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Original article

Relative validity of a semi-quantitative food frequency questionnaire to estimate the intake of iron and its absorption modifiers in young Saudi females

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Abstract. *Background and aim:* To date, there is a lack of published data regarding validated food frequency questionnaire (FFQ) design specifically for Saudi populations. Therefore, the purpose of this study was to investigate, for the first time, the relative validity of a semi-quantitative FFQ in estimating the intake of iron and its absorption modifiers in young Saudi females. *Methods:* A convenience sample of 101 apparently healthy, young Saudi females aged 18–24 from Jeddah, Saudi Arabia, participated in the study. All participants completed the FFQ and three non-consecutive days of food records (FR) to determine validity. Pearson's correlation was used to investigate the correlation between nutrients intake obtained from the FFQ and FR. The agreement between the two methods was compared using Bland-Altman analysis and Cohen's kappa. For the analysis, the significance level was set at $p < 0.05$. *Results:* There were no significant differences between the estimates of iron and calcium intake obtained via the two methods. However, the FFQ yielded higher estimates of vitamin A, vitamin C and fibre. The differences in iron were equivalent to 4%, with agreement ranging from an underestimation of 1.2% to an overestimation of 1.3%. For vitamin A, vitamin C and fibre, the difference between the two methods increased with increasing mean intake. The agreement on rankings showed that participants were correctly classified in the same or an adjacent quantile regarding nutrient intake. *Conclusions:* The semi-quantitative FFQ appears to be a reasonably valid method of estimating the intake of iron and its absorption modifiers in young Saudi females. The present findings are of interest for public health and could be applied in epidemiological studies.

Key words: food frequency questionnaire; validity; iron intake; anemia; young females; Saudi Arabia

1 Introduction

Iron deficiency (ID) is one of the most common nutritional disorders around the world, as well as being a public health problem that can cause anemia (1) . Although ID is not the only cause of anemia, it is the most significant contributor to being anaemic. Approximately half of global cases of anaemia are due to ID (2), but the percentage likely varies between population groups and areas, depending on local conditions. There are numerous health consequences associated with ID, such as decreased work productivity, impaired cognitive capacity and physical development and increased risk of child and maternal mortality, as well as of premature delivery (2-5). Women of childbearing age are at a higher risk of becoming anaemic due to the increasing demand for iron during childbirth and lactation, as well as blood loss during menstruation (4,6,7). In addition, previous research has found that iron intakes in women are usually lower than the average recommended intake (7,8).

Dietary iron is present in two types, haem iron (HI) and non-haem iron (NHI), with the effective absorption of HI via the intestines (9). Heam iron accounts for 55–70% of total iron found in animal products and is more readily absorbable than the NHI found in both meat and vegetable foods (9). Moreover, dietary factors have an impact on the absorption of iron; for example, ascorbic acid (vitamin C) enhances iron absorption in the body. Vitamin C plays a particularly important role in enhancing iron absorption by converting ferric (Fe^{3+}) to ferrous iron (Fe^{+2}) states. Therefore, vitamin C deficiency impairs the mobilisation of the body's iron stores (10). On the other hand, the absorption of iron can be inhibited by polyphenols, phytates, oxalate, calcium, fibre and some medications (6).

Therefore, there is a significant and important connection between nutrients and their relationship to one another within the human body, which influences the iron levels of individuals (11,12). Consequently, investigating the association between diet and diseases such as iron deficiency anaemia (IDA), which is the most common form of anaemia, through the analysis of dietary patterns is currently of considerable importance in enabling public health practitioners to prevent such diseases.

A recent study by Owaidah *et al.* (2020), revealed that ID and IDA are common epidemiological conditions in Saudi Arabia, especially among females (13). Thus, a reliable method, such as a food frequency questionnaire (FFQ), can be a powerful tool in epidemiologic studies in the area of ID prevention. The FFQ can evaluate long-term nutritional exposure (14), and it is commonly used to evaluate the association between dietary intake and disease (15). In addition, the FFQ is a convenient dietary assessment tool and informative approach with which to assess the intake of a certain food (16). However, in order to precisely interpret epidemiologic studies that use the FFQ method as an assessment tool, the method should be subjected to validation through other dietary intake assessment tools, such as the gold standard dietary record or 24-hour dietary recall (17,18). This is to overcome any inaccuracies, such as underestimated or overestimated nutrients intake, and ensure its suitability for a particular population (15,19).

