Socioeconomic Disparities in Flavonoid Consumption and Breast Cancer Risk: A Study Investigating the Effects of Dietary Counseling in Chennai, India

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ABSTRACT

Introduction: Breast cancer (BC) is a significant public health concern, with India exhibiting a high incidence rate (28.2% of all female cancers). Conventional treatments such as chemotherapy and surgery are effective, but often come with debilitating side effects. Dietary interventions, particularly those involving flavonoid-rich foods, offer a promising complementary strategy for breast cancer prevention. This study is aimed to explore variations in the intake of flavonoid rich food in relation to an individual's Body Mass Index (BMI).

Material and Methods: This longitudinal study was conducted among women at risk of breast cancer in Ramapuram, Chennai. A total of 342 participants were evaluated at baseline, 14th day, and 21st day of follow up. Dietary counseling emphasized the consumption of flavonoid-rich foods, such as berries, fruits, and vegetables.

Results: Results showed significant increases in the consumption of flavonoid-rich foods, with berry consumption rising notably and vegetable intake frequency exceeding seven times per week among 20.2% of participants by the 21st day follow-up. A strong relationship was found between Body Mass Index (BMI) categories and flavonoid-rich food intake, with "Obese Class I" participants demonstrating higher fruit consumption compared to their "Normal weight" and "Overweight" counterparts.

Conclusion: This study advocates for integrative public health strategies emphasizing dietary modifications to reduce cancer risks, particularly in vulnerable populations. The findings of this study underscore the importance of tailored dietary counseling in promoting sustainable eating habits and mitigating chronic disease risks, including breast cancer.

Keywords: Flavanoid, Breast Cancer, Diet Counselling

INTRODUCTION

According to GLOBOCAN 2020 estimates, cancer incidence and mortality are rising quickly globally, due to the population's aging, changes in the prevalence and distribution risk factors for cancer[1]. Breast cancer (BC) is the commonest malignancy among women globally. It has now surpassed lung cancer as the leading cause of global cancer with approximately 2.3 million new cases worldwide each year according to GLOBOCAN 2020. Around 80% of BC patients are over 50 years old[2]. Breast cancer is the most common cancer in India, accounting for 28.2% of all female cancers[3]. Breast cancer treatment depends on the type and stage of cancer, as well as individual patient factors. Risk identification among the general population involves developing prediction models relevant to a specific population[4]. Common treatments for breast cancer encompass surgical options such as lumpectomy or mastectomy, as well as radiation, chemotherapy, hormone therapy, targeted therapy, and immunotherapy[5]. However, these treatments are associated with various side effects, including skin irritation, fatigue, swelling, scarring, hair loss, mood swings, osteoporosis, and cardiovascular complications. Chemoprevention involves using natural or synthetic substances to prevent or delay the development of cancer. This approach is aimed at either preventing cancer in individuals at high risk or reducing the likelihood of cancer recurrence[6].

Flavonoids, which are found in fruits, vegetables, and plant-based products like green tea and wine, offer significant health benefits. Their effectiveness is attributed to their antioxidant, anti-inflammatory, anti-mutagenic, and anti-carcinogenic properties, along with their ability to modulate essential cellular enzymes. Flavonoids impact cancer through various mechanisms, such as modulating reactive oxygen species (ROS), arresting the cell cycle, inducing apoptosis, and inhibiting cancer cell proliferation

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How to cite this article: Poonguzhali Kannan, Gayathiri R, Lubna Fathima, Prabu D, Rajmohan M, Dinesh Dhamodhar, Sindhu R, Indira Nehru. Socioeconomic disparities in flavonoid consumption and breast cancer risk: a study investigating the effects of dietary counseling in Chennai, India. International Journal of Contemporary Medical Research 2025;12(4):D1-D9.

and invasiveness. They act as antioxidants in normal conditions and as pro-oxidants in cancer cells, triggering apoptosis and reducing inflammation[7]. Key flavonoids that have demonstrated potential in breast cancer prevention include Anthocyanin, Epigallocatechin-3-gallate, Genistein, Daidzein, Tangertein, Quercetin, Luteolin, Silibinin, Kaempferol, Apigenin, Epicatechingallate, Epigallocatechin[8].

