

Microbiota awareness of Turkish adults is associated with plant-based dietary patterns

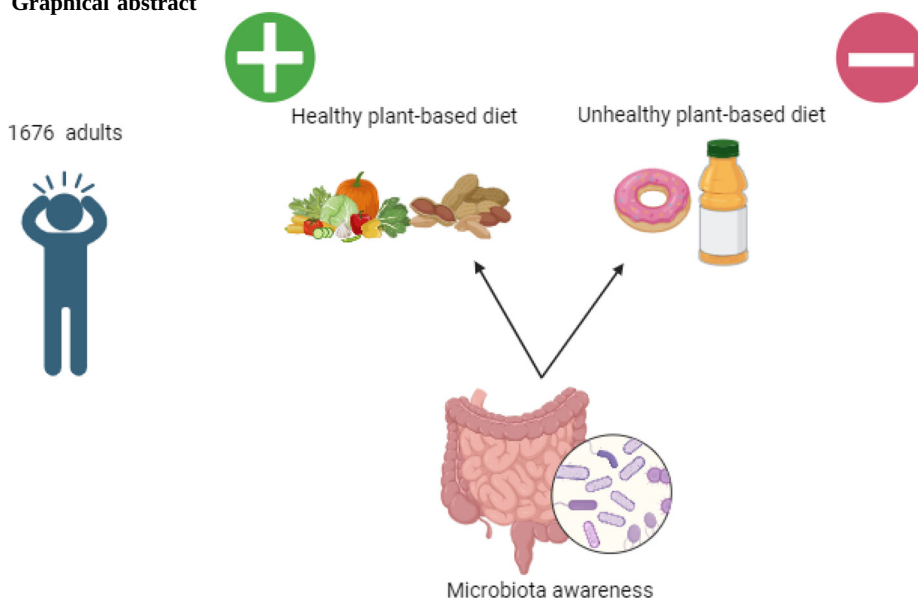
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Abstract

Purpose – Knowledge of microbiota and how it affects health can lead individuals to healthier lifestyle choices, such as dietary choices. The purpose of this study was to assess microbiota awareness and investigate its impact on plant-based dietary patterns, which are known to have proven benefits for both the environment and human health. In this study, the authors hypothesized that the microbiota awareness of Turkish adults may affect plant-based dietary patterns.

Design/methodology/approach – A cross-sectional study was conducted among 1,676 adults (63.8% women; 27.8 ± 13.0 years) in Turkey between March and May 2023. Data were collected using an online questionnaire that included demographic variables, anthropometric measurements, a validated microbiota awareness scale (64.7 ± 16.8) and a semi-quantitative food frequency questionnaire (FFQ). A plant-based diet index (PDI), a healthy plant-based diet index (hPDI) and an unhealthy plant-based diet index (uPDI) were derived from dietary assessments by a validated semi-quantitative FFQ.

Findings – Females had significantly higher microbiota awareness scores than males (67.3 ± 15.7 vs 60.1 ± 17.7 , $p = 0.001$). Microbiota awareness scores of individuals in the second tertile (65.9 ± 15.9) were significantly higher than those in the third tertile of uPDI (59.3 ± 17.9) ($p < 0.05$). For PDI and hPDI scores, microbiota awareness scores of individuals in the first tertile were significantly lower than in the third tertile. Multivariate linear regression analyses revealed that microbiota awareness was an independent predictor for PDI ($\beta = 0.035$, $p = 0.002$), hPDI ($\beta = 0.141$, $p = 0.001$) and uPDI ($\beta = -0.158$, $p < 0.001$).

Originality/value – Considering that awareness of microbiota may result in shifting lifestyle choices such as dietary patterns, further studies are needed to determine the relationship between microbiota awareness and PDI.

Keywords Microbiota awareness, Plant-based diet, Sustainability, Sustainable nutrition

Paper type Research paper

Introduction

Microbiota, one of the most interesting research topics in recent years, refers to approximately 100 trillion microorganisms found in the gastrointestinal tract of humans (Bayram and Ozturkcan, 2020). It has an important role in host immunity, digesting nutrients, regulating intestinal endocrine function and neurological signals, eliminating toxins, antimicrobial protection, immunomodulation, maintaining intestinal barrier integrity and the structure and functionality of the gastrointestinal tract (Tagliabue and Elli, 2013; Tomova *et al.*, 2019). Probiotics, prebiotics and synbiotics can be used to support the healthy functioning of the gut microbiota (Rahmi *et al.*, 2025).