Therefore, the aim of this study was to investigate the relative validity of a developed semi-quantitative FFQ in estimating the intake of iron and its absorption modifiers in young Saudi females.

2 Materials and methods

2.1 Study design and participants

A cross-sectional study was conducted in Jeddah, Saudi Arabia, using a convenience sampling of 101 apparently healthy, young Saudi females aged 18–24. Because this study is a validation study, the sample size identification was based on the number of participants that would provide adequate precision for the Bland–Altman limits-of-agreement test (20). In addition, this number is sufficient for the correlation coefficient tests (21). Participants were recruited from King Abdulaziz University. The exclusion criteria were participants reporting any chronic diseases or have long-term prescription medication. Females who were pregnant, lactating, or smokers were also excluded. This study was approved by the Ethics Committee of King Abdulaziz University, Unit of Biomedical Ethics (Ethic reference:- 498-16). Informed written consent was obtained from all participants prior to the commencement of the study, and the study was conducted in accordance with the Declaration of Helsinki.

2.2 Data collection

After females who were willing to take part in the study had been identified, participants were asked to attend an interview which, was conducted by two trained Arabic-speaking nutritionists. Data collection was performed in two stages: First, a face-to-face interview was conducted to adminster the study questionnaire and FFQ and collect anthropometric measurements, after which we asked the participants to complete three FR on non-consecutive days. In the second stage, the interviewers collected the three days'

FR and determined whether any information was missing or unclear.

2.2.1 Assessment of sociodemographic, anthropometric and health characteristics of study participants

Information about age, nationality, marital status, weight, height, medication, smoking and health conditions was collected. Body weight and height were measured by using a mechanical column scale with an eye-level beam (Seca Ltd., Hamburg, Germany), and body mass index (BMI) was then calculated.

2.2.2 Dietary assessment

2.2.2.1 Food records (FR)

All participants were requested to complete FR on all foods and beverages consumed in or outside the home on three non-consecutive days, two weekdays and a weekend day, following their initial interview, in order to reduce the recall bias. participants were provided with a photographic Atlas with which to estimate food portion sizes. Verbal instructions were given by the interviewers regarding how to complete the FR. Participants were asked to report information regarding the brand names of consumed items, the ingredients of mixed dishes, and amounts based on familiar household measurements, along with the times at which meals were consumed. The FR was reviewed with each participant to clarify the answers and to check for incomplete information. The FR data were analysed using computerised dietary analysis software based on the US Department of Agriculture (USDA) food database. For mixed dishes consumed by participants that were not included in the software, ingredients were coded and entered into the dietary analysis software in order to calculate participants' nutrient intake.

2.2.2.2 Food frequency questionnaire (FFQ)

A semi-quantitative FFQ was developed from a previously validated Zinc-FFQ intake in the typical Saudi diet by Alsufiani and Yamani (20), in addition to the Iron-FFQ study by Beck and Kruger (18), which considered not only iron intake but also nutrients' effect on iron intake and bioavailability. Thus, the current FFQ determined the intake of iron and other nutrients that were either inhibitors or enhancers of iron absorption, including vitamin C, calcium, fibre and vitamin A, one month prior to data collection. The FFQ was administered to each participant during a personal interview. The questionnaire contained 84 food items, with specified serving sizes that were commonly consumed by the study population. These items were classified into ten categories: eggs (one item), meat (nine items), seafood (five items), dairy (six items), vegetables (twelve items), fruits (17 items), beverages (seven items), seeds and nuts (two items), cereals (15 items), and miscellaneous (ten items; Table 1). The assessments of the intake frequency for each food item were measured on a seven-point scale ranging from 'never' to 'at least twice per day'. Additionally, in the last section of the FFQ, participants were asked whether they usually consumed other food items that were not included on the list to add these to the FFQ. Dietary intake for each nutrient (iron, vitamin C, calcium, fibre and vitamin A) based on the reported FFQ was calculated as described in detail in previous studies (22).

