



OPEN The use of functional foods and its association to chronic and multimorbid conditions: a cross-sectional study among Bangladeshi people

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Functional foods significantly impact health outcomes, particularly in the preventing and managing chronic diseases. However, there is a lack of studies in Bangladesh on the association between functional consumption and health outcomes in the adult population. This study aimed to explore the use of functional foods and their association with chronic multimorbidity among the adult population in Bangladesh. The study was conducted on 966 people in the southern region of Bangladesh. Data were collected on sociodemographic and lifestyle characteristics, chronic diseases, frequency of functional food consumption, and influencing factors. Binary logistic regression showed that respondents who consumed nuts weekly (OR = 0.58); natural products monthly (OR = 0.48); honey weekly (OR = 0.50), and egg occasionally (OR = 0.29) were less likely odds to chronic diseases. Furthermore, people who consumed probiotics daily (OR = 0.55) and monthly (OR = 0.39); prebiotics daily (OR = 0.19) and weekly (OR = 0.33); seeds monthly (OR = 0.51); tea and coffee daily (OR = 0.49), and black cumin daily (OR = 0.33) had lower odds to multimorbid condition. These results will support relevant policymakers in taking practical actions to improve healthy dietary practices with functional foods at the community level to prevent chronic multimorbidity in Bangladesh.

Keywords Dietary habit, Food consumption, Bioactive compounds, Non-communicable diseases, Comorbidity, Nutraceuticals

Abbreviations

FF	Functional foods
NCD	Non-communicable diseases
WHO	World health organization
CVD	Cardiovascular diseases
LDL	Low density lipoprotein
HDL	High density lipoprotein
CI	Confidence interval
OR	Odds ratio
USD	US dollar

Functional foods are defined as foods intended for consumption as part of a regular diet that offers specific health benefits beyond essential nutrition¹. They are primarily found in both conventional and modified food. The former, also known as “unmodified,” is composed of natural or whole food ingredients that contain functional substances. Examples of conventional functional foods include plant-based foods such as fruits,

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vegetables, herbs, cereals, nuts, beans, and fish. The latter is fortified with essential nutrients such as juices, dairy products, fortified eggs, and seafood². In South Asian countries, including Bangladesh, functional foods such as herbs and spices (turmeric, black pepper, cloves, cinnamon, ginger, garlic, etc.), seeds (black cumin, pumpkin, sesame, etc.), natural products (oyster mushroom, fenugreek, honey, etc.), and fermented yogurt are commonly used to prevent and manage chronic diseases^{3–5}. A study showed that regular consumption of functional foods can improve clinical outcomes in patients with comorbidity conditions⁶. Numbers of studies revealed that numerous phenolic compounds in herbs and spices, such as turmeric, cloves, garlic, ginger, and fenugreek, have anti-inflammatory and antioxidant properties that help lower multimorbidity, including protection from cancer, arthritis, and cardiovascular diseases^{3–5}. Additionally, omega-3 fatty acid-rich foods such as flaxseeds, walnuts, and fatty fish are associated with a lower risk of cardiovascular conditions such as hypertension and coronary artery disease^{2,4,6}. Food rich in dietary fiber, such as oat bran, chia seeds, and psyllium herbs, as well as fermented items such as probiotics, reduces the risk of gastrointestinal disorders, particularly inflammatory bowel diseases^{7–9}. In addition to these foods, whole grains, different citrus fruits, dry fruits, and eggs have numerous therapeutic properties that prevent chronic diseases, as a functional food^{4,6,10}.

Notwithstanding the numerous health benefits of functional foods, staple diets in South Asian countries, particularly Bangladesh, are heavily reliant on rice¹¹. In Bangladesh, rice is an indispensable part of daily meals, accounting for approximately two-thirds of the daily diet, along with vegetables, small amounts of pulses, and fish¹¹. In addition, there are differences in dietary habits between urban and rural areas of Bangladesh. A study in the southern districts of Bangladesh found that the primary dietary items in rural areas were mostly carbohydrate food sources and fish, whereas in urban areas that were sugary beverages and meat products¹². Furthermore, owing to urbanization and globalization, fast foods and soft drinks are becoming popular in Bangladesh, particularly for the younger generation¹³. However, traditional dietary patterns often include mainly carbohydrate-source foods and recent dietary trends in fast- and high-sugar foods in Bangladesh, which do not adequately meet nutritional needs¹⁴. Consequently, the prevalence of diet-related chronic diseases have increased in Bangladesh in recent years¹⁵. According to the World Health Organization, in 2021, NCDs accounted for an estimated 67% of all deaths in Bangladesh¹⁶. Recent studies demonstrated that the prevalence of chronic diseases with double and triple burdens in Bangladesh is alarming^{15,17}. Furthermore, diabetes, high blood pressure, and being overweight or obese are becoming common burdens for individuals aged 18–69 years in Bangladesh¹⁸. Multimorbidity is particularly concerning, with an estimated prevalence of 8.4% among adults and significantly higher rates (54%) among older adults in rural areas^{19,20}. Considering all these, health conditions, specific healthcare and the most crucial healthy dietary habits are highly required in Bangladesh.

With the growing body of evidence of the higher prevalence of chronic diseases in Bangladesh and, at the same time, the existing health benefits of functional foods for chronic diseases, there is a need to explore whether functional consumption can act as a protective factor against chronic and multimorbid conditions in Bangladesh. Understanding these associations is crucial for developing functional foods-based dietary practices to improve the health outcomes. Therefore, it is essential to explore the use of functional foods and their association with chronic multimorbidity in Bangladesh. Although numerous studies^{7,10,21–24} have examined the relationship between functional food consumption and chronic diseases in various countries, comprehensive research on this topic in Bangladesh is lacking. Hence, this cross-sectional study aimed to fill this gap by determining the consumption patterns of functional foods and their associated factors in people with chronic and multimorbidity conditions in Bangladesh. These findings will contribute to the development of culturally appropriate dietary recommendations for individuals with chronic multimorbidity and support relevant policymakers in formulating effective strategies to increase functional food consumption at the community level in Bangladesh.

