.39	50.69	0.21*	33.8	73.8	3.8
Magnesium, mg	297.25	109.3	234.49	93.05	62.75	41.06	0.25*	32.5	65	3.8
Selenium, mg	137.99	52.67	98.57	35.52	39.42	61	0.11	23.8	65	12.5
Phosphorous, mg	1260.86	470.84	1023.96	308.55	236.9	31.38	0.22*	26.2	70	8.8
Iron, mg	15.77	8.35	13.24	8.34	2.53	48.4	0.24*	38.8	61.3	1.2
Zinc, mg	11.12	4.16	10.31	5.51	0.81	31.49	0.2*	37.5	72.5	6.2
Copper, mg	1.53	0.59	0.98	0.38	0.55	78.48	0.18	43.8	73.8	7.5
Manganese, mg	3.08	1.24	2.67	4.04	0.41	69.9	0.02	31.2	71.2	10
Iodine-mcg	91.54	88.74	68.94	69.13	22.6	121.66	0.19*	43.8	85	2.5
Vitamin A, IU	6068.26	3640.84	4565.42	3870.14	1502.85	112.37	0.27**	36.2	71.2	5
Vitamin D, IU	117.64	95.3	137.53	121.09	-19.88	105.55	0.31**	32.5	72.5	3.8
Vitamin E, IU	9.93	5.15	9.01	5.73	0.92	38.36	0.37**	23.8	62.5	5
Vitamin K, mcg	192.23	125.13	130.42	92.86	61.81	234.58	0.16	28.7	73.8	6.2
Thiamin (B1), mcg	1.34	0.49	1.11	0.55	0.22	41.82	0.33**	30	73.8	6.2
Riboflabin (B2), mcg	1.75	0.76	1.39	0.74	0.37	49.42	0.23*	30	68.8	6.2
Niacin (B3), mg	34.09	13.82	23.3	9.73	10.79	67.18	0.18	27.5	67.5	5
Vitamin B6, mg	1.68	0.59	1.5	0.84	0.18	36.31	0.14	25	65	6.2
Cobalamins (B12), mg	5.03	3.31	3.56	2.04	1.47	75.59	0.07	30	70	7.5
Folate, mg	279.92	138.84	234.35	215.05	45.57	76.94	0.1	22.5	71.2	5
Pantothenic acid, mcg	4.95	1.82	3.61	1.28	1.34	52.65	0.16	26.2	71.2	10
Vitamin C, mg	150.73	78.94	101.58	59.32	49.16	130.78	0.34**	37.5	78.8	6.2
Food Groups										
Grains, g	360.95	163.33	184.44	111.8	176.51	25.58	-0.02	26.5	72.2	7.4
Vegetable, g	257.13	146.87	118.89	78.5	138.24	44.28	0.06	26.1	72.6	2.6
Fruit, g	244.92	142.41	132.78	113.17	112.14	36.7	0.08	28.3	72.6	2.6
Meat and alternatives, g	231.38	113	111.35	65.49	120.04	43.44	0.06	24.8	69.6	1.7
Dairy and alternatives, g	166.12	133.87	71.84	82.2	94.28	47.83	0.04	29.1	74.8	4.3

size was small and may not be generalized because participants were recruited in only on study site. The incorporation of supplements could have captured the nutritional intake to a greater extent as commercial supplements like marine DHA, calcium pills and traditional herbal tea are not uncommon among Chinese pregnant women [14]. Seasonal variation in diet and food intake should also be

Table 3: Results of the agreement of estimated daily intake of nutrients and food groups between eFFQ and FFQ.