2.3 Statistical analysis

To define the sample characteristics, descriptive statistics (means and standard deviations (SDs)) were utilised. A paired t-test was used to determine the differences in the mean daily intake of nutrients between the FFQ and FR. Pearson's correlation was used to investigate the correlation between nutrient intake data obtained from the FFQ and FR. Moreover, a Bland-Altman analysis was undertaken to investigate the agreement between the two methods in estimating nutrients intake. These were evaluated using the limit of agreement. Finally, Cohen's kappa statistic was used to assess the agreement between the two methods in classifying participants into similar or adjacent quartiles regarding daily nutrient intake. All statistical analyses were performed using Stata/IC 15.1 statistical software. For all analyses, the tests were two-sided, and statistical significance was set at $p < 0.05$.

Table 1. Food items (serving size) included in the FFQ.

Eggs	Peas (1/3 cup; 60 gm)	**White rice (1 cup; 175gm)**
egg (50g)	Chickpeas (1/2 cup; 100 gm)	Rice with milk (saleeq) (1 cup)
Meat	Broad bean (1/2 cup; 100 gm)	Rice with tomato sauce (kabsa) (1 cup)
Beef (120 gm)	Green salad (1 cup; 100 g)	Rice with lentil (1 cup)
Lamb (2 chops; 100 gm)	Olive (5g)	Whole meal crisp bread (1.5 gm)
Veal (1 chop; 90 gm)	Jew's mallow (Mulukiyah) (1cup; 216gm)	Oats (1 cup; 230 gm)
Diced meat (kabab or hamburger) (150 gm)	Fruits	Muffin (1 piece; 55 gm)
Meat Shawerma (1 medium sandwich; 200gm)	Apples (1 piece; 100gm)	Biscuits (bran, whole meal) (20 gm)
Chicken Shawerma (1 medium sandwich; 200gm)	Orange (1 piece; 100gm)	Miscellaneous
Chicken (1 breast or thigh; 110 gm)	Orange juice (1 glass; 205ml)	Meat pie (sambosak) (1 piece)
Liver (50 gm)	Lemon (1 piece; 65gm)	Cheese pie (sambosak) (1 piece)
Sausage (medium roll; 60g)	Guwava (1 piece; 55 gm)	Meet pie (fatayer) (160 gm)
Seafood	Grapefruit (1 piece; 40gm)	Cheese pie (fatayer) (160 gm)
Fish (whole; 1 fillet; 120 gm)	Mandarine (1 fruit)	Thyme pie (fatayer) (100 gm)
Oysters (smoked; 5 gm)	Bananas (1 fruit)	Pizza (150 gm)
Crab/ scallops (50 gm)	Kiwi (1 fruit; 69gm)	Tameya (30 gm)
Lobster/prawn/ squid (1/2 cup; 90 gm)	Mangos (1 fruit)	Popcorn (30 gm)
Tuna (100g)	Apricots (1 fruit)	Chips/ corn chips/ twisties (50 gm)
Dairy	Plums (1 fruit)	Chocolate /plain (1 bar; 50 gm)
Cheese (cheddar) (1 slice; 20 gm)	Figs (1 fruit)	Beverages
Yogurt (1 cartoon; 200g)	Melons (1 wedge)	Drinking chocolate (1 tbsp; 9 gm)
Cow's Milk (1 glass; 200 ml)	Watermelon (1 cup)	Tea (1 cup; 240ml)
Cow's Milk (with cereal) (½ cup ; 125 ml)	Grapes (50 gm)	Tea with milk (1 cup; 240ml)
Fermented milk (laban) (1 glass; 200gm)	Dried fruits (Raisins; 30g)	Tea with lemon (1 cup; 240ml)
Ice cream (2 scoops; 60 gm)	Cereals	Coffee (1 cup; 240ml)
Vegetables	Whole grain corn flakes (1 cup; 30 gm)	Coffee with milk (1 cup; 240ml)
Potato (1 medium; 100 gm)	Corn flakes (1 cup; 30 gm)	Soft drink (1 can)
Broccoli (50 gm)	Brown bread (1 slice;25 gm)	Seeds and nuts
Spinach, silver beet (1/3 cup; 60 gm)	White beta Bread (1 slice; 25 gm)	Sesame butter (1 teaspoon; slice 4.2gm)
Tabouli (100 gm)	Brown toast (1 slice; 25 gm)	Nuts (mixed) (15 gm)
Okra with tomato sauce (250 gm)	White toast (1 slice, 25 gm)	
Vegetables, stuffed (100gm)	White pasta (1 cup; 100gm)	

3 Results

3.1 General characteristics

One hundred and one females participated in this study. Their mean age was 21, and their mean BMI was 22.4 kg/m^2. The majority of the participants were single, in good health, non-smokers, and not taking any dietary supplements during the study period (Table 2).

