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The association between adherence to unhealthy plant-based diet and risk of COVID-19: a cross-sectional study

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Abstract

Background The fast spread of the coronavirus disease 2019 (COVID-19) epidemic and its high mortality were quickly considered by the health community. Dietary patterns play an important role in strengthening or weakening the immune system and thus incidence of diseases.

Aim The present study can provide a comprehensive picture of the association between adherence to unhealthy plant-based diet (uPDI) and COVID-19 incidence.

Methods This study was undertaken on 8157 adults' participants of the Yazd Health Study (YaHS) and Taghzieh Mardom-e-Yazd (TAMIZ) study aged 20 to 70 years. Data on dietary intakes were obtained using a validated food frequency questionnaire (FFQ). Multivariable logistic regression analysis was used to assess the association between uPDI and COVID-19.

Results We found a significant association between uPDI and the risk of COVID-19 (OR: 1.36; 95% CI: 1.05–1.75) in the crude model. After adjusting potential confounders, a significant increasing trend in the odds of COVID-19 across increasing quintiles of uPDI (OR: 1.58;95% CI: 1.05–2.37; *P*-value: 0.027) was observed. Stratified analysis based on sex indicated that uPDI significantly increased the risk of COVID-19 only in males (OR: 1.73;95% CI: 1.12–2.67; *P*-value: 0.012) and had no effect on females.

Conclusions Participants in the highest quintiles of the uPDI had 58% higher odds of COVID-19 compared to subjects in the lowest quintile of uPDI. Although our study has promising results, stronger clinical studies are needed.

Keywords PDI, UPDI, hPDI, COVID-19, SARS-CoV-2

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Introduction

The coronavirus 2019 (COVID-19) pandemic has caused mortality and morbidity around the world at a great economic cost [36]. The mortality rate of COVID-19 varies considerably depending on various factors including race and socioeconomic status, medical systems, and age [17]. While all groups are affected by the COVID-19, the elderly and those with co-existing diseases are at a higher risk [13]. One of the important risk factors for infection with respiratory viruses is a weakened immune system. The association between immunity and nutrition is well known and its role in is being considered and also, nutritional factors are involved in the development of COVID-19 [17, 20].

A proper diet and good nutritional status are considered to prevent infection by providing the nutrients needed for an optimal immune response [8]. Unhealthy diets activate the innate immune system and impairs adaptive immunity, leading to chronic inflammation and impaired host defense against viruses [39]. While, a healthy diet provides a variety of nutrients as well as non-nutrient bioactive compounds that modulate the immune system and inflammation [44]. Previous findings have shown that dietary patterns strongly influence inflammatory processes [1, 11, 14].

There is compelling evidence that plant-based diets modulate immune and inflammatory processes [46]. Plant-based diets, including vegetables and fruits, have high antioxidant activity that scavenge acid-free radicals, reduces oxidative stress, and increases resistance to many infectious diseases and mortality [3, 32, 51]. Also, low-carbohydrate and high-protein diets were significantly more likely to develop moderate to severe COVID-19 infection compared to plant-based diets [23]. Many studies have examined the association between dietary patterns and COVID-19 prevalence. In a prospective cohort study, the healthy plant-based diet was associated with a lower risk and severity of COVID-19 [28]. A case–control study showed that plant-based diets were associated with 73% lower odds of moderate-to-severe COVID-19 compared with other diets [23]. Moreover, high levels of saturated fats, sugars, and refined carbohydrates in the diet contribute to the prevalence of chronic diseases and can put these populations at a higher risk for severe COVID-19 and mortality [7]. Therefore, the quality of specific components of plant-based diets should also be considered, and if they contain low-quality plant-based foods such as refined carbohydrates and added sugars, they can have a negative effect on health [7]. While, eating fruits and vegetables, as well as whole grains (a healthy plant-based diet) is associated with a reduced risk of inflammation and chronic diseases [19, 45]. To the best our knowledge, despite studies examining the association between the COVID-19 prevalence and plant-based diets, no studies have examined this association based on healthy plant-based diet index (hPDI (and unhealthy plant-based diet index uPDI(. So, we examined the association between uPDI and the prevalence of COVID-19 in Iranian people.

