ORIGINAL RESEARCH ARTICLE

Development and Validation of a Food Frequency Questionnaire for Dietary Antioxidant Intake among Prediabetic Individuals in the South Indian Population

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ABSTRACT

Background: Prediabetes is a growing global public health concern, with dietary factors playing a major role in its progression to type 2 diabetes. Antioxidants can mitigate oxidative stress, a major contributor to prediabetes. This study developed a Food Frequency Questionnaire (FFQ) to assess the intake of key antioxidants, including vitamin C and E, selenium and zinc among prediabetic population in Chennai, India.

Methodology: The food list was based on the Indian Food Composition Table (2017), and the portion sizes and frequencies were derived through a focus group discussion with registered dietitians and physicians. The FFQ intake data were compared with the mean of two 24-hour dietary recall (DR) using Pearson correlation analysis.

Results: Strong correlations were observed for vitamin C (r=0.909) and vitamin E(r=0.915), and moderate correlations were observed for selenium (r = 0.696), and zinc (r = 0.706), with significant results ($p < 0.001$ for vitamin C, E, selenium, and $p = 0.036$ for zinc).

Conclusion: The results indicated good agreement between the FFQ and DR, validating the developed FFQ as a reliable tool for estimating antioxidant intake in prediabetic individuals. This tool is useful for monitoring antioxidant intake in both clinical and public health settings.

Keywords: 24-hour Dietary recall, Oxidative stress, Pearson correlation, Public health

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INTRODUCTION

Prediabetes is a growing global health concern with a prevalence of 15.3% in India,[1] and is projected to reach 471 million globally by 2035.[2] The World Health Organization (WHO) defines prediabetes as intermediate hyperglycemia, characterized by impaired fasting glucose (IFG) with plasma glucose levels in the fasting state between 110-125mg/dL and/or impaired glucose tolerance (IGT), with glucose levels between 140-200mg/dL 2 hours after a meal.[3]

The onset of prediabetes, driven by insulin resistance, initiates a vicious cycle of oxidative stress and inflammation, accelerating the progression to Type 2 diabetes mellitus (T2DM).[4] Studies have demonstrated a significant association between the consumption of exogenous antioxidants and a reduced risk of diabetes and its complications.[5,6]These antioxidants provide protection both in the early stages of insulin resistance and in the later phases of beta-cell dysfunction.[7]Vitamins and minerals, along with polyphenols and other compounds, are major contributors to the body's antioxidant defense system.[8] Framing interventions, including lifestyle modifications and dietary changes at this stage are essential to prevent T2DM.

Due to significant influence of dietary factors on the development and management of prediabetes,[9] understanding the dietary antioxidant intake is crucial to develop nutrition-based interventions for prediabetic individuals. One way to assess the dietary intake of antioxidants in the prediabetic population is through the use of food frequency questionnaires (FFQ). The FFQ tool is one of the most effective tools for assessing the dietary intake of the population in epidemiological studies because of its cost- effectiveness and suitability for large populations, and aids in understanding the relationship between diet and disease.[10] This study specifically focused on four essential nutrients: vitamin C, vitamin E, selenium and zinc and aimed to develop an FFQ to assess the dietary intake of these antioxidants in prediabetic individuals and validate it with 24-hr dietary recall (DR).

METHODOLOGY

The sample size for this study was determined to be 120 based on the prevalence rate of prediabetes in Tamil Nadu. A proforma was designed to collect socio-demographic data and lifestyle factors. A food list was developed using the Indian Food Composition Database, incorporating inputs from registered dietitians. Pilot testing of the Food Frequency Questionnaire (FFQ) was conducted with ten prediabetic individuals to collect feedback and refine the tool. After pilot testing, the FFQ was administered to 120 participants, and two 24-hour dietary recalls were obtained by the investigator. The mean nutrient intake was calculated for both the FFQ and the 24-hour dietary recalls. Statistical analysis was performed using SPSS version 26. The socio-demographic data were analysed descriptively using percentages and frequencies, while the association between the two dietary assessment methods was evaluated using Pearson correlation analysis.

Sampling framework and participant recruitment: This study employed a cross-sectional design and was conducted in Chennai, Tamil Nadu, India. This study was approved by the Institutional Ethics Committee. The inclusion criteria for the study included individuals, both male and female, age group 25-55 years diagnosed with prediabetes according to the WHO criteria. The sample size was calculated using the formula $n=Z^2P(1-P)/d^2$ [11] where p is the expected proportion/ prevalence in Tamil Nadu 8.3% (0.083),[1] d is the desired precision of 5%, Z is the desired confidence level of 95% and was estimated to be 120. The prediabetic individuals were recruited from a private hospital in Chennai, where participants were explained the study in detail and informed consent was obtained from them.