Methods and materials

Study setting

A cross-sectional study of the adult population was conducted in the southern region of Bangladesh. The survey was conducted from May 20 to June 30, 2023. We collected data from the Jashore, Magura, and Jenaidah districts, located in the southern part of Bangladesh. We conveniently selected one upazila (subdistrict) from each district to collect data. Then, we chose one urban and two rural locations from each upazila. These regions were selected because of their vulnerable health statuses. In 2016, the Bangladesh Health Ministry reported that 94,743, 14,995, and 18,220 cases suffered from relevant chronic morbidities (diarrhea, gastroenteritis, hemorrhages, myocardial infection, chronic obstructive pulmonary diseases, hypertension, stroke, and others). Furthermore, in terms of mortality, in 1911, 490 and 2777 deaths were primarily related to chronic diseases in the same year^{25–27}.

Participants

We followed some eligibility criteria in terms of recruiting participants in the study, these are: (i) being an adult (age ≥ 18 years), (ii) participants who did not maintain any special diet to prevent or manage chronic diseases (such as diabetes, high cholesterol, myocardial infarction, stroke, and others), (iii) physical and mental abnormalities, and (iv) women who were not pregnant or lactating at the time of data collection. We set these criteria because they can affect a person's usual diet, followed by previous studies^{22,28,29}.

Sample size

The required sample size was calculated using the following parameters, as per a previous study conducted in Bangladesh^{30,31}. Whereas, n = number of samples, z = 1.96 (95% confidence level), p = prevalence estimate (50%); as no study found in Bangladesh, q = $(1 - p)$, d = precision limit or proportion of sampling error (5%). So, $n = 1.962 \times 0.5 \times (1 - 0.5) / 0.052 \sim 384.16$. The use of this formula is justified by its ability to establish equilibrium between statistical robustness and practical effectiveness. The conservative assumption of 50% prevalence ensures the sufficiency of the estimated sample size over a spectrum of prevalence situations. With a corresponding

Z-score of 1.96 and a 95% confidence level that complies with accepted epidemiological norms, we can be confident in the accuracy of our estimations. By conducting a face-to-face survey, we collected 1022 samples from the respondents. We then excluded samples that were incomplete or missing any data from the collected survey questionnaire. Finally, the study sample consisted of 966 individuals, following the exclusion criteria.

Survey tool and data collection procedures

A structured questionnaire was used to collect data on sociodemographic and lifestyle variables, the frequency of functional food intake, and influencing factors. The questionnaire was reviewed by a public health nutrition expert and a clinical dietician, similar to a previous study³². The questionnaire was adjusted and modified in response to valuable feedback and corrections. Before the final survey, the questionnaire was pilot tested with small samples ($n=40$) in face-to-face surveys to clarify and eliminate irrelevant and repeated items. In order to make the questionnaire, more straightforward to comprehend, and more reliable, it was initially developed in English and then translated into Bengali, the respondents' native tongue.

Eight pre-trained interviewers conducted the face-to-face interviews. The interviewers had educational backgrounds in nutrition and diet, and had experience running health surveys. Interviewers were also trained on study instruments, participant recruitment, data collection procedures, and relevant ethical considerations. First, data were obtained from participants who visited the household. Anthropometric measurements (height and weight) were self-reported. If the respondents could not report, we measured their height and weight using a scale stadiometer and a digital weight balance. Subsequently, prescriptions and medical reports were reviewed by a registered physician to ensure the accuracy of the data, mainly to confirm chronic disease status. Before data collection, the enumerator reassured respondents that the information they supplied would be confidential. To complete one interview, the participants needed 15 to 20 min per sample.

Outcome variables

The primary outcome variables for this study were chronic diseases, including hypertension, heart disease, hypocalcemia, dementia, anemia, and chronic obesity^{21,22}. Respondents with two or more diseases were considered to have multimorbidity³³.

Explanatory variables

The explanatory variables examined in this study encompassed sociodemographic information (sex: male, female; Age: 18–29 years, 30–39 years, 40–49 years, > 50 years; education: illiterate, elementary school, secondary, higher secondary, and above; family members: ≤4 members, >4 members; profession: unemployed, housewife, day labor, farmer, service holder, business, student; residence: rural, urban; monthly family income: <10,000 BDT (<83.69 USD), 10,000–20,000 BDT (83.69–167.40 USD), >20,000 BDT (>167.40 USD); the monthly cost for functional food consumption was <500 BDT (<4.18 USD), 500–1000 BDT (4.18–8.36 USD), >1000 BDT (>8.36 USD); and lifestyle characteristics (BMI [kg/m^2] categories: underweight, normal, overweight, obese I, and obese II, according to Asian people categories³⁴; health status: poor, moderate, good; exercise regularly: no, yes; time of exercise: <30 min, ≥30 min; smoking: no, yes, and ex-smoker); Functional foods consumptions frequency of the last 1 year: never, daily (5/6 days weekly), weekly (3/4 days weekly), monthly (1/2 days weekly), and occasionally (3/4 times monthly)^{24,35}, most available functional foods throughout the year in Bangladesh (probiotics: probiotic yogurt/cheese/apple cider vinegar; prebiotics: banana/apple/garlic/onion; nuts: peanuts/walnuts/almonds; seed: pumpkin/sesame/flaxseed; fiber rich foods: psyllium herbs/oat's bran chia seed; whole grain: rice/flour; tea and coffee: green or black tea/black coffee; natural products: fenugreek/mushroom/spirulina; honey; black cumin; spices: garlic/ginger/ turmeric/clove; citrus fruit: lemon/orange/grapefruit; dry fruits: dates/raisins; egg; fortified foods)^{4,5,36,37} as well as influencing factors (reasons for taking FF: for health benefits, recommended by health professionals/others, meet daily requirements, motivate from online media, sensory taste, no specific reasons and reasons for not taking FF: unrecognize them, unknown health benefits, unaffordable, disinterest, unavailable, tasteless/adverse effect)^{38,39}.