Diet and dietary components have a significant impact on the composition of the gut microbiota and are among the most important contributors to bacterial flora alterations both short and long term (Beam *et al.*, 2021; Xie *et al.*, 2024). Evidence showed that bacterial composition, as a result of diet, can be associated with certain diseases, especially diseases that arise due to chronic low-grade inflammation, such as obesity and type II diabetes mellitus (Beam *et al.*, 2021; Singh *et al.*, 2017; Cao *et al.*, 2019). High intake of animal products, fat, and sugary foods, which are the components of the typical “Western diet,” have been associated with chronic low-grade inflammation, obesity and metabolic disease. Disruption in the balance between beneficial (probiotic) and pathogenic bacteria within the gut microbiota is associated with an increased risk of disease. Studies have shown that a high-fat, animal-based diet has the potential to affect the gut microbiota by increasing lipopolysaccharides, which may be a major cause of low-grade systemic inflammation (Jabeen *et al.*, 2023; Beam *et al.*, 2021; Singh *et al.*, 2017; Hersoug *et al.*, 2016). However, it was observed that a diet high in fiber and low in fat has the potential to positively affect the gut microbiota composition by increasing bacteria diversity, as well as beneficial butyrate-producing bacteria, imparting a positive metabolic influence (Tomova *et al.*, 2019; Beam *et al.*, 2021). In addition, early-life exposure to antibiotics, geographical location and contact with pesticides and heavy metals may also influence the composition of the gut microbiota (Yuan *et al.*, 2025).

A sustainable and healthy diet is characterized by energy intake aligned with individual physiological requirements, a greater emphasis on plant-based rather than animal-based foods, the substitution of saturated fats with unsaturated fats and a reduced consumption of refined grains, processed foods and added sugars (Willett *et al.*, 2019). Animal-based diets were associated with higher greenhouse gas emissions (GHGE), whereas higher consumption of plant-based diets was associated with lower GHGE (Werner *et al.*, 2014; Bayram and Ozturkcan, 2022; Clune *et al.*, 2017). In addition, animal-based products include harmful nutrients such as sodium, saturated fat and added sugars (Soedamah-Muthu and De Goede, 2018). Therefore, reduced consumption of animal-based products may result in higher sustainability, health advantages and a decrease in disease risks (Bayram and Ozturkcan, 2022).

Human microbiota has a significant impact on the health of individuals, and reciprocally, the dietary habits of individuals have an important effect on the diversity and composition of the microbiota (Abu-Humaidan *et al.*, 2021). Dietary patterns, including the use of probiotics and practices such as intermittent fasting, have also been shown to influence the composition of the gut microbiota (Altintas *et al.*, 2024). Therefore, knowledge of microbiota and how they affect health can lead individuals to healthier lifestyle choices, such as dietary choices and physical activity. However, there is no study in the literature that investigates the relationship between microbiota awareness and plant-based dietary patterns. Therefore, the aim of this study was first to determine microbiota awareness and examine the effect of microbiota awareness on plant-based dietary patterns, which have proven positive effects on the environment and health. In our study, we hypothesized that the microbiota awareness of Turkish adults may affect plant-based dietary patterns.

Materials and methods

Study design and participants

This cross-sectional study was conducted among adults in Turkey between March and May 2023. The inclusion criteria were age ≥ 18 years, resident of the city of Istanbul and approved written consent. The exclusion criteria were aged < 18 years, residents outside of Istanbul and unapproved written consent.

We used power analysis for sample selection. The prevalence was calculated as 20%, with a type I error rate (α) of 0.05, a type II error rate (β) of 0.05, and statistical power ($1-\beta$) equal to 0.95. According to the calculation, we included a total of 1,809 adults (64.0% women and 36.0% men) in this study. However, because 133 adults did not complete the survey, a total of 1,676 adults (63.8% women, 36.2% men) were included in the study.

An online questionnaire including some demographic characteristics (gender, age, disease, marital status and physical activity), microbiota awareness scale and semi-quantitative food frequency questionnaire (FFQ) was performed on the participants. In addition, some anthropometric measurements (body weight and height) were taken.

Ethics

The ethics committee of Istanbul Gelisim University Non-Interventional Clinical Research Ethics Committee (Number: 2023-03, date: 8/3/2023) approved the study, which followed the principles of the Declaration of Helsinki. Informed consent was obtained from all participants.