Methods

Study design and participants

This cross-sectional study was conducted using data of Yazd Health Study (YAHS) and Taghzieh Mardom-e-Yazd (TAMIZ). The participants in these two studies are the same. For the present study, the data from both projects (YaHS and TAMIZ) were merged. Dietary information was extracted from the TAMIZ study and other data were extracted from the YaHS study. YAHS was a prospective cohort study that was carried out to assess the association between various risk factor and chronic diseases among adults' population (20–70 years) of Yazd, Iran and described in details previously [30]. Of 10,208 individuals who were initially included in the current study, 1407 subjects were excluded and 8801 subjects remained for final analysis. The flow diagram of the study selection process was shown elsewhere (https://academic.oup.com/ije/article/47/3/697/4658812). On the basis of WHO STEP protocols for two-stage cluster sampling, patients were selected from September 2014 to March 2016. An informed written consent form was obtained from all of the enrolled patients. The protocol of the current study was also approved by the ethics committee of Shahid Sadoughi University of Medical Sciences (IR.SSU.SPH.REC.1403.145).

Assessment of COVID-19

A questionnaire was completed for each participant over the phone call regarding the history of infection with COVID-19 during February 2020 to February 2021 according to Yazd Central Health database. Patients have gone a polymerase chain reaction (PCR) test for a diagnosis of COVID-19. Moreover, serologic assay of IgM and IgG were measured to avoid false positive/negative results of PCR test [35, 47].

Assessment of dietary intake

Through a face-to-face interview, a 178-item semi-quantitative food frequency questionnaire was used to evaluate dietary intakes of participants during the previous year. This FFQ was a modified version of a 168-item FFQ in which 10 items of most commonly traditional foods of Yazd population was also added to the previous version. The frequency of consumed foods was chosen on daily, weekly, or monthly basis and reported values were transformed to gram per day. All of the final values were analyzed by Nutritionist IV software that was modified for Iranian foods [5].

Calculation of unhealthy plant-based dietary index (uPDI)

Eighteen food groups are produced and subsequently classified into three main categories: animal-based foods (fish/seafood, animal fats, eggs, dairy products, miscellaneous animal-based foods, poultry/red meat), less healthy plant foods (fruit juices, refined grains, sugar-sweetened beverages, potatoes, sweets, desserts), and healthy plant foods (legumes, whole grains, nuts, fruits, vegetables, vegetable oils, tea/coffee). These eighteen food groups were sorted into quintiles and applied scores between 1 and 5. For uPDI, a score between 1 and 5 was given to the lowest through the highest quintile of less healthy plant foods, while reverse scores were assigned to healthy plant and animal food groups [40]. Finally, scores were summed to establish the indices score ranged from 18–90.

Covariate measurements

Weight was measured using a digital scale (Omron Inc. Osaka, Japan) to the nearest 0.1 kg while participants were without shoes and minimum clothing. Height was estimated using an upstretched tape to the nearest 0.1 cm while subjects were in a standing position; shoulders were relaxed; and with bare foot. Body mass index was calculated using weight in kg divided by height in m^2. A validated version of the short form of the International Physical Activity Questionnaire (IPAQ) was implemented to evaluate physical activity status of participants and finally expressed as low, medium, and high, respectively [10, 31].

Statistical analysis

Study participants were categorized into quintiles base on their dairy food intake levels in 3 models. Frequency and percentage were used to describe the qualitative variables. Multivariable Logistic regression analysis was performed in different models to find the association between uPDI and COVID-19. In model 1, we adjusted only age and total energy intake. In model 2, sex, smoking status, physical activity, marital status, chronic disease, educational levels, occupation, native and family member were additionally adjusted. Final adjustments were performed for BMI. Logistic regression results were reported as the odds ratio (OR) and 95% confidence interval (95% CI). All analyses were performed using the SPSS software (version22; SPSS Inc, Chicago IL, USA). *P*-values < 0.05 were considered statistically significant.

Results

Characteristics of the study population

Overall, 8157 participants included in our analyses (3929 male and 4229 female). The prevalence of COVID-19 did not significantly differ among quintiles of uPDI. Significant differences were seen for education level and sex across quintiles of uPDI (Table 1). There was no significant difference in the age, smoking status, physical activity, marital status, chronic disease, occupation, native status, family member and BMI among quintiles of uPDI.

Dietary intakes of participants

Some food groups and nutrient intakes in quintiles of uPDI are presented in Table 2. Participants in the highest quintiles of uPDI compared to the lowest quintiles had a higher carbohydrate intake. While, intake of energy, fruits, vegetables, whole grains, legumes, calcium, iron, vitamin B12 and vitamin B9 in the highest quintiles was lower than in the first quintiles.