Data analysis

SPSS™ (version 26.0) and R™ Programming (version 4.3.0) were used to analyze the data. The percentage and frequency of the descriptive statistical analyses to summarize the data distribution and multicollinearity with other model fit tests were observed using SPSS, and the factors influencing functional foods were presented graphically with percentages using Microsoft Excel 365. The anthropometric data weight in centimeters was first converted into meters, and then the BMI (kg/m^2) was calculated using SPSS. The continuous variable BMI was then transformed into BMI categories according to the cut-off point for Asian people (underweight: ≤18.499; normal: 18.5–22.9; overweight: 23–24.9; obese I: 25–29.9; obese II: ≥30)³⁴.

The acquired data were analyzed using descriptive statistical methods and binary logistic regression using the gtsummary-R package. After the multicollinearity test (Model 1, VIF: range = 1.06–1.56, and Model 2, range = 1.06–1.62), two binary logistic regression models were used to assess the association between functional food consumption frequency and respondents who had chronic diseases and multimorbidity. Our analysis used the forward Wald approach, 5% significance threshold ($p < 0.05$), and 95% confidence interval. The adjusted models contained 15 independent variables and functional food consumption frequency, as presented in Fig. 1. The dependent variable was whether the respondents had chronic diseases or multimorbidity. All predictors in the model (Model 1: frequency of FF consumption vs. chronic diseases) were statistically significant, as demonstrated by the Omnibus test of the model coefficient ($\chi^2 = 100.693$, $\text{df} = 60$, $P\text{-value} = 0.001$) and the Hosmer and Lemeshow test ($\chi^2 = 14.696$, $\text{df} = 8$, and $P\text{-value} = 0.065$), which showed that the model could differentiate between respondents with and without chronic diseases. A total of 66.8% of cases were accurately classified by the model, which explained 9.9% (Cox and Snell R-squared) and 13.5% (Nagelkerke R-squared) of the variation

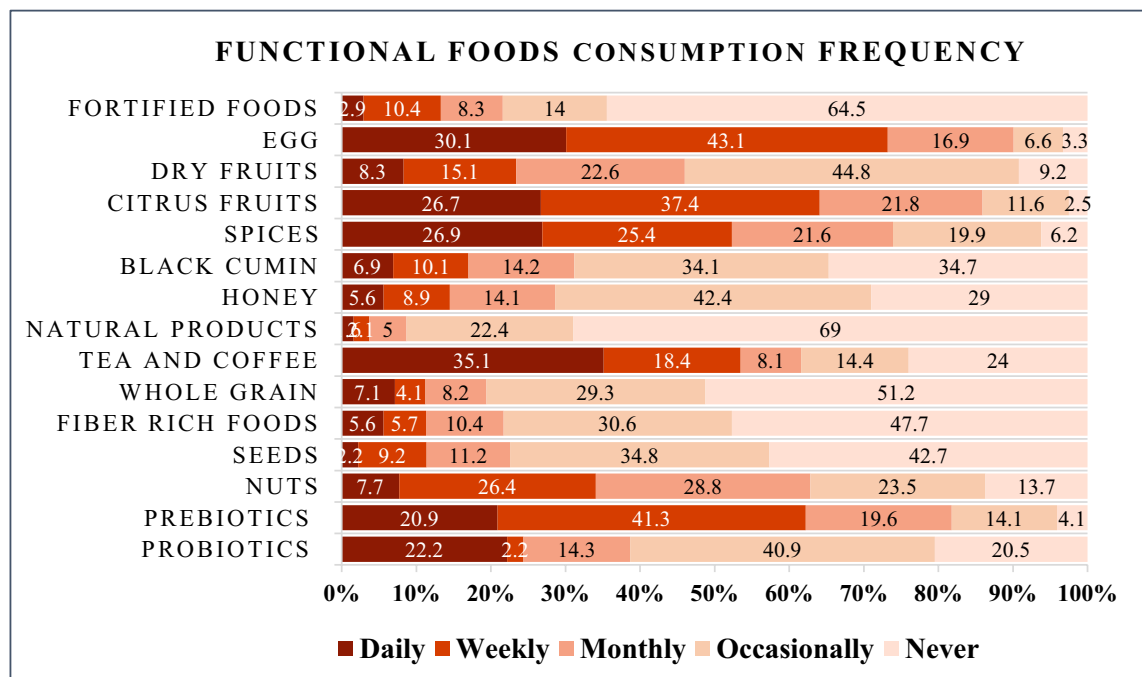


Fig. 1. Percentages of use of functional foods frequency among 966 respondents.

in chronic diseases. Another adjusted model (Model 2: frequency of FF consumption versus multimorbidity) was statistically significant according to the Hosmer and Lemeshow test ($\chi^2 = 2.574$, $df = 8$, and $P = 0.958$) and the Omnibus test of the model coefficient ($\chi^2 = 104.027$, $df = 60$, and $P = 0.000$), suggesting that the model could differentiate between respondents with and without multimorbidity. The model successfully identified 67.2% of cases and explained the variation in multimorbidity conditions between 15.7% (Cox and Snell R-squared) and 20.9% (Nagelkerke R-squared).

Ethical approval and informed consent

The ethical committee of the Faculty of Biological Science and Technology at Jashore University of Science and Technology, Jashore-7408, Bangladesh, approved and conformed to the study protocol (Ref: ERC/FBST/JUST/2024–198) and all of which were performed in accordance with the guidelines of the Declaration of Helsinki. All participants were asked to provide both verbal and written informed consent before participation. Those who refused to participate in the survey were excluded. Names or identifying numbers and thumbprints were obtained from participants who were unable to read and write during the data collection process.