Development of Proforma: The FFQ was developed with a proforma that included socio-demographic details of the participants including age, sex, socioeconomic status (SES)[12] and domicile, as well as behavioral data on physical activity, type of diet, alcohol, and smoking. It also included information on the intake of vitamin C, vitamin E, selenium and zinc fortified foods, along with the use of supplements for these nutrients. Yes or no responses were recorded for physical activity, smoking, alcohol consumption, and intake of fortified foods and supplements.

Development of the Food list: A detailed food list was developed based on the Indian Food Composition Table (2017)[13] and the Nutritive value of Indian foods, created by the National Institute of Nutrition. The foods included in the Indian Food Composition Table (IFCT) data base are based on the key food approach developed by the United States Department of Agriculture and contain 528 foods. A focus group discussion was conducted with a team of registered dietitians to identify key foods and to develop a regionally relevant FFQ. The final food list, comprising 208 items, was reviewed and approved by a general physician and two associate professors.

Ten prediabetic individuals participated in the pilot testing process to complete the FFQ in presence of the investigator. Feedback was collected from participants through open ended questions to identify any gaps in the food list, challenges with portion size estimation, and any ambiguity in the questionnaire. Based on the feedback, regional language (Tamil) was incorporated for clarity and cultural relevance.

Development of FFQ: The 208 items in the FFQ were categorized into 13 groups: cereals and millets (18), grains and legumes (19), green leafy vegetables (11), vegetables (44), fruits (38), spices and condiments (22), nuts and oilseeds (12), fats and oils (4), milk and milk products (4), sugars and beverages (3), eggs and egg products (10), meat and poultry (11), and fish and seafood (12) as described in previous studies.[14] The portion size for each food group was determined in consultation with registered dietitians, as they were aware of the common portion size in the region.

The FFQ is a self-administered tool, and the investigator explained the details for completing the questionnaire to the participants. Sufficient time was given to complete the questionnaire, and participants were assisted in understanding the portion sizes through standard measures of spoons and cups.[15] The developed FFQ measured diet intake over a month using seven frequency categories ranging from 1 to 7 times per week, with portion sizes noted as small, medium, and large. The nutrient content of each item was multiplied by the frequency and portion size to estimate nutrient intake.

24-hour Dietary Recall: The 24-hour DR was used as a reference method to validate the FFQ due to its lower overall variance.[14,16]Two 24- hour DR were calculated using open-ended, prompted questions by the investigator, once during the week and once on the weekend. The first recall was obtained at the initial administration of the FFQ, while the second recall was obtained through telephonic interview, and the final value was the mean of two 24-hour DR. The IFCT and nutritive value of the Indian food database were used to calculate the nutritive values.

Data Collection and Statistical Analysis: The investigator collected the data for the proforma and 24-hour DR and assisted the participants in completing the FFQ tool. All the statistical analyses were performed using SPSS software (version 26). Descriptive statistics, including frequencies and percentages, were used to analyze the responses from proforma data. The mean and standard deviation of nutrient intake for zinc, vitamin C, selenium, and vitamin E were calculated for both the FFQ tool, and 24-hour DR. Pearson correlation analysis was employed to assess the association between nutrient intakes estimated by the FFQ and the mean intake from the two 24-hour DR. This correlation analysis is the validity measure, to understand how closely the FFQ estimates align with the 24-hour DR.

Results

Population Demographics and Behavioural data

Table (1) provides the socio-demographic profiles and lifestyle behavioural data of the participants. A total of 120 participants completed the 24-hour DR and FFQ. It was observed that most participants did not engage in at least 150 minutes of physical activity, did not consume fortified foods, and lacked the habit of taking supplements for these nutrients. These findings indicate potential gaps in the intake of fortified foods and supplements and emphasize the need for increased awareness of the importance of lifestyle practices and targeted nutritional interventions.