Microbiota awareness scale

It consists of 20 items grouped into four subdimensions: General Information, Product Knowledge, Chronic Disease and Probiotic and Prebiotic Knowledge. The General Information

subdimension (items 1, 2, 4, 5, 6 and 13) includes questions on gut microbiota, its formation, the impact of antibiotics, diet, obesity and breastfeeding. The Product Knowledge subdimension (items 17–20) evaluates the ability to identify and list probiotic and prebiotic foods. The Chronic Disease subdimension (items 8, 10, 12, 14, 16) examines the relationship between gut microbiota and conditions such as colorectal cancer, diabetes, celiac disease, liver fat accumulation and mental health disorders. The Probiotic and Prebiotic Knowledge subdimension (items 3, 7, 9, 11 and 15) focuses on knowledge of these products, their usage and their effects on issues like diarrhea and constipation. Items 1–16 are rated on a five-point Likert scale from strongly disagree (1) to strongly agree (5). Items 17 and 18 are multiple-choice knowledge questions, scored using a formula that accounts for correct and incorrect responses, then multiplied by 5 and rounded. Items 19 and 20 are open-ended and scored from 1 to 5 based on correct answers. For open-ended questions, by adding 1 to every 1 correct response, 5 points for 4 or more correct responses and 1 point for no correct responses were calculated. The total score ranges from 18 to 100, with higher scores indicating greater microbiota awareness. The Cronbach's alpha in the present sample was 0.95 (Kulcu and Onal, 2022). After the scores were calculated, the microbiota awareness scores were divided into tertiles: ≤ 62 points were categorized as T1, scores between 63 and 72 points were categorized as T2, and ≥ 73 points and above were categorized as T3. Microbiota awareness increased as the scores progressed from T1 to T3.

Semi-quantitative food frequency questionnaire

We used the semi-quantitative FFQ derived from a validated FFQ designed to measure dietary intakes in adults for evaluating plant-based dietary habits (Gunes *et al.*, 2015). Participants were asked how often they consumed a defined portion of approximately 130 food items over the previous year. There were ten frequency response options ranging from “I never eat this food” to “six or more times per day.”

Plant-based diet index

Food items were modified for determining a plant-based diet index (PDI), a healthy plant-based diet index (hPDI) and an unhealthy plant-based diet index (uPDI). We distinguished between healthy and less healthy plant foods, according to Satija *et al.* (2016). Healthy plant food groups included whole grains, fruits, vegetables, nuts, legumes, vegetable oils and tea/coffee, less healthy plant food groups included juices, refined grains, potatoes, sugar-sweetened beverages, sweets and animal products. Foods (animal fat, dairy products, eggs, fish/seafood, meat and miscellaneous animal-based foods) were divided into 18 food groups. The classification of mixed-composition foods was made according to the predominant ingredient (Satija *et al.*, 2016). The 18 food groups were divided into consumption quintiles, with each quintile giving a score between 1 and 5. For PDI, participants received a score of 5 for each plant food group for which they were above the highest quintile of consumption, a score of 4 for each plant food group for which they were above the second-highest quintile but below the highest quintile and so on, with a score of 1 for consumption below the lowest quintile (positive scores). Participants received a score of 1 for each animal food group for which they consumed more than the highest quintile, a score of 2 for consumption between the highest and second-highest quintiles and so on, with a score of 5 for consumption below the lowest quintile (reverse scores). Positive scores were assigned to healthy plant food groups and reserve scores to less healthy plant food groups and animal food groups for hPDI. In addition for the uPDI, less healthy plant food groups received positive scores, whereas healthy plant food groups and animal food groups received reserve scores. The 18 food group scores for an individual were summed to obtain the scores. After the scores were calculated, the sample for each index (PDI, hPDI, and uPDI) was divided into tertiles (Satija *et al.*, 2016).

Statistical analysis

Data were analyzed using the SPSS Statistics program, version 28.0 (Statistical Package for the Social Sciences, Inc.; Chicago, IL). The distribution of the variables was verified by the Kolmogorov–Smirnov test. Data were expressed as mean and standard deviation. Categorical data were expressed as the frequency (percentage), and differences were analyzed using the chi-square test. Differences in quantitative variables were analyzed using the student's *t*-test or one-way ANOVA, as appropriate. Multiple linear regression analysis was applied to determine the effect of microbiota awareness on PDI, hPDI and uPDI. For all statistical tests, a *p*-value of ≤ 0.05 was considered statistically significant.

