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Vegetarian and plant-based diets associated with lower incidence of COVID-19

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ABSTRACT

Objective To evaluate the influence of dietary patterns on the incidence and evolution of COVID-19. We hypothesised that a plant-based diet or a vegetarian diet compared with an omnivorous diet might be associated with a lower incidence of COVID-19 infection and severity in those infected.

Design In this observational study, 702 participants provided information on sociodemographic characteristics, dietary information and COVID-19 outcomes between March and July of 2022. Individuals were divided into two groups based on their dietary habits, omnivorous (n=424) and plant-based (n=278). The plant-based group was further divided into vegetarian and flexitarian subgroups. The groups were compared with respect to the incidence of COVID-19 infection, severity and duration. We used multivariable logistic regression models to evaluate the influence of dietary patterns.

Results Plant-based and vegetarian groups had a higher intake of vegetables, legumes and nuts, and lower intake of dairy and meat. After adjusting for important confounders, such as body mass index, physical activity and pre-existing medical conditions, the plant-based diet and vegetarian group had 39% (OR=0.61, 95% CI 0.44 to 0.85; p=0.003) and 39% (OR 0.61, 95% CI 0.42 to 0.88; p=0.009) lower odds of the incidence of COVID-19 infection, respectively, compared with the omnivorous group. No association was observed between self-reported diets and COVID-19 severity or duration.

Conclusion Plant-based and mainly vegetarian diets were associated with a lower incidence of COVID-19 infection. These dietary patterns may be considered protective against COVID-19 infection. (Study protocol registered in CAAE: 54351421.4.0000.0068.)

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Several studies have hypothesised that dietary habits might play an important role in COVID-19 infection.

⇒ Populations that consume a diet rich in animal foods, with high amounts of saturated fats, and ultra-processed foods, have a higher prevalence of cardiometabolic diseases, risk factors for complications of COVID-19 in adults and the elderly.

WHAT THIS STUDY ADDS

⇒ Individuals consuming a plant-based diet and mainly vegetarian diet had a lower incidence of COVID-19 even after adjusting for several confounding variables.

⇒ They reported following plant-based diets or vegetarian diets and had higher intake of vegetables, legumes and nuts, and lower intake of dairy and meats.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ In light of these findings and findings of other studies and because of the importance of identifying factors that can influence the incidence of COVID-19, we recommend the practice of following plant-based diets or vegetarian dietary patterns.

INTRODUCTION

Coronavirus disease 19 (COVID-19), the clinical disease caused by infection with the novel coronavirus SARS-CoV-2 was not the world's first pandemic, but it is the worst pandemic in American history, which rapidly led to global changes to prevent the spread of this highly contagious disease. The COVID-19 pandemic surpassed the 1918 Spanish influenza death toll. According to the Centres for Disease Control, between early spring of 1918 and 1919 approximately 675 000 people died during the influenza pandemic in the USA. In comparison, on September 2022, over 1 million people in the USA had died from COVID-19 nationwide.[1] The COVID-19 pandemic also led to a historic breakdown in the world economy. However, in a way, it was predicted dramatically as a 'time bomb' 13 years earlier.[2] The initial epicentre of the COVID-19 pandemic was the Huanan seafood wholesale market in Wuhan, China,

where man was contaminated by zoonotic transmission. The market sold live, wild and breeding mammals for consumption, which were intermediate hosts being infected with SARS-CoV-2.[3]

Given the rapid advance of the disease, especially high morbidity and mortality, and the overload on the health services, health measures were adopted that affected large world economies, such as those in the USA and Brazil, both of which had the highest number of cases and deaths. Unlike in the West, Okinawa, Japan, one of the five blue zones on the planet, with a population already known for its longevity, lifestyle and reduced frequency of diseases, had low mortality due to COVID-19.[4] Similarly, in sub-Saharan Africa, lower mortality and infection rates were found compared with rates in North Africa, Europe and North America.[5] These populations have distinct geopolitical and socioeconomic contexts, but they have similar eating habits. Both have a plant-based diet, and a low incidence of chronic diseases, such as metabolic syndrome, which probably favoured the lower mortality due to COVID-19. On the other hand, populations that consume a diet rich in animal foods, with high amounts of saturated fats, and ultra-processed foods, have a higher prevalence of cardiometabolic diseases,[6] risk factors for complications of COVID-19 in adults and the elderly.