Table 1: Socio demographic profile and Lifestyle behavioural data of the participants (n=120)

Variable	Participants (%)
Socio demographic profile	
Age	
25-35 years	57 (47.5)
36-45 years	48 (40)
46- 55 years	15 (12.5)
Gender	
Male	77 (64.2)
Female	43 (35.8)
Type of diet	
Vegetarian	45 (37.5)
Non vegetarian	35 (29.2)
Lacto Ovo vegetarian	40 (33.3)
Socio economic status	
Upper class	27 (22.5)
Upper middle class	45 (37.5)
Lower middle class	35 (29.2)
Upper lower class	6 (5)
Lower class	7 (5.8)
Domicile	
Urban	66 (55)
Rural	54 (45)
Lifestyle and Behavioural data	
Alcohol consumption	37 (30.8)
Smoking	17 (14.2)
Physical activity (150 mins/wk)	46 (38.3)
Fortified foods consumption	14 (11.7)
Intake of supplements	111 (92.5)

Correlation analysis between FFQ and 24-hour dietary recall: Figures (1-4) represents the scatter plots of the intake of each nutrient, with the mean 24-hour DR on the x-axis and FFQ on y-axis. The data points cluster around line of identity indicating the agreement between the two methods of dietary assessment.

Table (2) provides the mean intake with standard deviation for each nutrient derived from 24-hour DR and FFQ. Pearson correlation was used to assess the validity of the developed FFQ against the 24-hour DR. Pearson correlation coefficient (r) was calculated to assess the strength and direction if relationship between the FFQ and the 24-hour DR. Positive correlation values indicate a direct linear relationship, whereas negative values indicate an inverse association between the two methods of dietary assessment. The correlation analysis showed alignment between the FFQ and 24-hour DR values, with positive correlation coefficient (r) observed for each nutrient. (Table 2) A strong positive value indicates high level of agreement between the two methods, implying the developed FFQ's reliability in capturing dietary antioxidant intake.[14,17]

Table (3) provides the correlation coefficient ranges from various FFQ validation studies conducted in India, which assessed a variety of nutrients across different populations. The correlation range observed in our study (0.69-0.91) is consistent with the findings of these studies, indicating similar validity metrics.

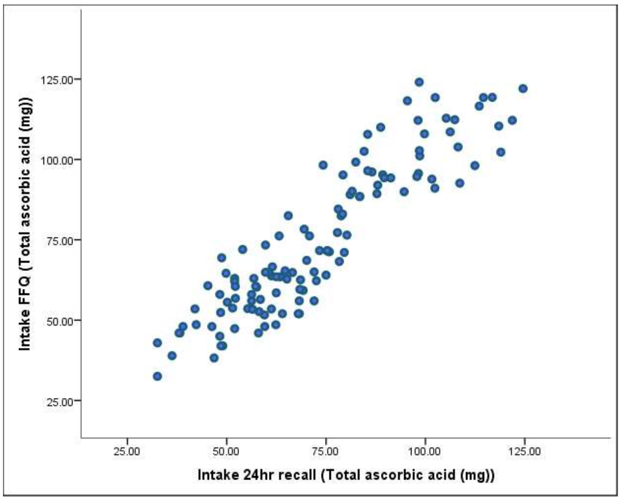

Figure1: Scatter Plot Depicting Vitamin C Intake from FFQ and 24-Hour Dietary Recall in study population

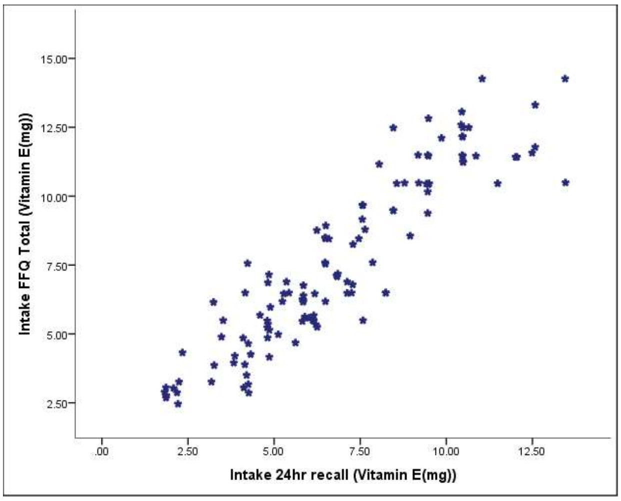

Figure 2: Scatter Plot Depicting Vitamin E Intake from FFQ and 24-Hour Dietary Recall in study population