Anthocyanin belongs to the class of water-soluble flavonoids widely present in fruits and vegetables. Dietary sources of anthocyanins include red and purple berries, grapes, apples, plums, cabbage, or foods containing high levels of natural colorants[9]. Epigallocatechin-3-gallate (EGCG) is a natural polyphenol, which is most abundant and powerful antioxidant in green tea for cancer chemoprevention[10]. Genistein is one of the numerous recognized isoflavones that is found in a variety of soybeans and soy products, including tofu and tofu products. Daidzein has a chemical structure similar to that of mammalian oestrogen and acts in two directions by either replacing or influencing the ER complex, oestrogen receptor, and the hormone oestrogen. It is found in foods produced from soy, such as textured soy protein, soy flour, and soy protein isolates, as well as tofu, tempeh, and miso. Additionally, supplementary flours made from wheat, rice and maize are fortified with soy flour[11]. Tangertein (TGN) is a key member of flavonoids that is extensively found in citrus fruits[12]. Quercetin, a plant pigment is a potent antioxidant, found mostly in onions, grapes, berries, cherries, broccoli, and citrus fruits[13]. Luteolin, is a common flavonoid that exists in many types of plants including fruits, vegetables, and medicinal herbs[14]. Silibinin's most common source is milk thistle[15]. Kaempferol is an antioxidant found in fruits and vegetables such as apples, grapes, broccoli, spinach and green tea[16]. Fresh parsley, vine spinach, celery seed, green celery heart, Chinese celery, and dried oregano are dietary sources with high apigenin concentration[17]. Epicatechin gallate (ECG) and Epigallocatechin (EGC) are primarily found in green tea and some other plant-based foods. I t is closely related to epigallocatechin gallate (EGCG).

While some studies indicate that consuming flavonoid-rich foods, particularly those containing flavones and flavanols, may lower the risk of breast cancer[18], other research suggests that a general diet rich in flavonoids could provide protective benefits against breast cancer in menopausal women[19]. The aim of the current study is to assess the difference in the intake of flavonoid rich foods post dietary counselling, which is linked to prevention of breast cancer. It is done by documenting a 7-day dietary history of the study participants who are at risk for developing breast cancer at baseline, 14th day and 21st day. Furthermore, the study aims to explore variations in flavonoid intake in relation to individual's body mass index (BMI), as dietary habits and access to certain foods can influence BMI.

MATERIALS AND METHODS

Study design and population

This longitudinal study was designed to record the dietary history over seven days, with follow-up assessments at the baseline (7th day), 14th and 21st days, to observe changes in flavonoid consumption following dietary counselling. The study was conducted at Ramapuram, Chennai, India, from May 2024 to July 2024. Participants were randomly selected based on their responses to breast cancer risk factors. The study included female participants who displayed more than 50% of the identified breast cancer risk factors. Individuals with fewer than 50% of the risk factors were excluded.

Data collection

Data were collected via a questionnaire administered by an interviewer, covering demographics and breast cancer risk factors as specified by the CDC[20]. These risk factors includes, being 50 years or older, starting menstruation before age 12, experiencing menopause after age 55, history of breast cancer or having a first-degree relative or multiple family members with breast or ovarian cancer, received radiation therapy before age 30, exposure to diethylstilbesterol (DES), and sedentary lifestyle, overweight or obesity, prolonged hormone replacement therapy with both oestrogen and progesterone (for more than 5 years), having a first pregnancy after age 30, never having a full-term pregnancy, not breastfeeding, and alcohol consumption.

Participants' dietary history was documented over a 7-day period at three intervals: baseline, the 14th day, and the 21st day, to assess their flavonoid intake. They were instructed to record the content and timing of their food. After reviewing the dietary history at the end of 7th and 14th day, dietary counselling was provided to promote increased consumption of flavonoid-rich foods, such as those high in Anthocyanin, Epigallocatechin-3-gallate, Genistein, Daidzein, Tangertein, Quercetein, Luteolin, Silibinin, Kaempferol, Apigenin, Epicatechingallate, Epigallocatechin. The final dietary history was collected at the end of 21st day to check the progress in consumption of flavonoid rich food post dietary counselling.