Plant-based diets consist of a diverse family of dietary patterns, defined in terms of the low frequency of consumption of animal foods.[7] To date, few investigations have been carried out on dietary patterns in the prevention and evolution of COVID-19,[8 9] indicating the need to expand this research, extending it to different populations. Thus, the present study aimed to evaluate the influence of dietary patterns on the incidence and evolution of COVID-19. We hypothesised that the plant-based diet or vegetarian diet might be associated with a lower incidence and severity of COVID-19 infection in those who consume such a diet compared with those who consume an omnivorous diet.

METHODS

Subjects

In the prospective observational study in Brazil called the Pandora Project, 723 adult volunteers were initially recruited through social networks and the internet during the period from 18 March to 22 July 2022. Initially, adults participants received an online questionnaire about sociodemographics, lifestyle, past medical history, eating patterns and eating habits. They were divided into two groups, omnivorous and plant-based, according to their self-reported dietary pattern. Both were requested to contemplate a minimum follow-up of 6 months. A basic food frequency questionnaire served as a tool for validation of the main self-reported dietetic pattern. The omnivorous were those who consumed any food of animal origin. The plant-based food pattern included flexitarian/semi-vegetarian (individuals who consumed meat at a frequency ≤3 times a week); lacto-ovo-vegetarians (individuals who consumed eggs and/or milk and dairy products, but without meat, fish or other shellfish); and strict vegetarians or vegans (people who do not consume any kind of animal food, such as egg, milk and dairy products, fish and red meat). The sample size to test the study hypothesis was estimated as 227 volunteers in each food group (omnivorous or plant-based diet). This calculation was based on an earlier study, with a sampling error of 5% and confidence level of 95%.[8] All participants provided informed consent to participate in the study. The research committee and the institutional review board of the Instituto do Coracao (InCor), Hospital das Clinicas, HCFMUSP approved the study protocol CAAE: 54351421.4.0000.0068.

Lifestyle, clinical and dietary assessment

For data on age, education, religion and ethnicity, the methodology approached by the Brazilian Institute of Geography and Statistics (IBGE)[10] and evaluation of smoking were used based on the systematics of the Surveillance of Chronic Diseases by Telephone Survey (Vigitel).[11] Participants reported their practice of physical activity using the short version of the International Physical Activity Questionnaire-Short Form (IPAQ), addressing exercise in different contexts (leisure, domestic, work or transportation) in relation to four domains: sedentary lifestyle, walking, moderate-intensity physical activity and physical activity of vigorous intensity in the last 7 days.[12] Through self-reported weight and height, the body mass index (BMI) was calculated by dividing body weight (kg) by height squared (m), considering four categories for adults: BMI <18.5 kg/m^2 low weight, BMI 18.5–24.9 kg/m^2 normal weight, BMI 25.0–29.9 kg/m^2 pre-obese, BMI ≥30.0 kg/m^2 obesity.[13]

Participants were asked about the presence of previous diseases through a confirmed medical diagnosis, such as diabetes, cardiovascular disease, lung disease, cancer, kidney disease and others (yes, no). We examined the factors related to exposure to COVID-19 (relationship between social isolation, contact with the disease and frequency of exposure) and vaccination received (yes, no). The severity of the disease considered guidelines for diagnosis and treatment of COVID-19 and Pan-American Health Organization and World Health Organization (PAHO/WHO), resulting in three distributions: no diagnosis of COVID-19; mild and moderate/severe COVID-19.[14] Individuals reported the number of days of duration of symptoms. Restriction of personal contact during the pandemic was divided into four categories: normal life without social isolation (person who continued to go out normally, going to events, seeing friends and family); reduced contact with people (avoided leaving the house, but eventually found friends and family); working from home only going out shopping at supermarkets and pharmacy (just to buy necessary items); and strictly at home (leaving only for health needs). Through a food frequency questionnaire, the pattern of consumption of the food groups was evaluated. For each food group, the

portion size determined by personal measurements and the frequency of consumption were evaluated. The food consumption frequency instrument used was based on the vegetarian lifestyle index described previously.[15]

Statistical analysis

Sociodemographic, clinical and lifestyle variables are presented, according to the self-reported dietary pattern (omnivorous or plant-based diet). A X^2 test was used to test differences between categorical variables, and in cases where there were variables with fewer than five observations per cell, Fisher's exact test was used. Linear regression was used to compare age and body mass index means.