Results

The sociodemographic, lifestyle, and health status characteristics

The sociodemographic and health characteristics of the participants are shown in Table 1. The findings from a sample of 966 adults revealed that more than half of the participants (55%) were female, 18.9% were illiterate, and 10.0% were farmers. Most respondents (35.6%) had a family income of more than 20,000 BDT (167.40 USD), whereas almost two-thirds (63.6%) resided in rural areas. Moreover, about 34.6% participants spent less than 500 BDT (4.18 USD) monthly for functional food consumption. In addition, 41.1% had a normal weight, 38.9% claimed good health, and 81.9% were non-smokers. Conversely, only 26.2% of the participants exercised regularly, and most participants (66.4%) exercised for more than 30 min. Notably, most participants had chronic diseases (63.0%), and approximately 50.6% had at least one chronic disease. Among the patients, 23.0% had hypertension, 15.7% had heart disease, 15.3% had hypocalcemia, 18.9% had dementia, 6.6% had anemia, and 29.6% had chronic obesity.

Consumption patterns of functional foods

Figure 1 shows the frequency of consumption of selected functional foods. A majority of consumers (35.1%) consumed tea and coffee daily, surpassing other functional foods. In terms of weekly consumption, eggs were predominantly (43.1%) consumed, followed by prebiotics (41.3%), citrus fruits (37.4%), nuts (26.4%). Furthermore, a large number of participants never consumed some notable functional foods, including natural products (69%), fortified foods (64.5%), whole grain (51.2%).

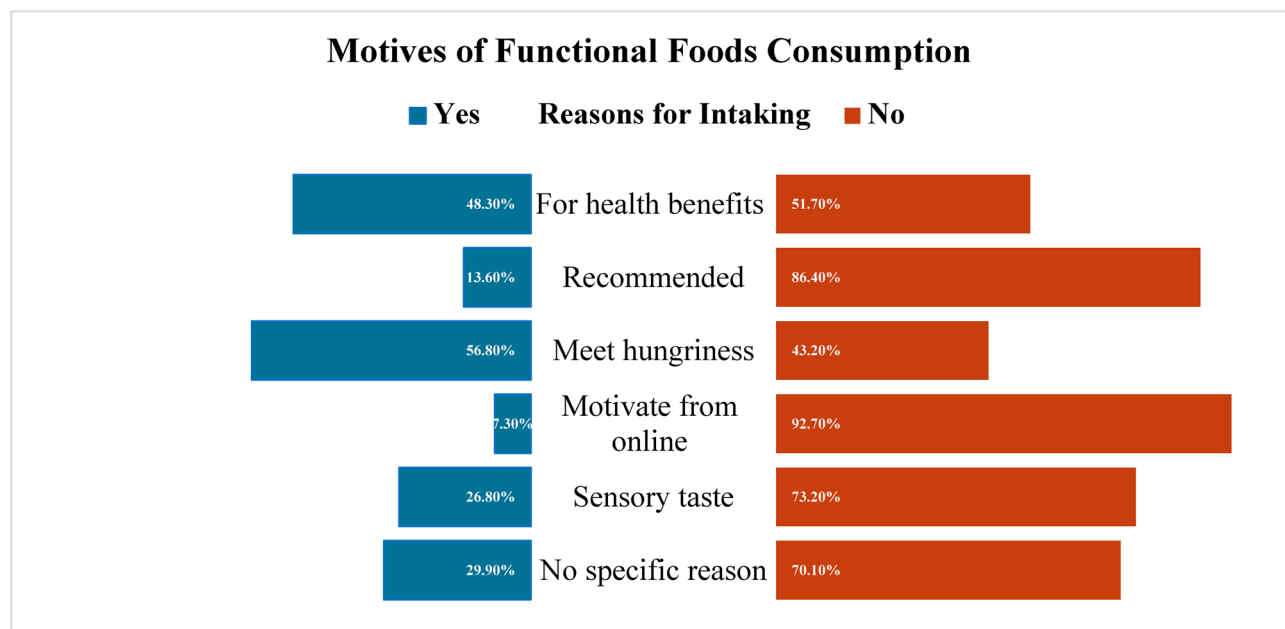
Figure 2a shows the motivations for the consumption of functional foods. The main motivation for consuming functional food among over half of the individuals was hunger (56.80%) followed by health benefits (48.30%), no specific reason (29.90%) and sensory taste (26.80%) among participants. As shown in Fig. 2b, unknown health benefits (34.10%) and inability to recognize FF (31.50%) were the leading reasons for not

Variables	Category	Total, n (%)
Sex	Male	435 (45.0)
	Female	531 (55.0)
Age	18–29	289 (29.9)
	30–39	256 (26.5)
	40–49	188 (19.5)
	> 50	233 (24.1)
Education level	Illiterate	183 (18.9)
	Elementary school	213 (22.0)
	Secondary school	252 (26.1)
	Higher secondary and above	318 (32.9)
Family member	≤ 4 members	436 (45.1)
	> 4 members	530 (54.9)
Profession	Unemployed	42 (4.3)
	Housewife	405 (41.9)
	Day labor	70 (7.2)
	Farmer	97 (10.0)
	Service holder	123 (12.7)
	Business	76 (7.9)
	Student	153 (15.8)
Monthly family income in BDT (USD)	< 10,000 BDT (< 83.69 USD)	295 (30.5)
	10,000–20,000 BDT (83.69–167.34 USD)	327 (33.9)
	> 20,000 BDT (> 167.40 USD)	344 (35.6)
Residence	Rural	614 (63.6)
	Urban	352 (36.4)
The monthly cost for functional food consumption in BDT (USD)	< 500 BDT (< 4.18 USD)	334 (34.6)
	500–1000 BDT (4.18–8.36 USD)	403 (41.7)
	> 1000 BDT (> 8.36 USD)	229 (23.7)
BMI categories	Underweight	68 (7.0)
	Normal	397 (41.1)
	Overweight	215 (22.3)
	Obese I	221 (22.9)
	Obese II	65 (6.7)
Self-reported health status	Poor	168 (17.4)
	Moderate	422 (43.7)
	Good	376 (38.9)
Exercise regularly	No	713 (73.8)
	Yes	253 (26.2)
Time of exercise	< 30 min	85 (33.6)
	≥ 30 min	168 (66.4)
Smoking	No	791 (81.8)
	Yes	132 (13.7)
	Ex-smoker	43 (4.5)
Chronic disease	No	357 (37.0)
	Yes	609 (63.0)
Number of chronic diseases	1	308 (50.6%)
	> 1	301 (49.4%)
Hypertension	No	744 (77.0)
	Yes	222 (23.0)
Heart disease	No	814 (84.3)
	Yes	152 (15.7)
Hypocalcemia	No	818 (84.7)
	Yes	148 (15.3)
Dementia	No	783 (81.1)
	Yes	183 (18.9)
Anemia	No	902 (93.4)
	Yes	64 (6.6)
Continued		