COVID-19 and uPDI score

Crude and adjusted odds ratios for COVID-19 across quintiles of uPDI are presented in Table 3. There was a significant association between uPDI and the risk of COVID-19 (OR: 1.36; 95% CI: 1.05–1.75) in the crude model. After adjusting potential confounders including, sex, smoking status, physical activity, marital status, chronic disease, educational levels, occupation, native and family member, a significant increasing trend in the odds of COVID-19 across increasing quintiles of uPDI (P-trend = 0.043) was observed. In addition, participants in the highest quintiles of the uPDI had 52% higher odds of COVID-19 compared to subjects in the lowest quintile of uPDI. This association remained significant after further adjustment for BMI (OR: 1.58;95% CI: 1.05–2.37; *P*-value: 0.027).

Stratified analysis based on sex indicated that uPDI significantly increased the risk of COVID-19 only in male (OR: 1.73;95% CI: 1.12–2.67; *P*-value: 0.012) and had no effect on female (Table 4).

Discussion

In this study, we found that higher adherence to uPDI, as a measure of adherence to a low-quality plant-based diet, was related to 52% higher odds of COVID-19. The association was independent of socio-demographic status and BMI. This finding suggested that the effect of the quality of plant-based diet on health outcomes should be considered. Although limited studies have been conducted on the association between adherence to plant-based diets and COVID-19, our results

Table 1 General characteristics of study participants across quintiles of uPDI

Variables		Total	Q1(≤53)	Q2(54-57)	Q3(58-61)	Q4(62-65)	Q5(≥66)	*P* value*
COVID-19 prevalence, yes (%)		723(8.9)	113 (7.8)	134 (8.5)	173 (9)	148 (8.8)	155 (10.3)	0.178
Age (n(%))	20-29 years	1585 (20.1)	257 (18.2)	330 (21.5)	372 (20)	342 (21)	287 (19.7)	0.559
	30_39 years	1588 (20.1)	529 (19.8)	513 (20.6)	543 (19.9)	543 (19.9)	543 (19.9)	
	40_49 years	1645 (20.8)	303 (21.4)	302 (19.7)	389 (20.9)	355 (21.8)	296 (20.3)	
	50-59 years	1591 (20.1)	297 (21)	324 (21.1)	383 (20.6)	301 (18.5)	286 (19.6)	
	60_69 years	1489 (18.9)	259 (18.3)	17.8 (273)	360 (19.3)	308 (18.9)	289 (19.8)	
Marriage (n(%))	Single	6705 (84.8)	1180 (83.2)	1308 (85.2)	1582(84.8)	1380 (84.8)	1255 (86.2)	0.349
	Married	860 (10.9)	178 (12.5)	170 (11.1)	199 (10.7)	169 (10.4)	144 (9.9)	
	Widowed or divorced	339 (4.3)	61 (4.3)	58 (3.8)	85 (4.6)	78 (4.8)	57 (3.9)	
Gender, male (n(%))		3929 (87.2)	717 (49.3)	774 (48.9)	959 (49.8)	760 (45)	719 (47.7)	0.039
Smoking (n(%))	Never smoker	6717(87.2)	1190 (86.2)	1301(87.3)	1593 (87.6)	1403 (88.4)	1230 (86.5)	0.761
	Current smoker	836 (10.9)	166 (12)	162 (10.9)	190 (10.9)	155 (9.8)	163 (11.5)	
	Ex_smoker	147 (1.9)	25 (1.8)	28 (1.9)	35 (1.9)	30 (1.9)	29 (2)	
Education(n(%))	Illiterate	2050 (26.1)	354 (24.9)	379 (24.8)	473 (25.5)	456 (28.2)	388 (26.8)	0.001
	Middle school	2228 (28.3)	355 (25)	423 (27.7)	563 (30.4)	449 (27.7)	438 (30.2)	
	Diploma	2355 (29.9)	452 (31.9)	453 (29.6)	538 (29)	482 (29.8)	430 (29.7)	
	Bachelor's degree	1024 (13)	214 (15.1)	221 (14.5)	228 (12.3)	203 (12.5)	158 (10.9)	
	Master and doctor	211 (2.7)	44 (301)	74 (3)	53 (3.5)	51 (2.8)	29 (1.8)	
Family member (n(%))	2 members	1442 (18.4)	252 (17.9)	263 (17.2)	347 (18.7)	300 (18.6)	280 (19.5)	0.308
	3-4 members	4306 (54.9)	750 (53.2)	855 (56)	1018 (55)	909 (56.5)	774 (53.8)	
	≥5 members	2090 (26.7)	409 (29)	410 (26.8)	486 (26.3)	401 (24.9)	384 (26.7)	
Occupation (n(%))	Employed	3114 (39.9)	577 (41)	626 (41)	759 (41.4)	598 (37.3)	554 (38.7)	0.163
	Housewife	3119 (40)	559 (39.7)	593 (38.9)	704 (38.4)	689 (43)	574 (40.1)	
	Unemployed	1569 (20.1)	272 (19.3)	307 (20.1)	370 (20.2)	317 (19.8)	303 (21.2)	
BMI (Kg/m^2)	26.85±5.88	2787 (35.2)	480 (33.9)	553 (35.9)	629 (33.6)	586 (35.9)	917 (63)	0.21
	26.85±5.88	5130 (64.8)	937 (66.1)	988 (64.1)	1241 (66.4)	1047 (64.1)	1048 (63)	
Native (n(%))		6097 (77.8)	1070 (76.4)	1213 (79.6)	1457 (78.5)	1247 (77.2)	1110 (77)	0.216
Heart disease, yes (n(%))		660 (8.5)	109 (7.8)	114 (7.5)	154 (8.4)	140 (8.7)	143 (10)	0.139
Diabetes, yes (n(%))		1146 (14.5)	204 (14.4)	235 (15.3)	346 (18.8)	257 (13.8)	238 (14.6)	0.812
Hypertension, yes (n(%))		1438 (18.4)	283 (20.2)	257 (17)	346 (18.8)	286 (17.9)	266 (18.5)	0.25
Hyperlipidemia, yes (n(%))		1335 (17)	230 (16.3)	249 (16.4)	319 (17.3)	285 (17.6)	252 (17.5)	0.791
Physical activity (MET. min/week)		847.36±891.15	848.62±904.29	871.85±896.15	900.44±911.62	882.12±920.12	870.66±904.47	0.442