The frequency of consumption of food groups (<1, 2–4 or ≥5 times/week) was presented according to dietary patterns (omnivorous, plant-based, flexitarian or vegetarian) and compared by the X^2 test, or Fisher's exact test when necessary.

Through logistic regression, we analysed the association of dietary pattern with the incidence of COVID-19 (yes or no) and its severity (mild to moderate/severe). Four linear regression models were tested, the first being a crude model. The other multiple models were adjusted for variables which, based on previous knowledge, might have an effect on the studied outcomes. The three models contain the following variables:

Model 1 – adjusted for sex (women or men), age (continuous variable in years), ethnicity (white, mixed race, black, Asian or indigenous) and educational level (elementary and high school, university level or postgraduate).

Model 2 – adjusted for covariates in model 1 plus smoking status (yes or no), physical activity (yes or no) and BMI (continuous variable in kg/m^2).

Model 3 – adjusted for covariates in model 2 plus presence of pre-existing medical conditions (yes or no), restriction of personal contact and vaccination (yes or no).

The dependent variables were COVID-19 incidence (none as the reference), symptoms' duration (<14 days as the reference) and severity status (mild as the reference); the food pattern (omnivorous as the reference) was the independent variable. In all tests, the level of significance considered was 5% ($p<0.05$). Analyses were performed using Stata 16.0.

RESULTS

A total of 723 individuals answered the online questionnaire. Of these, 21 people were excluded because they provided incongruent information about their dietary pattern, so 702 people were included in this study; 424 were omnivorous and 278 had plant-based diets (see figure 1). This last category was eventually divided into two groups: the vegetarians (including vegans and lacto-ovo-vegetarians) n=191 and the flexitarians n=87.

For the variables sex, age, vaccination and degree of isolation, no significant differences were found between omnivorous and plant-based groups. For educational level, we observed a significantly higher rate of postgraduate participants in the plant-based group compared with a lower educational level in the omnivorous group. Of the total sample, 330 people (47.0%) reported a diagnosis of COVID-19 (incidence). From these individuals, 224 (31.9%) were diagnosed with mild symptoms and 106 (15.1%) with moderate to severe symptoms. The omnivorous group had a significantly higher incidence of COVID-19 than did the plant-based diet group (51.6 vs 39.9%, p=0.005). With respect to severity of COVID-19 in the group with COVID-19 infection, the omnivorous group had a higher rate of moderate-severe infection compared with the plant-based diet group (17.7 vs 11.2%, p=0.005). The duration of symptoms in individuals with COVID-19 was not different between omnivorous and plant-based groups (p=0.549) (see table 1).

With respect to vaccination, restriction of contact with others and/or smoking status, there were no differences between the omnivorous and plant-based groups. For the presence of any pre-existing medical conditions, the omnivorous group reported having a higher rate than the plant-based group had (p=0.017). Physical activity was reported by 62.5% of the total sample. The plant-based diet group reported a higher rate of physical activity than the omnivorous group (p=0.01). The mean BMI was significantly lower in the plant-based diet group than in the omnivorous group and the prevalence of overweight and obesity was significantly higher in the omnivorous than in the plant-based group (p=0.001).

For the frequency of food groups' consumption, we divided the plant-based group into vegetarian and flexitarian groups and compared the three dietary patterns (omnivorous, vegetarian and flexitarian), and found that vegetarians had a higher consumption of cereals, fruits, vegetables, nuts and seeds, vegetable oils, and a lower consumption of dairy and eggs (all p<0.001). Conversely, the omnivorous group had a higher consumption of meats (p<0.001) than the other dietary groups (see table 2). We analysed the frequency of food group consumption and compared individuals with COVID-19 to individuals without COVID-19 for each of three dietetic groups; there were no differences in any group (see table 3).

When we analysed the association between dietary pattern and the incidence and severity of COVID-19 by using a crude model and three multivariable logistic regression models in two dietetic groups (omnivorous and plant-based), we observed a 38% lower incidence of COVID-19 in individuals in the plant-based groups, both in the crude model (OR=0.62, p=0.02). After adjusting for the variables included in the models, the incidence ranged from 41% in model 1 to 39% in model 3—the lowest chance of the incidence of COVID-19 being in the plant-based group (see figure 2A).