3.2 Agreement between FFQ and FR

Table 3 shows the differences between the FFQ and FR , as well as the correlation between them. The results showed that there were no significant differences between the estimates of iron and calcium intake obtained via the two methods. In contrast, the mean intakes of vitamin A, vitamin C, and fibre obtained via the FFQ were significantly higher than those obtained via the FR (72.7 ± 150mcg, p < 0.001; 26.6 ± 37.8mg, p < 0.001; 4.16 ± 7.19g, p < 0.001, respectively).

Regarding the correlation, the results show a moderately high, positive correlation between the two methods for the intake of vitamin A and vitamin C (r = 0.732, r = 0.498, respectively). A moderately low, positive correlation was observed for calcium and fibre (r = 0.404, p < 0.001; r = 0.262, p = 0.008, respectively). In terms of iron intake, a low positive relationship was obtained from the two methods (r = 0.221, p = 0.0261).

Figure 1 demonstrates the Bland-Altman plots obtained via the FFQ and FR. The differences in iron and calcium intakes as measured via the two different methods were consistent across the full range of intakes (Figure 1A and 1D, respectively). With a limit of agreement ranging from -10 to 10.7 for iron, which means that the FFQ may underestimate iron intake by 1.2% or overestimate iron by 1.3% on average. However, the differences in vitamin A, vitamin C, and fibre intake estimated by the FFQ and FR increased with increasing mean intake (Figure 1B, 1C, and 1E, respectively). Although the FFQ overestimated vitamin A, vitamin C, and fibre intake, Pearson's correlation showed a moderately high positive correlation and moderately low positive correlation between the two methods.

Table 2: General characteristic of the study participants (n=101).

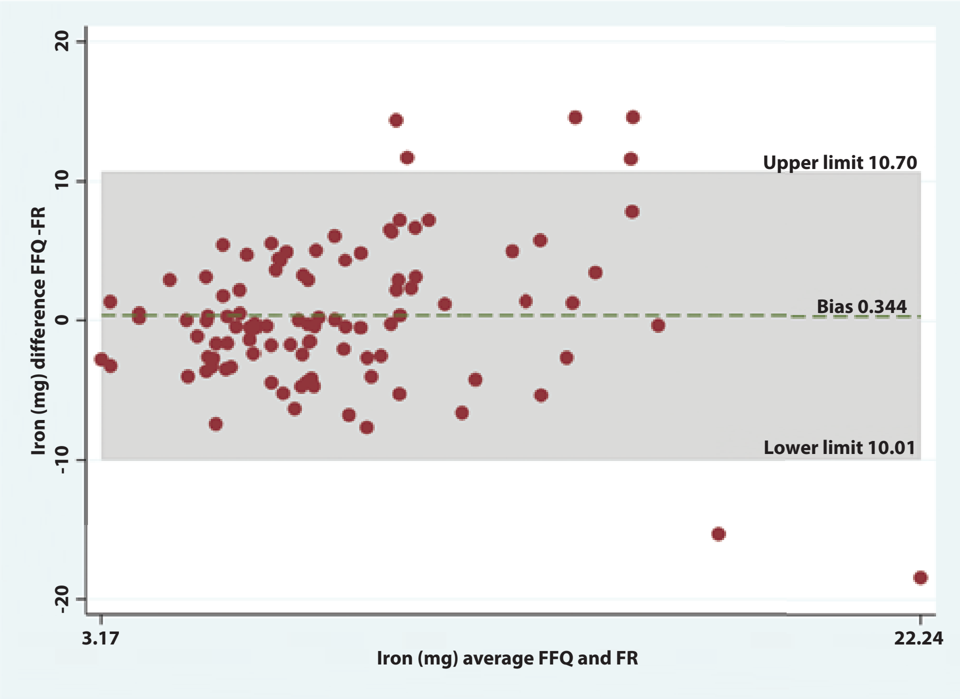
General Characteristic	**Mean**	**SD**
Age (years)	21.3	0.98
Height (cm)	158	6.25
Weight (kg)	55.9	11.9
BMI (kg/m^2)	22.4	4.16
	N	**%**
BMI classification:		
Underweight	17	17
Normal	50	49
Overweight	21	21
obese	13	13
Marital Status:		
Single	91	90
Married	10	10
Divorced	0	0
Good health:		
Yes	93	92
No	8	8
Taking dietary supplements:		
Yes	11	11
No	90	89
Smoking status:		
Smoker	3	3
Non-smoker	98	97