	eFFQ		FFQ		Mean Difference (eFFQ - FFQ)		ICC	Cross-classification		
	Mean	SD	Mean	SD	Mean	%		Same (%)	Same or adjacent (%)	Extreme (%)
Energy and Nutrients										
Energy, kcal	1639.4	667.74	2119.6	1143.14	480.2	11.77	0.3**	34.9	74.6	7.9
Protein, g	93.54	44.03	104.29	37.4	10.75	1.57	0.32**	33.3	79.4	11.1
Total fat, g	55.52	26.72	63.89	23.99	8.38	4.06	0.35**	33.3	76.2	11.1
Cholestesrol, mg	393.99	200	455.82	212.25	61.83	4.86	0.46**	39.7	76.2	1.6
Saturated fat, g	15.63	7.72	18.67	7.16	3.04	8.72	0.31**	36.5	77.8	11.1
Monounsaturated fat, g	17.53	9.62	20.07	8.62	2.54	0.96	0.4**	27	76.2	11.1
Polyunsaturated fat, g	10.35	5.11	11.17	4.59	0.83	4.55	0.4**	36.5	74.6	6.3
Carbohydrate, g	193.02	81.15	285.77	235.51	92.75	16.67	0.13	22.2	63.5	7.9
Added sugar, g	3.99	4.66	42.86	214.2	38.86	139.07	0.01	49.2	84.1	7.9
Total fibre, g	11.81	5.8	16.19	7.34	4.39	19.83	0.54**	38.1	73	1.6
Sodium, mg	1580.5	740.39	2250.44	1834.06	669.94	12.33	0.19	27	73	6.3
Potassium, mg	2092.57	907.99	2597.62	1014.71	505.04	13.36	0.4**	41.3	76.2	4.8
Calcium, mg	669.57	292.25	804.18	321.75	134.61	10.88	0.35**	41.3	84.1	4.8
Magnesium, mg	239.7	93.47	307.6	121.3	67.9	14.45	0.31**	34.9	76.2	4.8
Selenium, mg	122.26	54.81	143.08	53.44	20.82	5.29	0.27*	31.7	81	7.9
Phosphorous, mg	1085.51	462.15	1306.55	476.7	221.04	9.2	0.3**	38.1	76.2	9.5
Iron, mg	12.87	5.83	16.08	8.57	3.21	6.75	0.33**	30.2	74.6	6.3
Zinc, mg	9.37	4.27	11.54	4.27	2.17	8.77	0.21*	28.6	77.8	11.1
Copper, mg	1.24	0.55	1.56	0.65	0.32	11.15	0.24*	36.5	74.6	3.2
Manganese, mg	2.43	1.07	3.09	1.52	0.66	8.03	0.16	23.8	65.1	4.8
Iodine-mcg	62.05	39.58	98.11	93.06	36.06	17.76	0.15	33.3	81	3.2
Vitamin A, IU	4083.95	2885.3	5951.16	4159.55	1867.2	13.39	0.36**	30.2	74.6	3.2
Vitamin D, IU	99.33	74.45	129.62	101.69	30.28	9.2	0.52**	50.8	79.4	3.2
Vitamin E, IU	8.98	5	9.93	5.78	0.95	7.05	0.26*	36.5	74.6	3.2
Vitamin K, mcg	171.46	129.41	192.38	141.78	20.92	14.23	0.26*	34.9	73	3.2
Thiamin (B1), mcg	1.11	0.5	1.43	0.56	0.32	11.61	0.11	30.2	74.6	11.1
Riboflavin (B2), mcg	1.46	0.65	1.88	0.77	0.42	14.56	0.37**	30.2	71.4	3.2
Niacin (B3), mg	31.27	16.12	35.64	14.23	4.37	0.49	0.28*	31.7	81	12.7
Vitamin B6, mg	1.4	0.62	1.74	0.62	0.33	10.76	0.26*	36.5	73	11.1
Cobalamins (B12), mg	3.59	2.98	4.54	2.49	0.95	7.34	0.22*	38.1	87.3	1.6
Folate, mg	214.92	94.22	290.66	163.46	75.75	15.59	0.35**	38.1	76.2	3.2
Pantothenic acid, mcg	4.28	1.94	5.06	1.84	0.77	6.2	0.17	36.5	66.7	9.5
Vitamin C, mg	121.22	76.68	142.45	84.28	21.23	7.83	0.58**	38.1	87.3	1.6
Food Groups										
Grains, g	299.38	173.29	364.55	182.32	65.17	18.12	0.06	25.2	67.8	6.1
Vegetable, g	184.93	141.34	242.95	149.82	58.02	497.62	0.01	24.3	68.7	3.9
Fruit, g	187.35	154.85	242.3	155.35	54.95	20.54	0.09	27	69.1	3.5
Meat and alternatives, g	52.47	42.17	66.09	42.09	13.62	58.02	-0.02	25.2	69.6	6.5
Dairy and alternatives, g	154.01	130.86	188.07	131.68	34.05	26.28	0.12*	25.2	73	3.9

considered. As the present study took place in summer, it would be reasonable that certain winter produce would be missed. A retest in another season is likely to address the impact. Moreover, difference in culinary culture may pose challenge for portion size estimation. While a typical Western meal consists of clear separation of foods shown on a plate, the ingredients in Asian meals tend to be mixed, like fried rice, or that the dishes are shared together in the eating occasion, for example instead of having the whole piece of steak ready on individual plates, people take several slices of beef from the shared dish each time. Therefore, a change in portion size in favour of people's usual recognition of consumption size should reduce the cognitive challenge in remodeling consumed food into fractions or multiples of the standardized portion size present that could be culturally. A simple example is to replace the portion size of steak from a piece of big steak to a slice of beef.