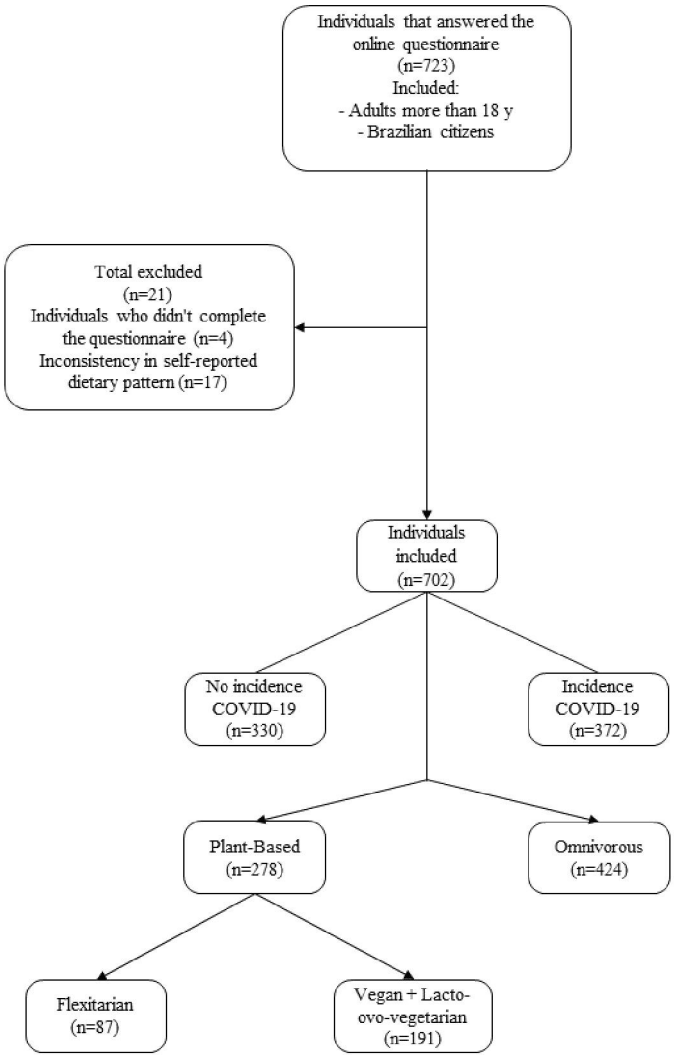

Figure 1 Enrolment and distribution of individuals according to dietary patterns and incidence of COVID-19.

We combined the vegan and lacto-ovo-vegetarian groups because of the relatively lower sample size of the vegan group. When dietetic groups (omnivorous, vegetarian and flexitarian) were analysed, we observed a lower chance of individuals in the vegetarian and flexitarian groups of having COVID-19 in the crude analysis (OR=0.62, p=0.007 and 0.63, respectively, p=0.054) and in model 1 (OR=0.58, p=0.003 and 0.61, p=0.045, respectively). The lower incidence of COVID-19 in the vegetarian group persisted after applying model 2 (OR=0.61, p=0.008) and model 3 (OR=0.61, p=0.009) (see figure 2B). For the severity of COVID-19, no significant differences were observed between omnivorous and plant-based groups (see figure 2C) or between the three dietetic groups (see figure 2D).

DISCUSSION

We found that Brazilian individuals consuming a plant-based diet, mainly a vegetarian diet, had a lower incidence of COVID-19 even after the results were adjusted for several confounding variables. Those who reported following plant-based diets or vegetarian diets had a higher intake of vegetables, legumes and nuts, and a lower intake of dairy and meats.

Previously, only two studies have reported such findings.[8 9] The relationship between COVID-19 severity and a plant-based diet was evaluated by Kim *et al* in a case–control study among health professionals from six countries, finding a lower evolutionary risk of moderate to severe disease in professionals who consumed a plant-based diet.[8] Although our study design was similar to that of the study by Kim *et al*, several differences do exist. The population studied in our report was the Brazilian public; in the other study the population was multicentric with health professionals from five European countries and the USA. The time when that study was carried out was during the first wave of COVID-19 (July to September 2020) and ours was in the third wave (March to July 2022). We found a lower incidence of COVID-19 infection in plant-based diet and vegetarian groups but not in the severity of outcomes. We found significant differences