METHODOLOGY

Sample size estimation:

Based on Chennai's reported breast cancer prevalence rate of 30.2%[21], we calculated the sample size (n = 337) using the formula $4pq/L^2$, with p = prevalence of breast cancer, q = 100-p, and L = precision set at 5%. To accommodate 10% potential attrition, the sample size was increased to 374.

STATISTICAL ANALYSIS

All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 24 (IBM, Chicago, IL). The data were screened for normality using the Kolmogorov-Smirnov test, which indicated significant deviations from normality ($p < .05$). Consequently, non-parametric tests were employed for subsequent analyses. Descriptive statistical analyses were conducted to characterize the study sample. To investigate the relationship between flavonoid-rich food intake and BMI, a Kruskal-Wallis test was conducted to compare means and examine correlations. The alpha level was set at .05 for determining statistical significance.

RESULTS

A follow-up study was employed to examine changes in the intake of flavonoid-rich food among women participants residing in Ramapuram, Chennai, at three assessment periods: baseline, 14th-day follow-up, and 21st-day follow-up, following dietary counseling (May 2024-July 2024). Of the 390 eligible participants, 27 were excluded based on inclusion criteria, and 11 declined to participate. Participant attrition occurred throughout the study, with 10 individuals lost to follow-up (8 at the 14th-day assessment and 2 at the 21st-day assessment), resulting in a final sample of 342 participants for data analysis. Flavonoid-rich food intake was grouped into three categories for enhanced data interpretation: Berries (raspberry), Fruits (apple, guava, pomegranate), and Vegetables (ladies' finger, moringa leaves, snake gourd, carrot, cabbage, radish, and bell pepper).

More than one-third (34.8%) of the participants were aged 50 years or older. Most participants (67.3%) reported Hinduism as their religious affiliation. The study participants' educational qualifications were categorized according to the Modified Kuppuswamy scale for socio-economic status. Participants' educational attainment was as follows: 23.4% were graduates, and 4.1% were illiterate. Overweight prevalence was 39.5% among participants (see Table 1).

Results of the Chi-Square Goodness-of-Fit test indicated that the observed distribution of participants with risk factor exposure differed significantly from expected proportions, $\chi 2$ (df) = 1, $p < 0.001$ and $p < 0.05$. Results indicated that the sample's distribution of risk factors did not significantly deviate from expected proportions, as shown in Table 2.

Results showed that dietary counseling yielded a significant increase in berry consumption, such that the percentage of participants reporting no consumption decreased from 21.3% at baseline to 1.8% at post-intervention. At the 21st-day follow-up assessment, approximately 27.2% of participants reported consuming berries with a frequency of twice per week (see Figure 1).

Results showed a substantial increase in fruit consumption, with the percentage of participants reporting no consumption decreasing from 21.3% at baseline to 1.8% post-intervention. By the 21st-day follow-up, 27.2% of participants reported consuming fruits twice per week, indicating successful habit formation (see Figure 2).

Results showed that 96.5% of participants reported consuming vegetables before study initiation, indicating widespread pre-existing habits. The results showed that 20.2% of participants boosted their weekly vegetable consumption to over 7 times following diet counseling at the 21st-day follow-up assessment (see Figure 3).

Kruskal-Wallis test indicated no significant differences in berry consumption across BMI categories, $\chi 2$(df) = 7, $p > 0.05$.Results revealed a significant difference in the intake of fruits high in flavonoids, $\chi 2$(df) = 7, $p < 0.05$.[Baseline: 27.28 (7), N=342, p<0.001; 14th day of follow-up: 16.00 (7), N=342, p=0.025; and 21st day of follow-up: 14.87 [7], N=342, p=0.038] and vegetables [Baseline: 18.95 [7], N=342, p=0.008]across BMI categories [Table 3].