BMI Body mass index, *MET* Metabolic equivalent, Unhealthy plant-based diet: (uPDI)

For quantitative variables mean ± SD and for qualitative variables frequency (%) were used

*For qualitative and quantitative variables Chi-square test and One-way ANOVA were used respectively

are in agreement with previous studies reporting adverse health outcomes of unhealthy plant-based diets. In a Korean cross-sectional study, a significant positive association was found between a higher uPDI and increased risk of metabolic syndrome [22]. Also, a cohort study conducted on US nurses demonstrated that uPDI was correlated with a greater risk of obesity in nurses [41]. Furthermore, the cross-sectional analysis of Nurses' Health Study II revealed that there was a significant positive association between a higher uPDI and plasma leptin and insulin concentrations, which are the long-term adiposity biomarkers [4]. In this regard, several studies showed that a higher score of uPDI was correlated with an increased risk of inflammation [6, 38, 49].

There are also evidences suggesting that the unhealthy dietary patterns are associated with COVID-19. The pattern of the Western diet (WD), characterized by high intakes of refined carbohydrates, sugars and saturated fats, is associated with an increased risk of COVID-19 pathology and mortality in people [7]. In contrast, there are evidences indicating that there is a significant association between healthy dietary patterns like the healthy plant-based diets and reduced COVID-19 risk.