Table 1 Sociodemographics and clinical characteristics of subjects according to self-reported dietary pattern

Sample size, n	Total (n=702)	Omnivorous (n=424)	Plant-based* (n=278)	P value
Sex, n (%)				
Women	565 (80.5)	341 (80.4)	224 (80.6)	0.961
Men	137 (19.5)	83 (19.6)	54 (19.4)	
Age, years	36.9 (35.9–37.9)	36.2 (35.0–37.5)	37.9 (36.4–39.5)	0.091
Ethnicity, n (%)† (n=699)				
White	456 (65.2)	258 (60.9)	198 (60.9)	<0.001 ‡
Mixed race	169 (24.2)	108 (25.5)	61 (22.2)	
Black	51 (7.3)	44 (10.4)	7 (2.6)	
Asian	21 (3.0)	12 (2.8)	9 (3.3)	
Indigenous	2 (0.3)	2 (0.5)	0 (0)	
Educational level, n (%)† (n=700)				
Elementary and high school	108 (15.4)	81 (19.2)	27 (9.7)	0.002
University level	276 (39.4)	165 (39.0)	111 (40.1)	
Postgraduate	316 (45.1)	177 (41.8)	139 (50.2)	
Incidence of COVID- 9/severity WHO				
No COVID-19 incidence	372 (53.0)	205 (48.4)	167 (60.1)	
COVID-19-mild	224 (31.9)	144 (33.9)	80 (28.8)	0.005
COVID-19-moderate+severe	106 (15.1)	75 (17.7)	31 (11.2)	
Symptoms duration, n (%) †	(n=319)			
≤14 days	266 (83.4)	177 (84.3)	89 (81.7)	0.549
>14 days	53 (16.6)	33 (15.7)	20 (18.4)	
Received COVID-19 vaccine, n (%)				
No	16 (2.3)	6 (1.4)	10 (3.6)	0.058
Yes	686 (97.7)	418 (98.6)	268 (96.4)	
Restriction of personal contact during the pandemic, n (%)† (n=600)				
Normal life without social isolation	30 (4.3)	21 (5.9)	9 (3.3)	0.375
Reduced contact with people	308 (44.0)	189 (44.8)	119 (42.9)	
Home, office, only going out shopping at supermarkets and pharmacy	287 (41.1)	173 (41.0)	114 (41.2)	
Strictly at home, leaving only for health needs	74 (10.6)	39 (9.2)	35 (12.6)	
Presence of pre-existing medical conditions, n (%)				
No	576 (82.1)	336 (79.2)	240 (86.3)	0.017
Yes	126 (17.9)	88 (20.8)	38 (13.7)	
Smoking status, n (%)† (n=699)				
No	642 (91.9)	387 (91.9)	255 (91.7)	0.926
Yes	57 (8.1)	34 (8.1)	23 (8.3)	
Physical activity practice, n (%)				
No	263 (37.5)	175 (41.3)	88 (31.7)	0.010
Yes	439 (62.5)	249 (57.7)	190 (68.3)	
BMI kg/m^2† (n=698)	25.4 (25.0–25.8)	25.9 (25.4–26.5)	24.6 (24.1–25.1)	0.001
BMI categories				
BMI <18.5 kg/m^2	31 (4.44)	17 (4.0)	14 (5.1)	0.001
BMI 18.5–24.9 kg/m^2	354 (50.7)	190 (45.0)	164 (59.4)	
BMI 25.0–29.9 kg/m^2	203 (29.1)	143 (33.9)	60 (21.7)	
BMI ≥30.0 kg/m^2	110 (15.8)	72 (17.1)	38 (13.8)	

Values are n (%) for categorical variables and mean (SD) for continuous variables.
*Participants self-reported that they followed vegan, lacto-ovo-vegetarian or flexitarian diets.
†In these variables, the number of people was not 702 due some missing data.
‡Fisher's exact test.