BMI: Body Mass Index

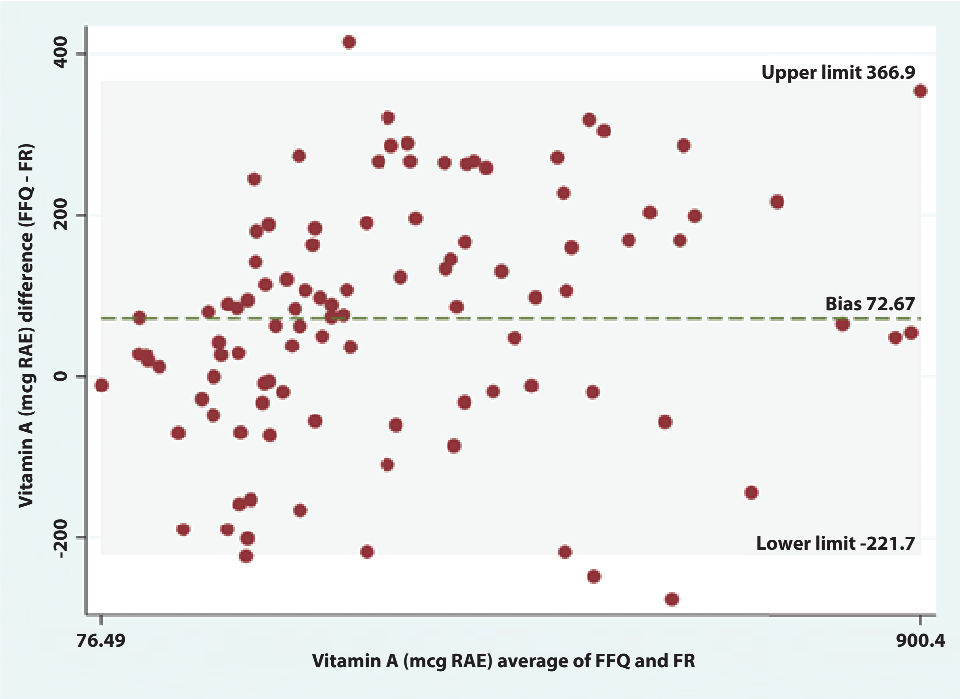
Table 3. Mean daily intakes of nutrients assessed by FFQ and FR among young Saudi females (n=101).

	FFQ		**FR**		**Differences between FFQ and FR****		**P value**	**Limit of agreement**		**Correlation coefficient (r)** ***	
Nutrient	**Mean**	**±SD**	**Mean**	**±SD**	**Mean**	**±SD**		**lower**	**upper**		**P value**
Iron (mg)	8.84	4.46	8.49	4.11	0.34	5.28	0.541	-10.0	10.7	0.221	0.0261
Vitamin A (mcg RAE)	408	217	336	184	72.7	150	<0.001	-221.7	367	0.732	<0.001
Vitamin C (mg)	71.2	39.86	44.62	35.15	26.57	37.81	<0.001	-47.6	100.7	0.498	<0.001
Calcium (g)	546	246	504	212	41.2	251	0.102	-451.3	533.7	0.404	<0.001
Fiber (g)	15	6.8	10.85	4.73	4.16	7.19	<0.001	-9.93	18.2	0.262	0.008

FFQ: Food Frequency Questionnaire; FR: Food Record; RAE; Retinol Activity Equivalents; CI: Confidence Intervals; RAE; Retinol Activity Equivalents. ** the differences was assessed using t-test
***Strength of the correlation: 0.75 <r≤ 1 (high positive relationship), 0.50 <r≤ 0.75 (moderately high positive relationship), 0.25 <r≤ 0.50 (moderately low positive relationship), 0 <r≤ 0.25 (low positive relationship).