Conclusion

This is the first report of examining the validity of an eFFQ for use in Chinese pregnant women to capture dietary data in this population. The eFFQ suggests satisfactory agreement with the validated FFQ, and has shown to be a reliable tool and option to measure the nutritional intake of Chinese pregnant women residing in Hong Kong.

Acknowledgements

The authors thank all participants for joining this study. We also thank WY Tse, Ken Ng, Keith Tung, and Bianca Chan for their great assistance in data acquisition and management.

Author Contributions Statement

PI, RC, MF, HS and WW designed the study. MF, KY acquired and assembled the data. MF, KY, HS and WW analyzed and interpreted the data. MF, KY, HS and RC drafted the manuscript. CC, AL, RC, WW and PI provided critical revision. PI and RC are the corresponding authors. All authors approved the final version of the manuscript.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Funding

The present study was funded by Health and Medical Research Fund (Vit D-HKU).

References

1. Barker DJ. Mothers, babies and health in later life 2nd ed. Churchill Livingstone: Edinburgh. 1998.
2. Phillips DI. Birth weight and the future development of diabetes: a review of the evidence. Diabetes care. 1998; 21: B150.
3. Barker DJ. Maternal and fetal origins of cardiovascular disease. In Epidemiology of Peripheral Vascular Disease. 1991. (247-254). Springer, London.
4. Lucas A. Programming by early nutrition in man. The childhood environment and adult disease. 1991; 1991: 38-55.
5. Lucas A. Role of nutritional programming in determining adult morbidity. Archives of disease in childhood. 1994; 71: 288.
6. Cusick SE, Georgieff MK. The role of nutrition in brain development: the golden opportunity of the "first 1000 days". The Journal of pediatrics. 2016; 175: 16-21.
7. Mameli C, Mazzantini S, Zuccotti GV. Nutrition in the first 1000 days: the origin of childhood obesity. International journal of environmental research and public health. 2016; 13: 838.
8. Martorell R. Improved nutrition in the first 1000 days and adult human capital and health. American Journal of Human Biology. 2017; 29: e22952.
9. Williamson C. Nutrition in pregnancy. Nutrition bulletin. 2006; 31: 28-59.
10. Langley SC, Jackson AA. Increased systolic blood pressure in adult rats induced by fetal exposure to maternal low protein diets. Clinical science. 1994; 86: 217-222.
11. Dahri S, Snoeck A, Reusens-Billen B, Remacle C, Hote JJ. Islet function in offspring of mothers on low-protein diet during gestation. Diabetes. 1991; 40: 115-120.
12. Langley SC, Browne RF, Jackson AA. Altered glucose tolerance in rats exposed to maternal low protein diets in utero. Comparative Biochemistry and Physiology Part A: Physiology. 1994; 109: 223-229.
13. Desai M, Crowther N, Ozanne S, Lucas A, Hales C. Adult glucose and lipid metabolism may be programmed during fetal life. Portland Press Ltd.; 1995.
14. Vioque J, Navarrete-Muñoz E-M, Gimenez-Monzó D, García-de-la-Hera M, Granado F, Young IS, et al. Reproducibility and validity of a food frequency questionnaire among pregnant women in a Mediterranean area. Nutrition journal. 2013; 12: 26.
15. Willett W. Nutritional epidemiology: Oxford university press; 2012.
16. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. Epidemiology and health. 2014; 36.
17. Pietinen P, Hartman Am, Haapa E, Räsänen L, Haapakoski J, Palmgren J, et al. Reproducibility and validity of dietary assessment instruments: II. A qualitative food frequency questionnaire. American Journal of Epidemiology. 1988; 128: 667-676.
18. Axelson J, Csernus M. Reliability and validity of a food frequency checklist. Journal of the American Dietetic Association. 1983; 83: 152-155.
19. Celis-Morales C, Livingstone KM, Marsaux CF, Macready AL, Fallaize R, O' Donovan CB, et al. Effect of personalized nutrition on health-related behaviour change: evidence from the Food4me European randomized controlled trial. International journal of epidemiology. 2017; 46: 578-588.
20. Fallaize R, Franco RZ, Hwang F, Lovegrove JA. Evaluation of the eNutri automated personalised nutrition advice by users and nutrition professionals in the UK. PloS one. 2019; 14.
21. Fallaize R, Forster H, Macready AL, Walsh MC, Mathers JC, Brennan L, et al. Online dietary intake estimation: reproducibility and validity of the Food4Me food frequency questionnaire against a 4-day weighed food record. Journal of medical Internet research. 2014; 16: e190.
22. Kolasa KM, Miller MG. New developments in nutrition education using computer technology. Journal of Nutrition Education. 1996; 28: 7-14.
23. Sacks N, Cabral H, Kazis L, Jarrett K, Vetter D, Richmond R, et al. A web-based nutrition program reduces health care costs in employees with cardiac risk factors: before and after cost analysis. Journal of medical Internet research. 2009; 11: e43.
24. Kato E, Takachi R, Ishihara J, Ishii Y, Sasazuki S, Sawada N, et al. Online version of the self-administered food frequency questionnaire for the Japan Public Health Center-based Prospective Study for the Next Generation (JPHC-NEXT) protocol: Relative validity, usability, and comparison with a printed questionnaire. Journal of epidemiology. 2017; 27: 435-446.
25. Forster H, Fallaize R, Gallagher C, O'Donovan CB, Woolhead C, Walsh MC, et al. Online dietary intake estimation: the Food4Me food frequency questionnaire. Journal of medical Internet research. 2014; 16: e150.
26. Heningburg AM, Mohapatra A, Potretzke AM, Park A, Paradis AG, Vetter J, et al. Electronic nutritional intake assessment in patients with urolithiasis: A decision impact analysis. Investigative and clinical urology. 2016; 57: 196-201.
27. Boushey CJ, Coulston AM, Rock CL, Monsen E. Nutrition in the Prevention and Treatment of Disease: Elsevier; 2001.
28. Woo J, Leung S, Ho S, Lam T, Janus E. A food frequency questionnaire for use in the Chinese population in Hong Kong: description and examination of validity. Nutrition research. 1997; 17: 1633-1641.