Variables	Category	Total, n (%)
Chronic obesity	No	680 (70.4)
	Yes	286 (29.6)

Table 1. Sociodemographic and lifestyle characteristics of the participants ($n = 966$). Note: 1 USD = 119.46 BDT (Bangladeshi currency).

(a)



(b)

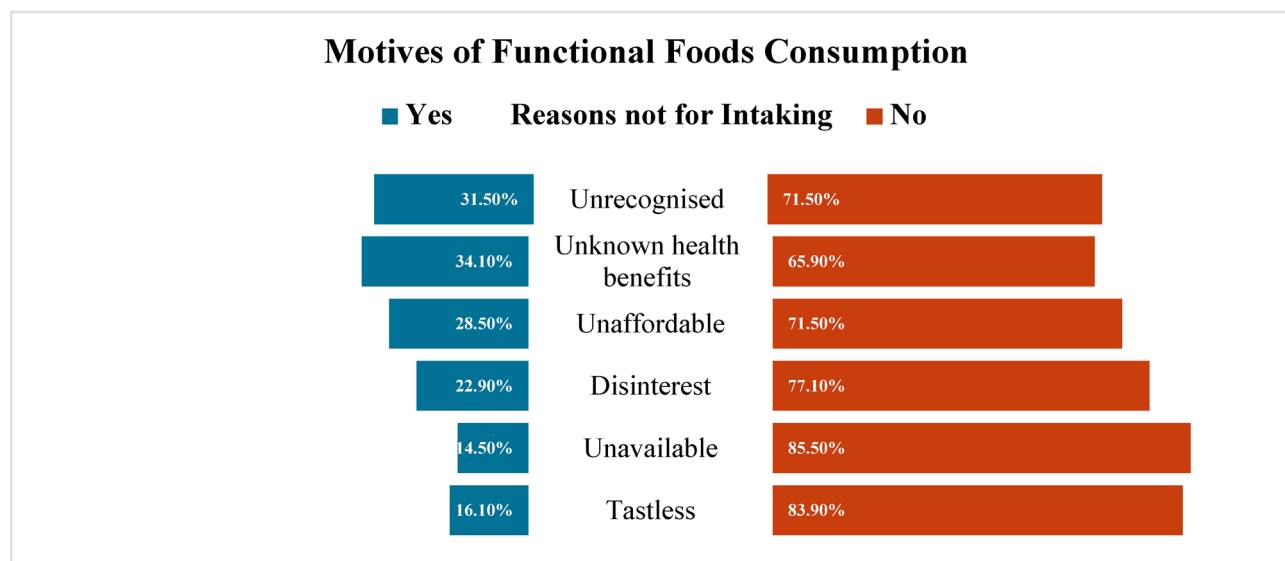


Fig. 2. (a) Motives of functional foods intaking among 966 respondents. (b) Motives of functional foods intaking among the 966 respondents.

taking FF. Unaffordability (28.50%), disinterest (22.90%), and tastelessness (16.10%) were also responsible for not consuming FF, respectively.

Association of functional foods consumption frequency with chronic and multimorbid conditions

Table 2 presents the functional food consumption associated with chronic diseases and multimorbidity among the participants in the binary logistic regression model. Findings from regression analysis showed that participants who had consumed nuts such as peanuts, walnuts, and almonds weekly had lower likelihood of developing chronic diseases (OR = 0.58, 95% CI 0.34–0.97, $p = 0.038$) than those who had never taken them. Monthly natural products such as fenugreek, mushroom, spirulina consumption was associated with lower odds of chronic disease (OR = 0.48, 95% CI 0.23–0.96, $p = 0.039$) as compared to non-consumers. Weekly honey consumption was associated with lower odds of chronic disease (OR = 0.50, 95% CI 0.27–0.93, $p = 0.028$) than never consuming honey.

Furthermore, individuals who had eaten eggs occasionally had lower odds of developing chronic disease (OR = 0.29, 95% CI 0.11–0.78, $p = 0.016$) than those who had never consumed eggs.

On the other hand, those who consumed probiotics such as probiotic yogurt, cheese, and apple cider vinegar on both daily and monthly basis had lower chances of developing multimorbidity (OR = 0.55, 95% CI 0.31–0.99, $p = 0.046$) and (OR = 0.39, 95% CI 0.19–0.77, $p = 0.008$) compared to those who had never engaged in such consumption, respectively. Participants who consumed prebiotics such as banana, apple, garlic, onion daily and weekly were less likely to develop multimorbidity (OR = 0.19, 95% CI 0.06–0.60, $p = 0.005$) and (OR = 0.33, 95% CI 0.11–0.96, $p = 0.044$) than those who never consumed such food, respectively. Individuals who consumed seeds such as pumpkin, sesame, and flaxseed monthly had lower odds of multimorbidity (OR = 0.51, 95% CI 0.26–0.98, $p = 0.045$) compared to those who had never consumed them. Daily consumption of tea and coffee reduced the likelihood of developing multimorbidity (OR = 0.49, 95% CI 0.29–0.83, $p = 0.008$) compared with those who had never consumed them. The risk of multimorbidity decreased when participants had daily consumption of black cumin (OR = 0.33, 95% CI 0.12–0.82, $p = 0.020$) compared to those who had not consumed it.