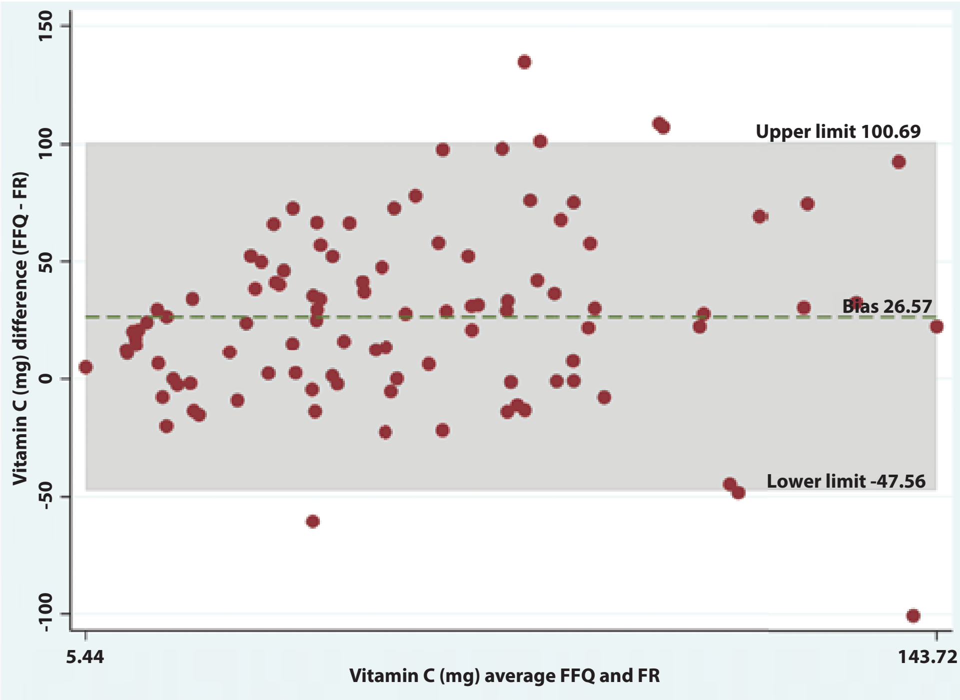


(A) Iron

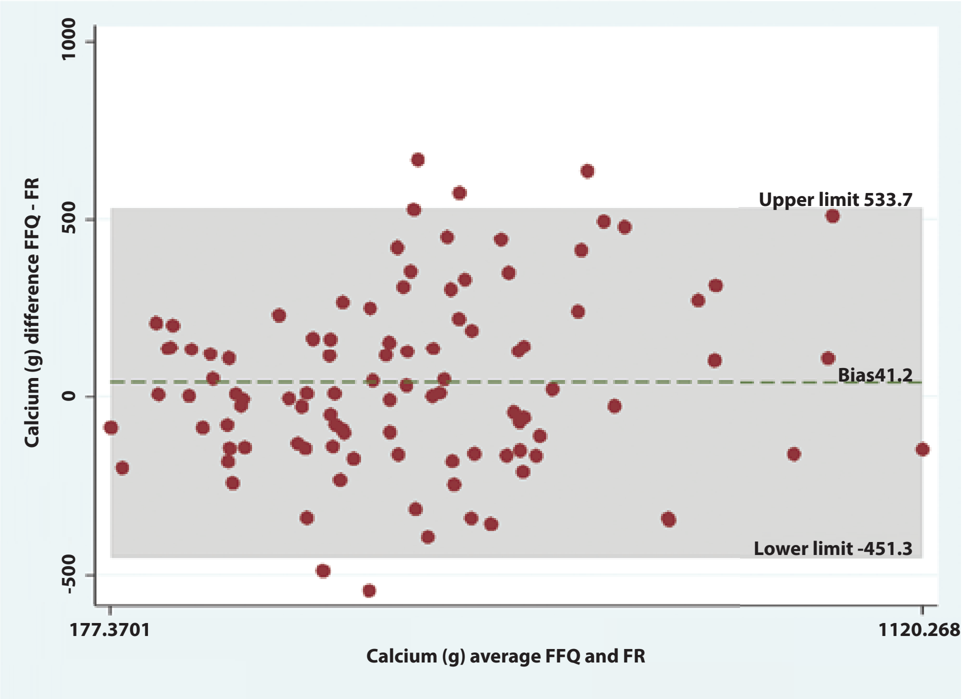


(B) Vitamin A

Figure 1. Bland-Altman Plot showing the differences in daily intake of (A) Iron ,(B) Vitamin A, (C) Vitamin C, (D) calcium and (E) fibre estimated via the FFQ and FR versus the mean daily intake of these nutrients estimated via the two methods. FFQ: Food Frequency Questionnaire; FR: Food Record; RAE; Retinol Activity Equivalents.