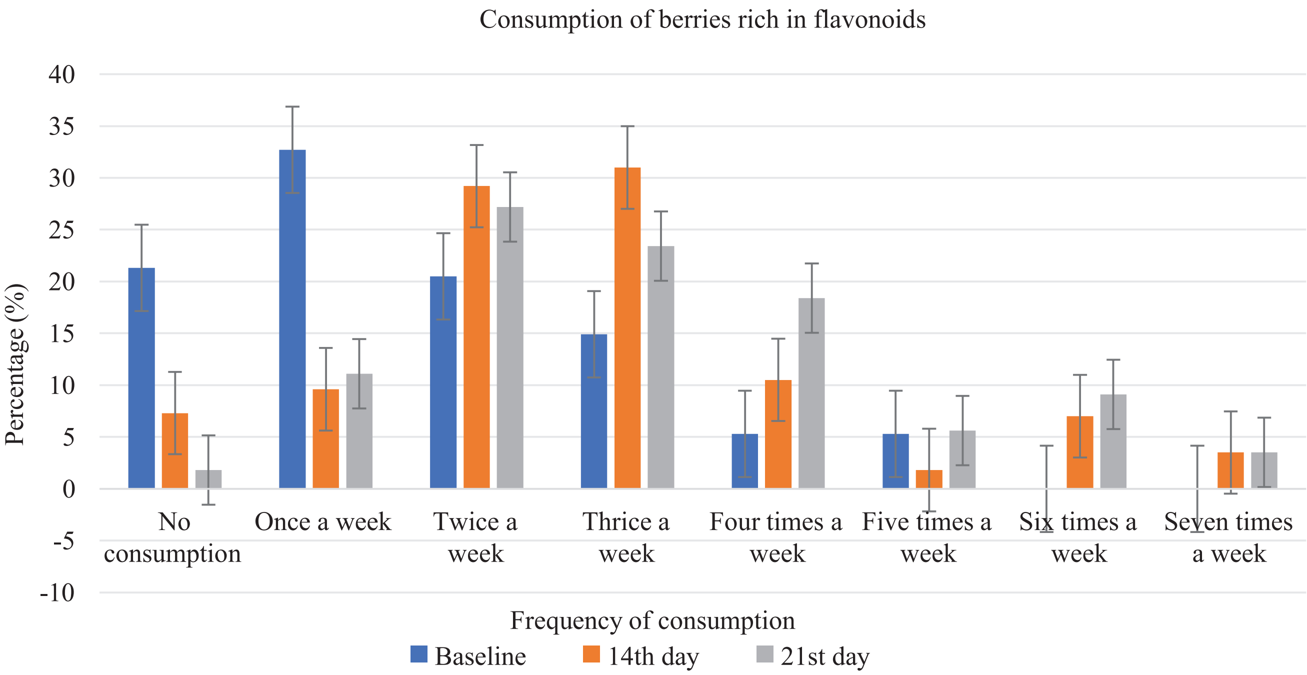

Figure-1: Distribution of Berry Consumption Across Time: Baseline, 14-Day, and 21-Day Follow-Up, by Frequency per Week