Results

The sample of our study consisted of 1,676 participants with a mean age of 27.76 ± 13.01 years and 63.8% ($n = 1,070$) of whom were women. When the general characteristics of the individuals were analyzed according to the microbiota awareness score tertiles, males were found to have lower microbiota awareness compared to females, and individuals with high school and below education level were found to have lower microbiota awareness compared to individuals with high school and above education level ($p < 0.05$). When microbiota awareness scores were analyzed, microbiota awareness of females (67.3 ± 15.7) was higher than that of males (60.1 ± 17.7) ($p = 0.001$). In addition, those with the highest tertiles of microbiota awareness had higher age, lower body weight and body mass index (BMI) ($p < 0.05$). The presence of chronic disease and regular exercise status did not show a significant difference between the tertiles ($p > 0.05$). The general characteristics of the participants according to microbiota awareness scores are shown in Table 1.

Table 1. General characteristics of the participants ($n = 1.676$)

General characteristics	Microbiota awareness scores			<i>p</i> -value
	T1 ($n = 564$)	T2 ($n = 568$)	T3 ($n = 544$)	
Age (years)	26.7 ± 8.8	26.8 ± 17.7	29.7 ± 10.3	<0.001
Body weight (kg)	70.7 ± 15.7	66.4 ± 14.8	66.5 ± 14.8	<0.001
Body mass index (kg/m^2)	23.6 ± 3.9	23.0 ± 4.3	23.2 ± 4.5	0.050
Gender				<0.001
Women (%)	275 (25.7)	393 (36.7)	402 (37.6)	
Men (%)	289 (47.7)	175 (28.9)	142 (23.4)	
Education level				<0.001
High school and less than high school education (%)	278 (38.1)	262 (35.9)	189 (25.9)	
More than high-school education (%)	286 (30.2)	306 (32.3)	355 (37.5)	
Presence of chronic disease				0.557
Yes (%)	111 (32.3)	113 (32.8)	120 (34.9)	
No (%)	453 (34.0)	455 (34.2)	424 (31.8)	
Regular exercise				0.057
Yes (%)	180 (33.0)	168 (30.8)	197 (36.1)	
No (%)	384 (34.0)	400 (35.4)	347 (30.7)	

Note(s): *Continuous variables as mean $\pm$ standard deviation; categorical variables were expressed as percentages. PDI = plant-based diet index; hPDI: healthy plant-based diet index; uPDI = unhealthy plant-based diet index

Source(s): Created by authors

The mean microbiota awareness score of all participants was found to be 64.7 ± 16.8 . The microbiota awareness scores of the participants according to their adherence to a plant-based diet are analyzed in Figure 1. For PDI and hPDI scores, individuals in the first tertile had significantly lower microbiota awareness scores than individuals in the third tertile. In addition, for uPDI scores, the microbiota awareness scores of individuals in the second tertile (65.9 ± 15.9) were significantly higher than those in the third tertile (59.3 ± 17.9) ($p < 0.05$).

Multivariate linear regression models to determine the effect of microbiota awareness on PDI, hPDI and uPDI scores are shown in Table 2. Microbiota awareness ($\beta = 0.035$) on PDI; gender ($\beta = -4.149$), age ($\beta = 0.091$), regular exercise ($\beta = -2.036$) and microbiota awareness ($\beta = 0.141$) on hPDI; age ($\beta = -0.077$), education level ($\beta = -1.896$), regular exercise ($\beta = 1.265$) and microbiota awareness ($\beta = -0.158$) had significant effects on uPDI ($p < 0.05$ in all models).

Discussion

To our knowledge, this was explored for the first time, to determine the relationship between microbiota awareness and plant-based dietary patterns of adults. We found that the microbiota awareness and hPDI scores were higher in women compared to men, and the hPDI scores of participants with regular exercise were found to be higher than participants who did not regularly exercise, and the results were statistically significant. Microbiota awareness scores were found to be higher in the third tertiles of PDI and hPDI and lower in the third tertile of uPDI. In addition, it was found that microbiota awareness had significant effects in all three models in which the dependent variables were PDI, hPDI and uPDI.