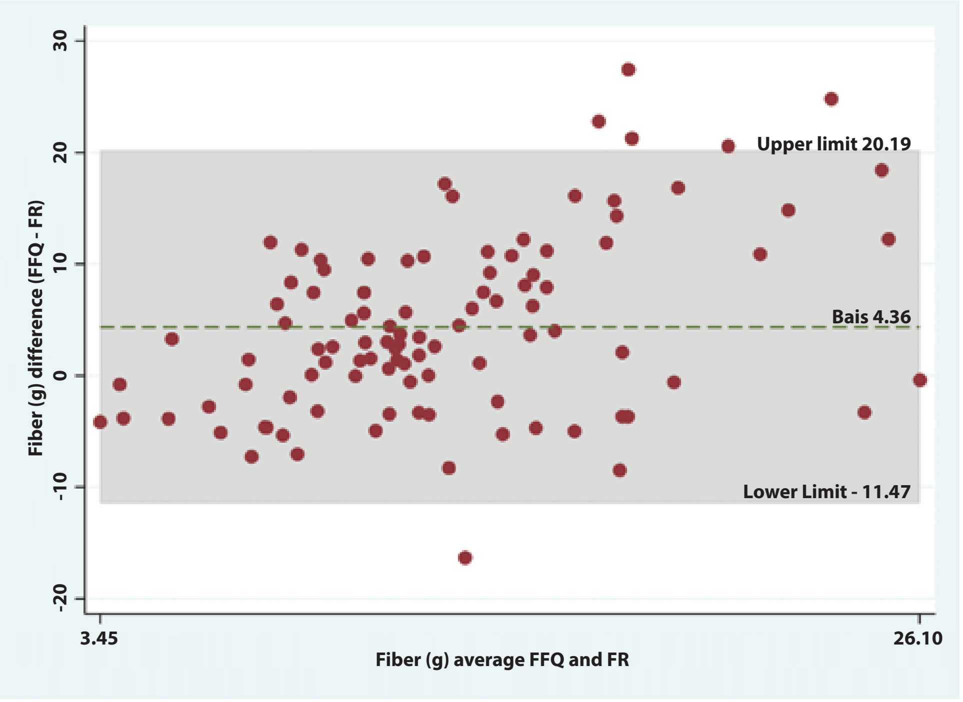


(C) Vitamin C



(D) Calcium

Figure 1. (Continued)



(E) Fiber

Figure 1. (Continued)

Table 4. Agreement on the ranking of nutrients into quartiles of intakes estimated by FFQ and FR among young Saudi females (n=101).

Nutrients	Same or adjacent*	Kw	Agreement**
Iron (mg)	64.4%	0.23	Faire
Vitamin A (mcg RAE)	78.2%	0.48	Moderate
Vitamin C (mg)	72.3 %	0.34	Faire
Calcium (g)	67%	0.26	Faire
Fiber (g)	63 %	0.12	Slight

*Percentage of adults classified into same or adjacent quartile
**Strength of agreement: 0.00-0.20 (slight), 0.21-0.40 (faire), 0.41-0.60 (moderate), 0.61-0.80 (substantial), 0.81-1.00 (almost perfect); RAE; Retinol Activity Equivalents.

3.3 Agreement on rankings of iron, vitamin A, vitamin C, calcium and fibre

The agreement between the FFQ and FR in classifying individuals into the same or adjacent quartiles of the intake distribution is shown in Table 4. The highest proportion of participants correctly classified in the same or adjacent quantile of intake was observed for vitamin A and vitamin C, followed by calcium, iron, and fibre (-78%, 72%, 67%, 64%, and 63%, respectively).