Table 2 Dietary intakes in across quintiles unhealthy plant-based diet

Variable	Q1(≤53)	Q2(54-57)	Q3(58-61)	Q4(62-65)	Q5(≥66)	*P* *
Energy intake(kcal)[a]	3406.95±1183.25	2940.36±1199.45	2666.90±1210.43	2553.79±1286.45	2556.89±1359.63	<0.001
Carbohydrate (% of total daily energy)	52.74±8.19	54.47±8.39	55.93±9.25	57.29±9.96	60.11±10.06	<0.001
Protein (% of total daily energy)	17.69±3.88	17.15±4.34	16.47±4.02	15.42±4.01	16.19±4.20	<0.001
Fat (% of total daily energy)	34.44±7.09	33.38±7.17	33.14±8.71	33.26±10.05	33.45±10.70	0.005
Fruits (gr/1000 Kcal)	242.13±148.84	212.18±144.18	189.99±141.02	175.29±130.94	145.94±112.83	<0.001
Vegetable (gr/1000 Kcal)	132.97±95.26	116.65±79.65	104.38±69.54	90.96±71.33	71.91±61.48	<0.001
Whole grain (gr/1000 Kcal)	22.36±30.15	20.53±33.57	16.06±29.11	13.61±24.82	9.20±15.67	<0.001
Legumes (gr/1000 Kcal)	16.12±17.06	14.84±16.36	13.71±14.49	12.52±16.80	9.48±11.04	<0.001
DHA (gr/1000 Kcal)	0.02 ±0.05	0.02±0.05	0.02 ± 0.05	0.01± 0.03	0.02± 0.05	0.007
EPA (gr/1000 Kcal) (gr)	0.01±0.02	0.01±0.02	<0. 01	<0. 01	<0. 01	0.002
Calcium (mg/1000 Kcal)	374.73±109.48	367.13±106.74	358.98±104.98	338.54±97.72	321.73±99.33	<0.001
Iron (mg/1000 Kcal)	18.70±30.46	16.80±27.40	16.37±28.58	15.72±27.37	13.05±12.46	<0.001
VitaminB12(µg/1000 Kcal)	2.34±1.33	2.26±1.24	2.12±1.10	1.99±1.40	1.81±1.42	<0.001
Folate (µg/1000 Kcal)	149.11±47.22	141.18±47.77	132.65±42.45	128.24±45.21	117.81±40.92	<0.001
ViaminB6(mg/1000 Kcal)	0.91±0.22	0.89±0.24	0.86±0.23	0.84±0.28	0.84±0.30	<0.001

DHA Docosahexaenoic acid, *EPA* Eicosapentaenoic acid

* Obtained from linear regression

[a] Values are means ± SDs and adjusted for energy intake

Table 3 Crude and multivariable-adjusted odds ratio and 95% confidence interval for incidence of the COVID-19 across quintiles of uPDI

uPDI quintiles						*P*_value*
COVID-19	**Q1(≤53)**	**Q2(54-57)**	**Q3(58-61)**	**Q4(62-65)**	**Q5(≥66)**	
Cases(N,%)	113 (7.8)	134 (8.5)	173 (9)	148 (8.8)	155 (10.3)	
Crude	1	1.09 (0.84_1.42)	1.17 (0.91_1.49)	1.13 (0.88_1.47)	1.36 (1.05_1.75)	0.017
Model I	1	1.10 (0.80_1.51)	1.18 (0.87_1.60)	1.01 (0.73_1.40)	1.37 (1_1.88)	0.043
Model II	1	1.25 (0.87_1.81)	1.16 (0.81_1.66)	1.08 (0.74_1.57)	1.52 (1.06_2.19)	0.022
Model III	1	1.29 (0.86_1.94)	1.35 (0.91_2.01)	1.14 (0.75_1.72)	1.58 (1.05_2.37)	0.027

COVID-19 Coronavirus disease, *uPDI* Unhealthy plant-based diets index

Model I: adjusted for age and energy intake

Model II: additionally adjusted for gender, smoking status, physical activity, marital status, chronic disease, educational levels, occupation, native and family member

Model III: further adjustment for BMI

* Obtained from logistic regression

Table 4 Multivariable-adjusted odds ratios for the associations between adherence to uPDI and COVID-19, stratified by gender

uPDI quintiles						*P*_value*,**
COVID-19	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	
Men	1	1.40 (0.91_2.16)	1.38 (0.91_2.16)	1.19 (0.77_1.85)	1.73 (1.12_2.67)	0.012
Women	1	1.06 (0.24_4.63)	1.43 (0.35_5.71)	0.80 (0.18_3.57)	0.70 (0.14_3.43)	0.667

COVID-19 Coronavirus disease, *uPDI* unhealthy plant-based diets index

* Obtained from logistic regression

** Adjusted for age and energy intake, smoking status, physical activity, marital status, chronic disease, educational levels, occupation, native, family member and BMI

A large-scale prospective cohort study demonstrated that there was an inverse correlation between a healthy plant-based diet and risk and severity of COVID-19 [28]. Also, the pattern of Mediterranean diet, characterized by the inclusion of the plant-derived nutritional components, has protective effects on COVID-19 infection and

COVID-19 -related outcomes [2]. In this regard, another cohort study indicated that higher intakes of fruits and vegetables were correlated with reduced risk of SARS-CoV-2 infection [12].