The gut microbiota is as unique as a fingerprint, creates a different pattern in each person and affects health. Furthermore, awareness of how microbiota can affect human health is

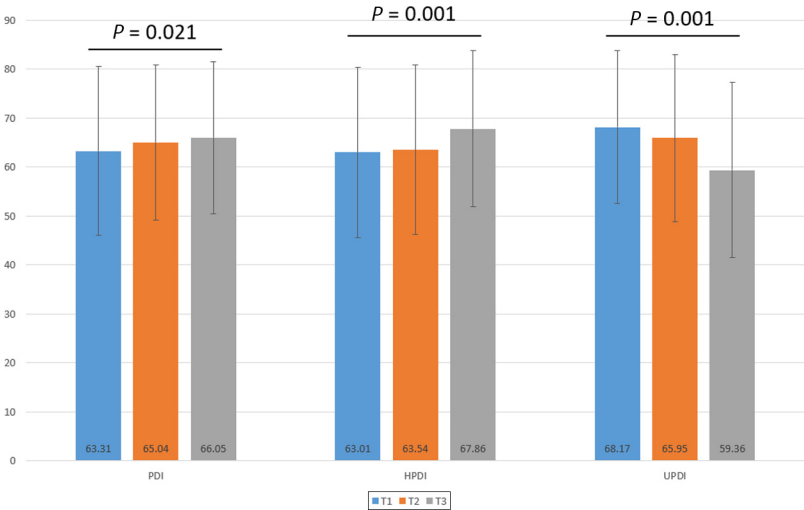


Figure 1. Microbiota awareness of participants according to different plant-based dietary index tertiles
Note(s): When plant-based dietary indices were divided into tertiles, there was a significant difference between tertile 1 and 3 in PDI scores. Moreover, tertiles 1 and 3 were statistically significant for hPDI, whereas tertiles 2 and 3 were statistically significant for uPDI ($p < 0.05$); *PDI = plant-based diet index; hPDI = healthy plant-based diet index; uPDI = unhealthy plant-based diet index

Source: Created by authors

Table 2. Multiple linear regression analysis of different plant-based dietary index scores

Variables	PDI				hPDI				uPDI			
	β	95% confidence interval		p-value	β	95% confidence interval		p-value	β	95% confidence interval		p-value
Gender	-0.267	-1.406	0.872	0.645	-4.149	-5.342	-2.957	<0.001	0.399	-0.934	1.733	0.557
Age	-0.021	-0.051	0.009	0.163	0.091	0.059	0.122	<0.001	-0.077	-0.112	-0.042	<0.001
Education level	0.705	-0.055	1.464	0.069	0.519	-0.277	1.314	0.201	-1.896	-2.786	-1.007	<0.001
Body weight (kg)	0.021	-0.040	0.082	0.504	-0.052	-0.115	0.012	0.111	-0.004	-0.076	0.067	0.902
Body mass index (kg/m ²)	-0.076	-0.260	0.107	0.414	0.238	0.046	0.430	0.055	-0.013	-0.228	0.202	0.906
Presence of diagnosed disease	-0.373	-1.291	0.545	0.426	-0.956	-1.917	0.005	0.051	0.673	-0.402	1.748	0.220
Regular exercise	0.564	-0.235	1.363	0.166	-2.036	-2.873	-1.200	<0.001	1.265	0.330	2.201	0.008
Microbiota awareness	0.035	0.012	0.057	0.002	0.141	0.016	0.063	0.001	-0.158	-0.144	-0.092	<0.001

Note(s): * PDI = plant-based diet index; hPDI = healthy plant-based diet index; uPDI = unhealthy plant-based diet index, CI = confidence interval. PDI: $R^2 = 0.021$, $F = 2.550$, $p = 0.013$; hPDI: $R^2 = 0.115$, $F = 27.133$, $p = 0.001$; uPDI: $R^2 = 0.086$, $F = 19.594$, $p = 0.001$

Source(s): Created by authors

important for individuals and societies alike because this knowledge can influence lifestyle choices such as dietary habits and physical activity. (Timmis *et al.*, 2019). However, only a recent study evaluated the knowledge of microbiota. This study showed that most university students, even those who have not taken a formal microbiology course, exhibit good knowledge of what microbiota is and how it can be affected by personal and environmental factors. Moreover, there were no statistical differences between genders (Abu-Humaidan *et al.*, 2021). In the present study, the mean microbiota awareness score was 64.75 ± 16.85 , with significantly higher scores observed in women compared to men. The reason for this may be that this study was not conducted only with university students. The microbiota awareness scale score was also unexpectedly high. The knowledge of microbiota may have been obtained through social media, probiotic advertisements or popular science.