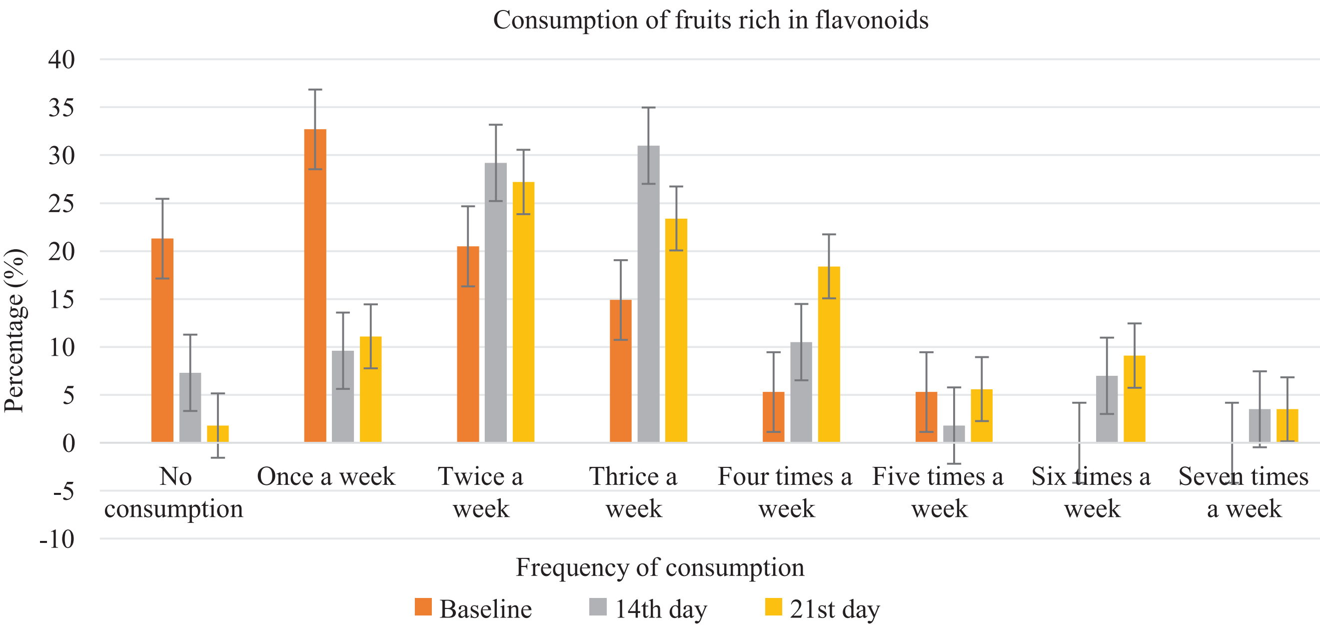

Figure-2: Changes in Fruit Consumption Over Time: Distribution Across Baseline, 14-Day, and 21-Day Follow-Up Assessments by Frequency per Week