Discussion

Functional foods provide health benefits by being enriched with essential vitamins, minerals, and fatty acids, which promote overall well-being and enhance the immune system's ability to combat chronic diseases⁴⁰. Obtaining enough of these nutrients regularly with standard diets alone can be challenging, particularly for individuals with higher requirements. Functional foods with beneficial effects on disease treatment outcomes have been shown in randomized controlled studies and experimental models. These include fatty fish, soy, nuts, seeds, legumes, yogurt, chocolate, berries, tomatoes, and whole grains that contain bioactive components⁴¹. To the best of our knowledge, our study is the first to investigate the association of multimorbidity with functional food consumption frequency in a cross-sectional nature.

From figure 1, tea and coffee were the predominant functional foods consumed on a daily basis by the participants, consistent with other study⁴². Regular tea consumption is a common habit throughout Bangladesh⁴². Based on weekly consumption, majority of the participants consumed egg. Eggs are readily accessible, cost-effective, and a significant source of proteins, lipids, vitamins, and minerals⁴³. Previous study indicates that the availability of eggs surpasses the national average⁴⁴. This expanded availability, cost-effectiveness and nutritional importance may have significant role in addressing hunger fulfilling nutritional requirements in their diets among the participants which led to consume more on weekly basis. This possible role aligns with our findings that determine motivation for FF consumption which showed majority of the participants consumed for meeting hunger, followed by health benefits (Fig. 2a). On the other hand, most least consumed functional food were natural products including mushroom, spirulina (Fig. 1) while unknown health benefits accounted main reason for not consuming FF (Fig. 2b). The general population in Bangladesh remains mostly unaware about the nutritional and therapeutic significance of mushrooms⁴⁵.

Table 2 shows that consuming nuts on a weekly basis was associated with a lower probability of developing chronic diseases than those who never consumed nuts. This finding is supported by a recent cohort study conducted among Korean adults showing that consumers taking 1–2 servings (15–30 g) of nuts weekly had a 34% reduced risk of cardiovascular disease mortality compared to non-consumers⁴⁷. We also found notable findings that consuming natural products (fenugreek, mushroom, spirulina) monthly might have the potential benefit of lowering the risks of chronic disease compared to never consuming them. Fenugreek seeds are high in antioxidants, such as polyphenols and flavonoids, which prevent oxidative stress and mitigate damage from free radicals; hence, their antioxidant activity may safeguard cells from ageing and diminish the risk of chronic diseases⁵⁰. A previous investigation from the Ohsaki cohort 2006 study indicated that consuming mushrooms three times a week or more was linked to a 19% decrease in the risk of developing dementia in those aged 65 and older in Japan⁵¹. Participants who had consumed honey weekly had fewer odds of having chronic disease than those who had never consumed it.

Previous studies have revealed an inverse correlation between honey consumption and the likelihood of cardiovascular disease. Honey consumption can enhance lipid profile by decreasing total cholesterol and LDL while boosting HDL, thus serving a preventive function in cardiovascular health⁴⁶. Another important finding was that occasional egg consumption significantly reduced the odds of chronic diseases compared to non-consumers. A recent clinical study found that enriched egg intake improved vascular function, reduced inflammation, and enhanced oxidative status in patients with chronic coronary syndrome, indicating its potential benefits for chronic disease management¹⁰.