Plant-based diets have been around for hundreds of years (Leitzmann, 2014). Plant-based dietary patterns focus on foods primarily from plants. This includes not only fruits and vegetables but also nuts, seeds, oils, whole grains, legumes and beans (McManus, 2021). In addition, dietary composition can influence the bacterial profile of the gut microbiota, which may contribute to the development of chronic diseases (Beam *et al.*, 2021; Singh *et al.*, 2017; Cao *et al.*, 2019). For example, high consumption of animal products, fat and sugary foods has been associated with chronic low-grade inflammation, obesity and metabolic disease by increasing harmful bacteria (Beam *et al.*, 2021; Singh *et al.*, 2017; Hersoug *et al.*, 2016). On the contrary, high consumption of plant-based foods can improve health consequences by increasing the number of beneficial bacteria (Tomova *et al.*, 2019; Beam *et al.*, 2021). Therefore, individuals with a high awareness of microbiota may have plant-based dietary patterns. In this study, it was determined that microbiota awareness increased PDI and hPDI and decreased uPDI. Moreover, the uPDI scores of participants who exercise regularly were found to be significantly lower compared to those who did not regularly exercise. Individuals who have knowledge of the microbiota may be prone to decrease their health risks through dietary patterns. Thus, the association between microbial awareness and PDI and physical activity is to be expected.

Chronic diseases have increased dramatically during the past few decades. Obesity, diabetes mellitus, cardiovascular disease, respiratory diseases and cancer account for 63% of global death each year (Fehér *et al.*, 2020). However, plant-based diets have become popular among the general population due to their positive effect on health and the environment (Fehér *et al.*, 2020; Willett *et al.*, 2019). Several studies examined the relationship between plant-based diet index and health. A study found that hPD was inversely associated with cardiometabolic conditions in men (Li *et al.*, 2021). Similarly, it was found that higher adherence to PDI was associated with a lower risk of coronary heart disease in adults (Satija *et al.*, 2019). Another study reported that both PDI and hPDI were inversely associated with type II diabetes mellitus (Satija *et al.*, 2016). We found that there was no relationship between the presence of chronic disease and PDI score. This may be due to the small sample size, as only 20.5% of the participants in the study had a chronic disease.

Excess body fat is a risk factor for many disease conditions. Studies showed that healthy plant-based diets were related to decreased body weight and BMI (Satija *et al.*, 2019; Chen *et al.*, 2019). Although there are limited studies evaluating the relationship between PDI and BMI, the results are inconsistent (Chen *et al.*, 2019; Alvarez-Alvarez *et al.*, 2020; Kim *et al.*, 2020; Ratjen *et al.*, 2020; Amini *et al.*, 2021). In this study, we did not find any relationship between PDI scores and BMI. A recent meta-analysis noted the lack of association between PDI and BMI as not all plant foods are healthy and PDI should be considered in the context of food processing (Siqueira *et al.*, 2022). However, no relationship was found between hPDI

and uPDI, and BMI in this study. This may be because the mean BMI of the participants was within the normal range.

The study has some limitations and strengths. First, the questionnaire was distributed to participants online; thus, it was not possible to calculate a true response rate because the participants might search the terms of microbiota. Second, the diet was self-reported, and measurement errors are inevitable. However, we used cumulative diet metrics. Cumulative diet metrics decrease measurement errors in long-term dietary habits. The strength of the study is that the relationship between microbiota awareness and plant-based dietary patterns was first evaluated. Therefore, this study could serve as a stepping stone for further research.

Conclusion

Here, the relationship between awareness of microbiota and plant-based dietary patterns was explored for the first time. According to our results, individuals with higher microbiota awareness scores tended to have higher PDI and hPDI scores and lower uPDI scores (Graphical Abstract). In addition, the microbiota awareness and hPDI scores were higher in females compared to males, and the hPDI scores of participants with regular exercise were found to be higher than participants who did not regularly exercise and the results were statistically significant. Considering that awareness of microbiota may result in shifting lifestyle choices such as dietary patterns and further studies are needed to determine the relationship between microbiota awareness and plant-based diet index.

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