4 Discussion

This study aimed to assess the relative validity of the developed semi-quantitative FFQ in estimating the intake of iron and its absorption modifiers, including calcium, vitamin A, vitamin C and fibre, in young Saudi females. The findings of the current study showed reasonable relative validity for the investigated nutrients.

Frequently, FFQs are used as the primary nutritional assessment instrument in large prospective studies. These FFQs can be used to investigate correlations between diet and health issues (15). However, the FFQ should be subjected to validation against the gold standard, FR, to overcome any inaccuracies, such as underestimated or overestimated nutrient intake. The findings of this study showed that there were no significant differences between the estimates of iron and calcium intake obtained via the two methods. However, the FFQ yielded higher estimates of vitamin A, vitamin C and fibre intake than those obtained from the three-day FR. This could be explained by the presence of a large number of food items on the current FFQ, as it contains 84 food items. These items may not have been consumed during the food recording of the participants. Another factor to consider is that potential FFQ measurement errors resulted from over-reporting the frequency of a consumed food and its serving size. The results are consistent with the previous findings of Alsufiani et al. (2015), Barrett and Gibson (2010), Pakseresht and Sharma (2010), Segovia-Siapco et al. (2007) and Sauvageot et al. (2013). These FFQ validation studies have reported that the FFQ overestimates nutrients intake as compared to FR estimates (22-26)

The correlation coefficients between the FFQ and the reference method (the mean of three FR) showed reasonable validity between the two methods, as moderately and weakly positive relationships were observed for vitamin A, vitamin C, calcium, fibre and iron intakes, respectively. These results compare favourably with those of previous studies (22,27). According to Araujo and Yokoo (25) and Kaaks and Riboli (26), the correlation between nutrient intakes estimated by the two methods in FFQ validation studies commonly ranges from 0.50 to 0.70. Another study which reviewed 42 FFQ validation studies found significantly higher correlation coefficients when applying FR for eight to 14 days rather than one to seven days (28). However, in the current work, the FR was performed on three non-consecutive days. Thus, applying FR for a longer period could improve the correlation coefficients between FFQ and FR (27).

Unlike the correlation coefficients (which can be misleading because they are limited to measuring the relationship between the two methods), the Bland-Altman analysis assesses the agreement between the nutrient intake values estimated via the two methods (18,29). Thus, the latter approach was applied, and the plots indicated that the difference in estimated intakes of iron and calcium was consistent across the full range of intakes. Conversely, for vitamin A, vitamin C and fibre, the difference found via the two different methods increased with increasing mean intake. This finding could be due to the large number of food items on the FFQ, which may not have been consumed during the food recording of the participants. The results of the current study are consistent with the previous findings of Araujo *et al.* (2010) and Alsufiani *et al.* (2015) (22,27). The agreement between the FFQ and the reference method (FR) in classifying participants into the same or adjacent quartiles regarding daily nutrient intake showed that participants were correctly classified in the same or adjacent quantile of nutrient intake. The weighted kappa values were in the range of 0.12–0.48, which was in line with the acceptable outcomes for the cut-off points used for weighted kappa statistics, as the values for all nutrients of interest, except fibre, showed moderate agreement, (30,31). A similar range of kappa values for the investigated nutrients was reported in the validation study carried out by Masson and McNeill (32), in which the values ranged from 0.15 to 0.43. Namely, the weighted kappa provides better insight into performance.

The finding of this study could be valuable in the Saudi context, where the prevalence of iron deficiency is quite high, especially given the lack of validated tools. Monitoring iron intake in large groups of young women may be a very significant goal and will provide a road map for future programs. This will help the country achieve the WHO's global target of a 50% reduction in anemia among women of reproductive age by 2025 (33).

Conclusion

This study indicates that the developed semi-quantitative FFQ appears to be a reasonably valid method of estimating the intake of iron and its absorption modifiers, including vitamin C, calcium, fibre and vitamin A, in young Saudi females. The present findings are of interest regarding public health and could be applied in epidemiological studies.

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Conflicts of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Authors' Contributions: M Almaghrabi and A houssien conceived the idea and designed the study. R Zamka, S Alyafie and A houssien collected data. S Albar and H Alsufiani analyzed the data. S Albar performed the statistical analysis. M Almaghrabi performed the literature search and wrote the manuscript. S Albar and H Alsufiani reviewed the original manuscript. All authors have read and agreed to the published version of the manuscript.

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