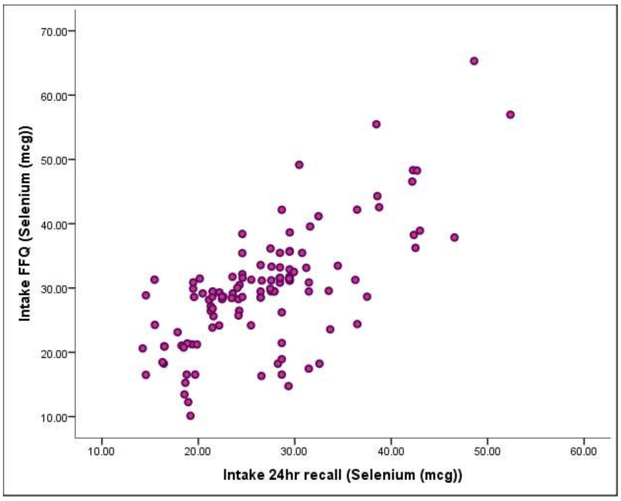

Figure 3: Scatter Plot Depicting Selenium Intake from FFQ and 24-Hour Dietary Recall in study population

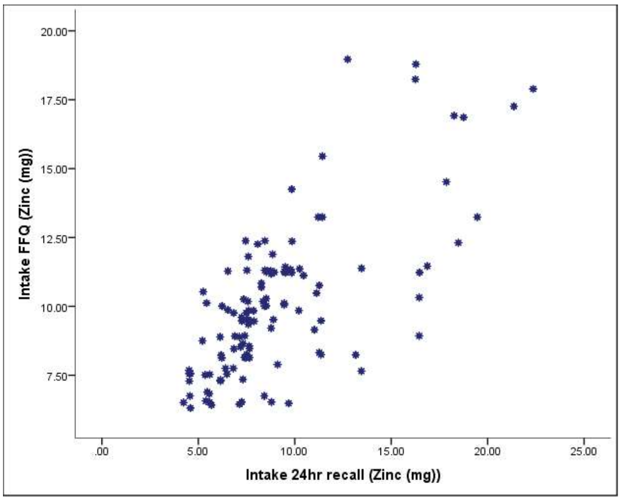

Figure 4: Scatter Plot Depicting Zinc Intake from FFQ and 24-Hour Dietary Recall in study population

Table 2: Mean intake and Pearson Correlation analysis between FFQ and 24-hour dietary recall

Nutrient	FFQ intake	Mean of 24-hour dietary recall intake	Pearson correlation (r)	P value
Total ascorbic acid(mg)	74.83 ± 23.26	72.99±22.01	0.909	p<0.001*
Vitamin E (mg)	7.59±3.09	6.86±2.83	0.915	p<0.001
Selenium (mcg)	29.75±9.06	27.01±7.59	0.696	p<0.001
Zinc (mg)	16.20±1.67	10.05±2.73	0.706	P=0.036**

*p<0.001 indicates significance at 0.01 level and **p=0.036 indicates significance at 0.05 level

Table 3: Correlation Coefficients of Food Frequency Questionnaire (FFQ) Validation Studies Across Different Regions and Populations in India

Study	Region	Population	Correlation Coefficient Range (r)
Hebert et al., 1998[18]	Kerala	General population	0.32–0.72
Hebert et al., 1999[19]	Gujarat	General population	0.55–1.00
Shaikh et al., 2017[20]	Vijayapura, South India	Adolescents	0.33–0.80
Pandey et al., 2005[21]	North India	Affluent individuals	0.49–0.90
Sajjanar et al., 2024[14]	North Karnataka	North Karnataka population	0.71–0.96

Discussion

Prediabetes is a crucial stage, and making necessary changes in lifestyle and diet is essential to delay the progression to T2DM.[4] Antioxidants play a major role in combating oxidative stress, and dietary antioxidants such as polyphenols, vitamins and minerals with antioxidant activity support endogenous antioxidants in counteracting free radicals,[5,22,23] emphasizing the need to assess the dietary intake of antioxidants in this population to develop appropriate nutrition interventions. The FFQ is an effective tool in dietary assessment to understand habitual intake and is often used to investigate the link between diet and chronic diseases.[24] The majority of research conducted in India has explored the use of FFQs to assess macronutrient intake, as well as some micronutrients, within the general population or specific age groups. However, no FFQ has specifically addressed the intake of antioxidant nutrients in prediabetic individuals as a target population