Variables	Categories	Chronic diseases			Multimorbidity		
		OR	95% CI	p-value	OR	95% CI	p-value
Probiotics (Probiotic yogurt/cheese/apple cider vinegar)	Never	1.00			1.00		
	Daily	1.14	0.71, 1.82	0.590	0.55	0.31, 0.99	0.046*
	Weekly	0.39	0.14, 1.06	0.067	0.29	0.03, 1.55	0.181
	Monthly	0.80	0.48, 1.31	0.368	0.39	0.19, 0.77	0.008**
	Occasionally	1.03	0.69, 1.53	0.899	0.84	0.51, 1.40	0.516
Prebiotics (banana/apple/garlic/onion)	Never	1.00			1.00		
	Daily	1.09	0.48, 2.46	0.829	0.19	0.06, 0.60	0.005**
	Weekly	1.62	0.74, 3.51	0.226	0.33	0.11, 0.96	0.044*
	Monthly	1.50	0.66, 3.36	0.324	0.55	0.18, 1.63	0.280
	Occasionally	2.08	0.87, 4.97	0.098	0.31	0.09, 1.00	0.053
Nuts (peanuts/walnuts/almonds)	Never	1.00			1.00		
	Daily	1.61	0.75, 3.57	0.229	1.20	0.49, 2.98	0.689
	Weekly	0.58	0.34, 0.97	0.038*	0.70	0.36, 1.37	0.301
	Monthly	0.77	0.46, 1.29	0.327	1.12	0.59, 2.10	0.735
	Occasionally	0.65	0.38, 1.09	0.102	0.94	0.49, 1.80	0.858
Seeds (pumpkin/sesame/flaxseed)	Never	1.00			1.00		
	Daily	0.51	0.18, 1.45	0.201	0.52	0.12, 2.02	0.356
	Weekly	1.24	0.72, 2.17	0.435	1.61	0.80, 3.31	0.185
	Monthly	1.34	0.81, 2.27	0.263	0.51	0.26, 0.98	0.045*
	Occasionally	1.17	0.81, 1.70	0.395	0.66	0.41, 1.05	0.078
Fiber-rich foods (Psyllium herbs/ oat's bran chia seed)	Never	1.00			1.00		
	Daily	1.02	0.47, 2.27	0.952	1.03	0.32, 3.22	0.957
	Weekly	0.99	0.52, 1.93	0.972	1.49	0.64, 3.57	0.363
	Monthly	1.39	0.81, 2.45	0.238	1.29	0.66, 2.55	0.454
	Occasionally	0.79	0.54, 1.17	0.238	0.84	0.50, 1.41	0.518
Whole grains (rice/flour, etc.)	Never	1.00			1.00		
	Daily	1.01	0.53, 1.97	0.970	1.37	0.57, 3.35	0.489
	Weekly	0.78	0.37, 1.67	0.519	1.75	0.59, 5.47	0.321
	Monthly	0.79	0.45, 1.40	0.417	1.56	0.73, 3.37	0.255
	Occasionally	1.26	0.89, 1.81	0.199	1.24	0.79, 1.94	0.349
Tea and coffee (green/black tea/ black coffee)	Never	1.00			1.00		
	Daily	0.78	0.51, 1.18	0.247=	0.49	0.29, 0.83	0.008**
	Weekly	0.65	0.41, 1.04	0.070	0.73	0.40, 1.33	0.303
	Monthly	0.59	0.33, 1.09	0.090	0.58	0.27, 1.26	0.169
	Occasionally	0.82	0.50, 1.35	0.441	0.70	0.38, 1.32	0.271
Natural products (fenugreek/mushroom/ spirulina)	Never	1.00			1.00		
	Daily	1.14	0.35, 3.92	0.827	0.15	0.01, 1.04	0.100
	Weekly	1.25	0.44, 3.68	0.673	0.83	0.18, 3.31	0.795
	Monthly	0.48	0.23, 0.96	0.039*	1.45	0.47, 4.38	0.511
	Occasionally	0.83	0.56, 1.22	0.346	1.51	0.90, 2.55	0.123
Honey	Never	1.00			1.00		
	Daily	0.68	0.30, 1.57	0.361	1.59	0.55, 4.60	0.392
	Weekly	0.50	0.27, 0.93	0.028*	1.21	0.53, 2.77	0.658
	Monthly	0.78	0.45, 1.36	0.383	0.78	0.37, 1.63	0.515
	Occasionally	0.75	0.48, 1.15	0.187	1.18	0.68, 2.03	0.552
Black cumin	Never	1.00			1.00		
	Daily	1.59	0.77, 3.37	0.221	0.33	0.12, 0.82	0.020*
	Weekly	1.41	0.79, 2.53	0.246	0.60	0.28, 1.27	0.188
	Monthly	0.83	0.49, 1.41	0.482	0.70	0.34, 1.43	0.325
	Occasionally	1.05	0.68, 1.61	0.826	1.12	0.64, 1.95	0.698
Spices (garlic/ ginger/ turmeric/ clove)	Never	1.00			1.00		
	Daily	1.45	0.73, 2.86	0.283	1.25	0.53, 3.03	0.612
	Weekly	0.97	0.49, 1.89	0.927	1.40	0.59, 3.43	0.454
	Monthly	1.08	0.55, 2.08	0.830	1.34	0.57, 3.27	0.511
	Occasionally	1.24	0.62, 2.46	0.533	1.80	0.75, 4.45	0.192
Continued							

Variables	Categories	Chronic diseases			Multimorbidity		
		OR	95% CI	p-value	OR	95% CI	p-value
Citrus fruits (lemon/orange/grapefruit.)	Never	1.00			1.00		
	Daily	0.87	0.29, 2.39	0.788	1.03	0.30, 3.67	0.965
	Weekly	0.80	0.27, 2.18	0.673	0.89	0.26, 3.11	0.856
	Monthly	0.90	0.30, 2.49	0.841	1.11	0.32, 3.94	0.869
	Occasionally	0.52	0.17, 1.51	0.243	0.53	0.14, 2.08	0.358
Dry fruits (dates/raisins)	Never	1.00			1.00		
	Daily	1.41	0.66, 3.02	0.376	1.91	0.68, 5.41	0.221
	Weekly	0.32	0.70, 2.49	0.398	1.91	0.82, 4.50	0.137
	Monthly	1.03	0.58, 1.84	0.919	2.08	0.95, 4.63	0.070
	Occasionally	1.47	0.85, 2.55	0.168	1.28	0.61, 2.69	0.514
Egg	Never	1.00			1.00		
	Daily	1.12	0.46, 2.62	0.798	0.81	0.25, 2.50	0.720
	Weekly	0.97	0.40, 2.24	0.945	0.61	0.19, 1.86	0.397
	Monthly	0.82	0.33, 1.94	0.651	0.52	0.15, 1.63	0.269
	Occasionally	0.29	0.11, 0.78	0.016*	0.39	0.08, 1.67	0.214
Fortified foods	Never	1.00			1.00		
	Daily	0.78	0.34, 1.85	0.563	0.46	0.12, 1.53	0.218
	Weekly	0.78	0.47, 1.28	0.317	0.70	0.35, 1.39	0.306
	Monthly	0.74	0.43, 1.26	0.256	0.85	0.40, 1.79	0.674
	Occasionally	1.34	0.84, 2.14	0.222	0.88	0.50, 1.57	0.672

Table 2. Binary logistic regression analysis of the association of functional foods consumption frequency with chronic diseases and Multimorbidity among the participants ($N=966$). OR odds ratio, CI confidence interval, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

We also found that probiotics consumption, both daily and monthly, contributed to a lower risk of multimorbidity than never probiotics consumption (Table 2). Recently, researchers have shown that obesity may be affected by gut microbes, and that specific probiotics, including *Lactobacillus gasei*, can decrease weight gain and body fat⁶. In addition, yogurt is abundant in probiotics, including lactobacilli, which may enhance the equilibrium of intestinal flora and inhibit the proliferation of unfavorable bacteria, thereby contributing to the reduction of blood pressure⁵². Participants who had consumed prebiotics both daily and weekly had lower odds of having multimorbidity compared to those who had never ingested them. Research indicates that prebiotics help alleviate anemia in both clinical and animal models, likely by improving iron metabolism⁵³. Moreover, a recent study demonstrates that prebiotic supplementation enhances iron absorption and mitigates anemia in people⁵⁴. We found that participants who consumed seeds monthly had less risk of developing multimorbidity than those who had never consumed them. A past study corroborates our findings that women who take seeds 1–2 times per month had considerably reduced levels of total cholesterol (T-C) and low-density lipoprotein cholesterol (LDL-C) compared to women who do not consume seeds⁵⁵. Maintaining blood cholesterol levels is crucial for reducing heart disease risk factors⁵⁰. The likelihood of multimorbidity was significantly reduced among those who had drunk tea and coffee daily compared to those who had never drunk them. A previous study found that consuming two to three cups of coffee and tea daily is linked to a lower risk of cardiovascular disease (CVD), chronic respiratory disease (CRD), and both of these diseases²³.