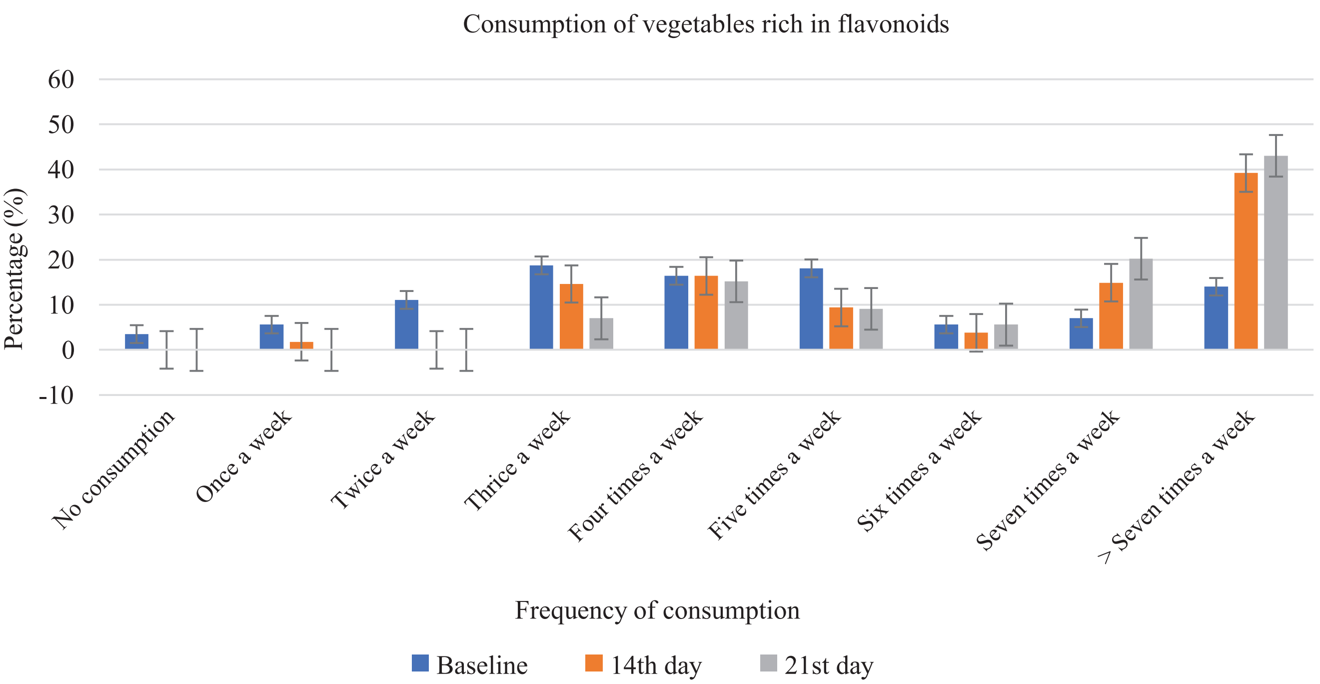

Figure-3: Changes in Vegetable Consumption Over Time: Distribution Across Baseline, 14-Day, and 21-Day Follow-Up Assessments by Frequency per Week

The outcomes of post hoc analysis indicated that the 'Obese Class I' group consumed significantly more fruits than the 'Overweight', 'Normal weight', and 'Underweight' groups ($p < 0.001$, $p < 0.001$, and $p = 0.037$, respectively) across the study period. Results showed that at baseline, vegetable consumption was significantly greater in the 'Overweight' and 'Obese Class I' groups than in the 'Normal weight' group ($p = 0.041$ and $p = 0.025$, respectively) [Table 4].

DISCUSSION

In this follow-up study assessing the impact of dietary counseling on the intake of flavonoid-rich foods, including berries, fruits, and vegetables, among women in Ramapuram, Chennai, repeated assessments were conducted over three follow-up periods to evaluate changes in dietary behavior following dietary counselling. The findings emphasize the efficacy of dietary interventions in promoting healthier eating patterns, with notable effects on BMI and the prevention of chronic diseases, such as breast cancer. The intervention resulted in a significant increase in the consumption of flavonoid-rich foods across all categories. For instance, the proportion of participants reporting no berry consumption decreased

Groups		Frequency (n)	Percentage %
Age	≤20 years	7	2
	21-29 years	19	5.6
	30-39 years	87	25.4
	40-49	110	32.2
	>50 years	119	34.8
Religion	Hindu	230	67.3
	Christian	62	18.1
	Muslim	50	14.6
Body Mass Index (BMI)	Severely underweight: <16	5	1.5
	Underweight: 16-17	13	3.8
	Mildly underweight: 17-18.5	23	6.7
	Normal weight: 18.5-24.9	89	26.0
	Overweight: 25-29.9	135	39.5
	Obese class I: 30-34.9	53	15.5
	Obese class II: 35-39.9	14	4.1
	Obese class III: >40	10	2.9
Educational qualification	Illiterate	14	4.1
	Primary school	32	9.4
	Middle school	48	14.0
	High school	66	19.3
	Intermediate / diploma	73	21.3
	Graduate	80	23.4
	Professional	29	8.5

Table-1: Demographic characteristics of study samples

Exposure to risk factor		N (%)	χ^2	df	*p*-value
Age >50 years	Yes	119 (34.8)	214.544	4	<0.001**
	No	223 (65.2)			
Starting menstrual periods before age 12	Yes	225 (65.8)	34.105	1	<0.001**
	No	117 (34.2)			
Starting menopause after age 55	Yes	64 (18.7)	133.906	1	<0.001**
	No	278 (81.3)			
Breast cancer survivor	Yes	2 (0.6)	334.047	1	<0.001**
	No	340 (99.4)			
First-degree relative or multiple family members diagnosed with breast or ovarian cancer	Yes	5 (1.5)	322.292	1	<0.001**
	No	337 (98.5)			
Radiation therapy before 30 years of age	Yes	2 (0.6)	334.047	1	<0.001**
	No	340 (99.4)			
Exposure to the drug diethylstilbestrol (DES).	Yes	11 (3.2)	433.807	3	<0.001**
	No	295 (86.3)			
	Don't Know	36 (10.5)			
Sedentary behavior	Yes	193 (56.4)	5.661	1	0.017*
	No	149 (43.6)			
Overweight or obese	Yes	212 (62.0)	19.661	1	<0.001**
	No	130 (38.0)			
Hormone replacement therapy (those that include both estrogen and progesterone) taken for > 5 years	Yes	27 (7.9)	242.526	1	<0.001**
	No	315 (92.1)			
First pregnancy after age 30	Yes	139 (40.6)	11.977	1	<0.001**
	No	203 (59.4)			
Never had a full-term pregnancy	Yes	59 (17.3)	146.713	1	<0.001**
	No	283 (82.7)			
Never breast fed	Yes	38 (11.1)	206.889	1	<0.001**
	No	301 (88.9)			
Alcohol consumption	Yes	18 (5.3)	273.789	1	<0.001**
	No	324 (94.7)			

N= number of study participants; χ^2=chi square; df=degree of freedom; **p<0.001, *p<0.05 is considered as statistically significant.