There are several mechanisms suggesting that nutrition especially the unhealthy plant-based diets are associated with the susceptibility of COVID-19. The food composition of the unhealthy plant-based diets would have higher intakes of pro-inflammatory food components and lower intakes of antioxidants, which could adversely influence immune system [16]. One of the strongest impacts of nutrition on susceptibility to the risk of COVID-19 is through an integral role of it in immune function [21]. Unhealthy dietary patterns lead to the chronic activation of the innate immune system and the also the inhibition of the adaptive immune system via increasing oxidative stress [7]. Oxidative stress impairs the T and B cells proliferation and maturation, contributing to immune depression [18]. Also, unhealthy dietary patterns significantly impairs innate and adaptive immunity, leading to host defense impairing against viral pathogens [7]. In patients with severe COVID-19, the SARS-CoV2 virus can trigger the host immune responses, resulting in the production of high concentrations of free radicals, followed by severe oxidative stress [33] to be the leading cause of severe COVID-19 infections pathophysiology [21].

In addition to impacts of the whole dietary patterns, single foods and nutrients also influence the risk of diseases. In the present study, an association was found between higher uPDI score and lower intakes of fruits, vegetables, whole grains, the total energy, Iron, folic acid and vitamin B12. Intake of fruits and vegetables has been examined for potential benefits on respiratory and inflammatory conditions because of their nutrients composing of antioxidants and phytochemicals such as phenolic compounds that can have antioxidant, anti-inflammatory, and antiviral effects [9, 43].

Regarding energy intake, studies indicated that lower energy intake along with the inadequate nutrient intake can lead to immune deficiency, susceptibility to infections and is a risk factor for viral infections, including influenza and SARS-CoV-2 [26, 48].

In the current study, there was no data about the serum iron levels or anemia; however, studies showed that both deficiency and excess intakes of iron could cause a predisposition to inflammation and infection [15]. Iron can play an important role in the immune response and adequate iron intake is essential to healthy innate and adaptive responses maintenance [50]. The other two nutrients involving in immune function are folic acid and cobalamin [29]. As previously mentioned, in the present study, there was an association between lower intakes of vitamin B9 and B12 and the higher uPDI scores. Studies have shown that the inadequate levels of folic acid and B12 can considerably alter immune responses via influencing the protein synthesis, inhibition of immune cells activity, and interfering with metabolic processes such as methylation [27]. Inefficient methylation can contribute to hyperhomocysteinemia, leading to systemic inflammation associated with infection susceptibility [25].

In addition to direct impacts of whole dietary intake on susceptibility and risk of SARS-CoV-2 infection, as previously mentioned, unhealthy dietary patterns like unhealthy plant-based diets are correlated with an enhanced risk of obesity, diabetes, metabolic syndrome and other chronic diseases. Studies have shown that obesity and obesity-related chronic conditions, including metabolic syndrome and other cardio metabolic disorders may contribute an enhanced risk of COVID-19, and poor COVID-19 outcomes [37, 42]. Pathophysiological features, including chronic inflammation, immune dysregulation and endothelial dysfunction are among the factors contributing to worse COVID-19 outcomes [24, 37]. It is therefore of paramount importance to adopt healthy eating habits to the prevention of COVID-19 and the outbreak of it [2].

In the present study, in the stratified analysis by sex, the positive association was found between dherence to uPDI and COVID-19 risk in male, indicating the sex hormone related to immune responses. In general, estrogens are known as immune stimulators and trigger immune responses and thus females are able to fight pathogens more efficiently than males, whereas testosterone acts as immuno-suppressor, leading the higher susceptibility of infection in males [34]. This discrepancy in the immune system functionality in males and females highlights the importance of more healthy dietary intakes in males.

Although the large sample size and controlling many potential confounders are the strengths of this study, there are some limitations that should be taken into account while interpreting the results. Despite careful and rigorous adjustment of confounders, we cannot rule out the possibility of residual confounding. Measurement bias is a feature observed in any dietary assessment.

Conclusion

In conclusion, greater adherence to unhealthy plant-based diets were correlated with higher odds of COVID-19, suggesting that it is important to consider the quality of consumed plant foods in the general population to health outcomes improvements.

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Author contributions
M.H. supervision, study concept and design analysis of data, review and editing and M.D. drafting the manuscript and SH.H. analysis of data, statistical analysis and S.G. and E.K. writing the manuscript and M.M. revising the manuscript and V.A. and A.N. revising and final approval of the version to be submitted. All authors reviewed the manuscript and approved the final manuscript submitted for publication.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The protocol of the current study was also approved by the ethics committee of Shahid Sadoughi University of Medical Sciences (IR.SSU.SPH.REC.1403.145). An informed consent was obtained from all subjects and/or their legal guardian(s).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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