Our investigations revealed that participants who had daily consumed black cumin had a lower probability of multimorbidity than those who had never consumed it. A recent study showed that daily ingestion of *Nigella sativa* (black cumin) oil resulted in notable decreases in critical inflammatory markers, such as IL-1 β and IL-6, associated with obesity-related inflammation and metabolic problems. Moreover, the hormone leptin, which controls appetite and adipose tissue storage but frequently becomes imbalanced in obesity, is also markedly diminished⁴⁸.

Policy implications

The present study investigated the association between functional food consumption and chronic multimorbidity. These findings indicated that regular functional foods consumption positively contributed to the reduction of chronic diseases. However, the study also showed that a considerable number of participants did not take FF because they did not know its health benefits. Policymakers should first focus on promoting awareness and education about the health benefits of functional foods that could increase FF consumption among people. Public health policies should then disseminate clear definitions and health claims for functional foods to avoid confusion and misinformation to consumers. Because functional foods contain bioactive compounds that potentially reduce disease risks, they should be included in preventive health policies within healthcare systems. To increase the accessibility of FF, the government can ensure that FF is affordable and available in all districts of the country.

Limitations and strengths

The current study has several limitations. First, the cross-sectional approach in the survey permits the establishment of associations but does not allow for drawing causal judgments between functional food consumption and chronic/multimorbid conditions. Second, the data collected were based on self-reports (e.g., health status, food consumption frequency) that led to recall bias, which means that there is a possibility of affecting the accuracy of our findings. Moreover, our convenience sampling from three southern districts may not accurately represent the dietary patterns or disease frequency throughout all of Bangladesh. Therefore, the outcomes of the present study may not be generalized to different populations. Additionally, the wide classification of functional food may encompass substances with diverse bioactive qualities, thus masking or confounding the observed associations.

Notwithstanding these limitations, this study is the first to comprehensively understand functional food consumption and its association with chronic disease in Bangladesh. This study focuses on a crucial and current subject with considerable implications for public health. Moreover, the study employed a cross-sectional design with a large sample size, which enhanced its strength and fostered a reasonably high level of confidence in the acquired results. Additionally, the data were analyzed, and conclusions were drawn using suitable statistical procedures.

Future prospects

Functional foods have attracted global attention because of their capacity to prevent chronic diseases and multimorbidity. This capability was attributed to their bioactive compounds. Future studies should focus on identifying unidentified bioactive compounds in functional foods that may reduce the incidence of chronic diseases. Research attention should also be allocated to previously identified bioactive substances to elucidate their efficacy against certain yet unidentified diseases. In this context, the implementation of sophisticated clinical studies would be recommended. Further research is required about nutrition for aging or ill individuals to elucidate the factors influencing the varied responses to functional foods or nutrients and to explore their role in a comprehensive strategy for enhancing well-being and quality of life⁴⁹.

Conclusion

This study aimed to explore the consumption patterns of functional foods and their association with chronic diseases and multimorbidity. The findings revealed that respondents primarily consumed functional foods to satisfy hunger, while a significant portion reported using them for perceived health benefits. The analysis showed that the weekly consumption of nuts, monthly intake of natural products, weekly honey consumption, and occasional egg consumption were all associated with reduced odds of developing chronic diseases. Additionally, daily and monthly consumption of probiotics, daily and weekly intake of prebiotics, daily consumption of tea and coffee, and daily intake of black cumin were linked to lower odds of multimorbidity. However, other functional foods demonstrated either inconsistent or non-significant associations. Chronic diseases and multimorbidity are widely recognized as being associated with persistent inflammation and metabolic dysfunction. Functional foods are believed to offer anti-inflammatory and immune-boosting properties, as supported by various research studies, including cohort and clinical trials. The results of this study further suggest that the regular consumption of certain functional foods may have a protective effect against chronic diseases. Increasing the frequency of functional food consumption could help strengthen the immune system, promote overall health, and reduce healthcare costs. Therefore, functional foods play a vital role in public health nutrition for the prevention and management of chronic and multimorbid conditions. Policymakers should take effective actions by focusing on functional foods to include national nutrition policy to reduce chronic and multimorbidity conditions among the people for achieving the sustainable goal of nutrition and health in Bangladesh and invest more in research in food and nutrition field to better understand their disease-mitigating benefits.

Data availability

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

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Author contributions

Sanaullah Mazumdar: Conceptualization, Study design & Methodology, Data curation, Formal analysis, Visualization, Investigation, Writing – original draft preparation, and reviewing & editing; Md. Moshuazzaman Adnan: Data curation, Data entry, Result interpretation, Formal analysis, Writing – original draft preparation; Tanjum Kabir Khuku: Data curation, Data entry, Result interpretation, Writing – original draft preparation; Shuvasish Das Shuvo: Study design & Methodology, Formal analysis, Supervision, Validation, Writing: critically review & editing, , Validation; Farjana Fardaus: Data curation and data entry; Sharmin Asha: Data curation and data entry; Md. Hasan Al Banna: Validation, Writing- critically reviewing the manuscript for potential intellectual content; Md Riazuddin: Data curation; Md Nowshad Mahmud Choyon: Data Curation and data entry. All authors read and approved the final version of the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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