Table-2: Distribution of exposure to risk factor: Chi-Square Goodness-of-Fit test

Groups	Subgroups	BMI	N	Mean Rank	χ^2	*p* value
Berries	Baseline	Severely underweight	5	171.50	0.000	1.000
		Underweight	13	171.50		
		Mildly underweight	23	171.50		
		Normal weight	89	171.50		
		Overweight	135	171.50		
		Obese class I	53	171.50		
		Obese class II	14	171.50		
		Obese class III	10	171.50		
	14th day of follow-up	Severely underweight	5	209.40	8.330	0.304
		Underweight	13	180.46		
		Mildly underweight	23	170.74		
		Normal weight	89	179.43		
		Overweight	135	161.27		
		Obese class I	53	176.49		
		Obese class II	14	189.86		
		Obese class III	10	158.10		
	21st day of follow-upw	Severely underweight	5	134.00	6.552	0.477
		Underweight	13	195.15		
		Mildly underweight	23	168.57		
		Normal weight	89	171.52		
		Overweight	135	174.79		
		Obese class I	53	155.91		
		Obese class II	14	185.21		
		Obese class III	10	185.15		
Fruits	Baseline	Severely underweight	5	170.00	27.284	<0.00w1**
		Underweight	13	207.73		
		Mildly underweight	23	185.02		
		Normal weight	89	187.31		
		Overweight	135	179.12		
		Obese class I	53	112.21		
		Obese class II	14	148.54		
		Obese class III	10	196.85		
	14th day of follow-up	Severely underweight	5	171.10	16.005	0.025*
		Underweight	13	185.73		
		Mildly underweight	23	188.07		
		Normal weight	89	185.49		
		Overweight	135	168.68		
		Obese class I	53	129.50		
		Obese class II	14	204.64		
		Obese class III	10	204.85		
	21st day of follow-up	Severely underweight	5	187.70	14.871	0.038*
		Underweight	13	195.42		
		Mildly underweight	23	192.98		
		Normal weight	89	190.01		
		Overweight	135	163.65		
		Obese class I	53	134.77		
		Obese class II	14	194.43		
		Obese class III	10	186.75		

Table 3 Continue to next page

Groups	Subgroups	BMI	N	Mean Rank	χ^2	*p* value
Vegetables	Baseline	Severely underweight	5	182.30	18.950	0.008*
		Underweight	13	204.62		
		Mildly underweight	23	187.96		
		Normal weight	89	187.70		
		Overweight	135	145.19		
		Obese class I	53	197.82		
		Obese class II	14	178.36		
		Obese class III	10	147.05		
	14th day of follow-up	Severely underweight	5	189.70	13.878	0.053
		Underweight	13	181.15		
		Mildly underweight	23	203.13		
		Normal weight	89	193.40		
		Overweight	135	157.00		
		Obese class I	53	156.75		
		Obese class II	14	187.25		
		Obese class III	10	134.15		
	21st day of follow-up	Severely underweight	5	182.10	9.635	0.210
		Underweight	13	174.54		
		Mildly underweight	23	196.00		
		Normal weight	89	188.00		
		Overweight	135	155.83		
		Obese class I	53	173.85		
		Obese class II	14	185.29		
		Obese class III	10	138.85		

N= number of study participants; χ^2=chi square; df (degree of freedom) is 7; **p<0.001, *p<0.05 is considered as statistically significant

Table-3: Kruskal-Wallis Test Results: Relationship Between Flavonoid Intake From Food Sources and BMI Categories