29. Willett WC, Hu FB. Not the time to abandon the food frequency questionnaire: point. Cancer Epidemiology and Prevention Biomarkers. 2006; 15: 1757-1758.

30. Ahuja J, Montville JB, Omolewa-Tomobi G, Heendeniya KY, Martin CL, Steinfeldt LC, et al. USDA Food and Nutrient Database for Dietary Studies, 5.0-Documentation and User Guide. US Department of Agriculture, Agricultural Research Service, Food Surveys Research Group: Beltsville, MD, USA. 2012.

31. Bland JM, Altman D. Statistical methods for assessing agreement between two methods of clinical measurement. The lancet. 1986; 327: 307-310.

32. Giavarina D. Understanding bland altman analysis. Biochemia medica: Biochemia medica. 2015; 25: 141-151.

33. Deriemaeker P, Aerenhouts D, Hebbelinck M, Clarys P. Validation of a 3-Day Diet Diary: Comparison with a 7-Day Diet Diary and a FFQ1946Board# 97 8: 30 AM–9: 30 AM. Medicine & Science in Sports & Exercise. 2006; 38: S328.

34. Perreault M, Xu VY, Hamilton S, Wright D, Foster W, Atkinson SA. Validation of a food frequency questionnaire for bone nutrients in pregnant women. Canadian Journal of Dietetic Practice and Research. 2016; 77: 133-139.

35. Tayyem R, Allehdan S, Mustafa L, Thekraallah F, Al-Asali F. Validity and Reproducibility of a Food Frequency Questionnaire for Estimating Macro- and Micronutrient Intakes Among Pregnant Women in Jordan. Journal of the American College of Nutrition. 2020; 39: 29-38.

36. Beaton G. Interpretation of results from diet history studies. The diet history method. 1991: 15-38.

37. Zhang H, Qiu X, Zhong C, Zhang K, Xiao M, Yi N, et al. Reproducibility and relative validity of a semi-quantitative food frequency questionnaire for Chinese pregnant women. Nutrition journal. 2015; 14: 56.

38. Barbieri P, Crivellenti L, Nishimura RY, Sartorelli DS. Validation of a food frequency questionnaire to assess food group intake by pregnant women. Journal of human nutrition and dietetics. 2015; 28: 38-44.

39. Giavarina D. Understanding bland altman analysis. Biochemia medica: Biochemia medica. 2015; 25: 141-151.

40. Cheng Y, Yan H, Dibley MJ, Shen Y, Li Q, Zeng L. Validity and reproducibility of a semi-quantitative food frequency questionnaire for use among pregnant women in rural China. Asia Pacific journal of clinical nutrition. 2008; 17: 166-177.

41. Steinemann N, Grize L, Ziesemer K, Kauf P, Probst-Hensch N, Brombach C. Relative validation of a food frequency questionnaire to estimate food intake in an adult population. Food & Nutrition Research. 2017; 61: 1305193.

42. Jinyuan L, Wan T, Guanqin C, Yin L, Changyong F. Correlation and agreement: overview and clarification of competing concepts and measures. Shanghai archives of psychiatry. 2016; 28: 115.

43. Hankin JH, Wilkens LR, Kolonel LN, Yoshizawa CN. Validation of a quantitative diet history method in Hawaii. American journal of epidemiology. 1991; 133: 616-628.