This study undertook a rigorous approach to assess the intake of key vitamins and minerals with antioxidant properties in prediabetic individuals, and validating the findings through a 24-hour DR as a reference, as there is no truly gold standard method.[16] Although biomarkers provide a more accurate measure for validity, multiple biomarkers and various determinants must be considered to select the appropriate assay for specific nutrient.[25]

The results of acquired responses in lifestyle and behavioral data, (Table 1) demonstrates the need to raise awareness of the importance of physical activity and consumption of fortified foods that contain these nutrients and supplements in maintaining good health and delaying the progression of T2DM.The correlation analysis (Table 2) demonstrate positive correlations for all these nutrients between FFQ and 24-hour DR indicating linear relationship between both the methods of assessment. Vitamin C (r=0.909) and vitamin E (r=0.915) showed strong correlations, while selenium(r=0.696) and zinc (r=0.706) showed moderate correlations, but the result was significant at 0.01 and 0.05 level respectively. The correlation coefficient range obtained in this study (0.69-0.91) are comparable to those reported in previous validation studies in India.[14,18-21](Table3)

The slightly lesser correlations for trace minerals such as selenium and zinc are attributed to various factors including, variability in the dietary sources of these minerals, lower concentration in foods, high within-person variability, and differences in individual recall accuracy. These nutrients are present in small quantities in wide range of foods and have a more variability in the intake both between individuals and within the same person over time. Hence, these trace minerals tend to have a lesser correlation value as reported in previous studies.[14,16-19,21,26] Despite the difference in the correlation strength, the significant positive correlation indicates that the developed FFQ is a reliable and valid tool for estimating the dietary intake of antioxidants in prediabetic individuals.

Strengths and Limitations:

A significant strength of this study is that FFQ was tailored to include region specific foods and was provided in regional language, making it more user friendly. The involvement of registered dietitians in focus group discussions during the development of food list further strengthened the validity of FFQ. Additionally, the participants were informed about the portion sizes and frequency of intake before the initial administration of the questionnaire, which avoided underreporting bias and enhanced the consistency of the study.

However, the study has certain limitations. The length of the FFQ (208 items) might have caused fatigue in the participants. Other sources of inaccuracy could be factors that are usually related to the use of the FFQ in general, such as the fixed list of foods, recall memory of the participants, interpretation of questions, and seasonal variations. [17] However, as most of the fruits and vegetables are available throughout the year, and since the study was conducted during the summer season, it ensured the inclusion of a wide variety of fruits in dietary assessment.

Conclusion

In summary, this study is the first attempt to develop and validate a food frequency questionnaire specifically designed to assess the intake of antioxidants in the diet of prediabetic individuals in the Tamil Nadu region. Despite certain limitations, the FFQ, comprising 208 items could be used in epidemiological studies to understand dietary intake in a large population to develop necessary interventions. Overall, this study supports the validity of this FFQ as a dietary assessment tool for vitamin C, vitamin E, selenium, and zinc in prediabetic individuals.

Future Directions

Future work should focus on including other key antioxidant nutrients in the questionnaire and examine the relationship between biochemical markers and factors such as smoking, alcohol consumption, intake of fortified foods and supplements, and physical activity levels in relation to plasma antioxidant status. Additionally, the values currently available in the IFCT database represent raw ingredients and this FFQ is designed for ingredients rather for whole foods. Future work should focus on developing a questionnaire that includes standardized recipes for commonly consumed antioxidant-rich foods, incorporating frequently consumed beverages such as coffee and tea. Cross validation against biochemical markers of antioxidant status should be considered in future studies. [25]This FFQ, can be refined and validated for use in the general population and extrapolated to other parts of India according to regional dietary habits.

Approval of Institutional Ethical Review Board (with name of board & approval letter number) This study was approved by the Sri Ramachandra Institutional Ethical Committee for the clinical evaluation of drugs in India. (IEC/22/SEP/174/58).

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Individual Authors' Contributions: SR: Conceptualization, Methodology, Investigation Writing - Original Draft, Writing - Review and Editing **SV:** Validation, Supervision, Resources, Writing – Review and Editing **RM:** Visualization, Project Administration **SK**: Supervision, Validation

Availability of Data: The manuscript incorporates all datasets produced or analyzed throughout this research study, including the scattered plots representing the data points, but the raw data used for analysis are not publicly available.

Informed consent: Informed consent was obtained from the participants.

No use of generative AI tools This article was prepared without the use of generative AI tools for content creation, analysis, or data generation. All findings and interpretations are based solely on the authors' independent work and expertise.

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