		Reference group	Comparison group	Mean difference	Sig
Fruit consumption	Baseline	Obese Class I	Overweight	66.91	<0.001**
		Obese Class I	Normal weight	75.10	<0.001**
		Obese class I	Underweight	95.52	0.037*
	14th day of follow-up	Obese Class I	Normal weight	55.99	0.022*
	21st day of follow-up	Obese Class I	Normal weight	55.23	0.028*
Vegetable consumption	Baseline	Overweight	Normal weight	42.51	0.041*
		Overweight	Obese Class I	-52.62	0.025*

**p<0.001, *p<0.05 is considered as statistically significant

Table 4. Kruskal-Wallis Post Hoc Analysis: Pairwise Comparisons of Fruit and Vegetable Consumption Across BMI Categories

markedly from 21.3% at baseline to 1.8% by the 21-day follow-up. Similarly, fruit and vegetable intake showed substantial improvement, with 20.2% of participants increasing their vegetable consumption frequency to more than seven times per week by the end of the study. These results demonstrate that dietary counseling serves as an effective strategy for fostering sustainable dietary habits, particularly among populations at elevated risk for non-communicable diseases[22].

In line with the study by Amireault et.al, the present study emphasizes the need for tailored, integrative interventions targeting multiple health behaviors to achieve comprehensive benefits for populations at risk of chronic diseases like cancer[23]. A study conducted by Li et.al, emphasizes the potential of dietary natural products, such as soy, citrus fruits, and cruciferous vegetables, in reducing breast cancer risk, aligning with our study's findings with 27.2% of participants reporting consuming fruits twice daily[24].On another study conducted by Minjung Cheon et.al, showed that intake of flavonoids was associated with reduced risk of cancer recurrence, particularly in obese breast cancer patients[25], with 22.5% of obese participants in our study. The results of the study conducted by Ujjwal Das et.al, confirm the role of menstrual and reproductive factors in breast cancer in Indian women. Creating awareness and providing knowledge on cancer could be key strategies for the reduction of breast cancer in Indian reproductive age group women[26]. A study conducted by Ulrike Haug et.al, found that first-degree relatives of breast cancer patients had an increased perception of cancer risk (higher than average in 24% of cases) and showed greater motivation to adopt healthier lifestyle changes, highlighting their potential as a key target group for preventive interventions[27]. 1.5% of participants had first degree relatives with breast cancer in our study. A study by Alison Stuebehas consistently shown that never breastfeeding is associated with an elevated risk of premenopausal breast cancer. A significant body of evidence indicates that women who never breastfed exhibit a 2.4-fold increased incidence of premenopausal breast cancer compared to their counterparts who have ever breastfed[28]. In our study, about 11.1% of the participants had never breast fed.

This study has few inherent limitations that should be acknowledged. First, the follow-up periods, which were conducted at baseline, 14 days, and 21 days, were relatively short, potentially restricting our ability to capture long-term dietary impacts on health outcomes. Additionally, the study did not include a quantitative assessment of food intake, which could have provided more precise insights into the relationship between diet and cancer incidence. Furthermore, the generalizability of our findings is limited by the characteristics of the study population. Participants' dietary preferences may have been influenced by the availability of foods within their specific demographic and cultural context. This limitation means that our results may not accurately reflect the dietary habits or health outcomes of broader populations with different food environments or cultural practices. Consequently, caution should be exercised when attempting to extrapolate our findings to other groups or settings.

CONCLUSION

The growing incidence of breast cancer in India necessitates comprehensive public health strategies. Promoting dietary changes to increase flavonoid intake, alongside broader public health efforts, may be pivotal in addressing this trend. This study's findings revealed significant disparities in flavonoid consumption across different classes of BMI, underscoring potential inequalities in diet quality and access to health-promoting foods. However, longitudinal and clinical studies are essential to confirm the efficacy of flavonoid-rich foods in preventing breast cancer through dietary counseling.

Informed consent:
Was obtained from the study participants

Acknowledgements
Nill

Funding: Nill

Conflict of interest: The authors declare no conflict of interest.

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Source of Support: Nil; **Conflict of Interest:** None

Submitted: 22-02-2025; **Accepted:** 27-03-2025; **Published:** 30-04-2025