Table 2 Frequency of food consumption according to self-reported dietary pattern in the entire group

Dietary pattern				
Frequency of intake of food groups	**Omnivorous (n=424)**	**Vegetarian (vegan+lacto–ovo-vegetarian) (n=191)**	**Flexitarian (n=87)**	**P value**
Cereals				
≤1 time/week	29 (6.9)	11 (5.8)	7 (8.1)	0.090
4 times/week	72 (17.1)	19 (10.0)	18 (20.7)	
≥5 times/week	319 (76.0)	160 (84.2)	62 (71.2)	
Beans				
≤1 time/week	104 (24.8)	4 (2.1)	17 (19.5)	<0.001
2–4 times/week	107 (25.4)	19 (10.0)	27 (31.0)	
≥5 times/week	209 (49.8)	167 (87.9)	43 (49.4)	
Fruits				
≤1 time/week	74 (17.5)	12 (6.3)	19 (21.8)	<0.001
2–4 times/week	116 (27.4)	20 (10.5)	18 (20.7)	
≥5 times/week	233 (55.1)	159 (83.2)	50 (57.5)	
Vegetables				
≤1 time/week	75 (17.7)	4 (2.1)	13 (14.9)	<0.001
2–4 times/week	118 (27.9)	8 (4.2)	22 (25.3)	
≥5 times/week	230 (54.4)	179 (93.7)	52 (59.8)	
Nuts and seeds				
≤1 time/week	319 (75.6)	64 (33.5)	55 (63.2)	<0.001
2–4 times/week	54 (12.8)	51 (26.7)	16 (18.4)	
≥5 times/week	49 (11.6)	76 (39.8)	16 (18.4)	
Vegetable oils				
≤1 time/week	134 (31.7)	31 (16.2)	29 (33.3)	<0.001
2–4 times/week	96 (22.7)	14 (7.3)	17 (19.5)	
≥5 times/week	193 (45.6)	146 (76.5)	41 (47.1)	
Dairy				
≤1 time/week	68 (16.1)	119 (62.6)	31 (35.6)	<0.001
2–4 times/week	109 (25.8)	26 (13.7)	22 (25.3)	
≥5 times/week	245 (58.1)	45 (23.7)	34 (39.1)	
Eggs				
≤1 time/week	132 (31.4)	117 (61.9)	24 (27.6)	<0.001
2–4 times/week	146 (34.4)	35 (18.5)	34 (39.1)	
≥5 times/week	142 (33.8)	37 (19.6)	29 (33.3)	
Meats (red, processed, poultry, fish and seafood)				
≤1 time/week	20 (4.7)	191 (100)	34 (39.1)	<0.001 *
2–4 times/week	102 (24.1)	0	53 (60.9)	
≥5 times/week	302 (71.2)	0	0	
Sweets and desserts				
≤1 time/week	152 (36.0)	71 (37.2)	36 (41.4)	0.737
2–4 times/week	141 (33.4)	58 (30.4)	23 (26.4)	
≥5 times/week	129 (30.6)	62 (32.5)	28 (32.2)	

*Fisher's exact test.

Table 3 Frequency of food consumption according to self-reported dietary pattern and COVID-19 diagnoses

Dietary pattern									
	Omnivorous (n=424)			Vegetarian (vegan+lacto-ovo-vegetarian) (n=191)			Flexitarian (n=87)		
Frequency of food groups intake	Control (n=205)	COVID (n=219)	P value	Control (n=115)	COVID (n=76)	P value	Control (n=52)	COVID (n=35)	P value
Cereals									
≤1 times/week	16 (7.9)	13 (5.9)	0.339	6 (5.3)	5 (6.6)	0.081	4 (7.7)	3 (8.6)	0.071
2–4 times/week	39 (19.3)	33 (15.1)		7 (6.1)	12 (15.8)		15 (28.9)	3 (8.6)	
≥5 times/week	147 (72.8)	172 (78.9)		101 (88.6)	59 (77.6)		33 (63.5)	29 (82.8)	
Beans									
≤1 times/week	42 (20.8)	62 (28.4)	0.100	2 (1.8)	2 (2.6)	0.897	12 (23.1)	5 (14.3)	0.439
2–4 times/week	59 (29.2)	48 (22.0)		11 (9.7)	8 (10.5)		17 (32.7)	10 (28.6)	
≥5 times/week	101 (50.0)	108 (49.5)		101 (88.6)	66 (86.8)		23 (44.2)	20 (57.1)	
Fruits									
≤1 times/week	33 (16.2)	41 (18.7)	0.775	8 (6.9)	4 (5.3)	0.571	13 (25.0)	6 (17.1)	0.293
2–4 times/week	56 (27.5)	60 (27.4)		10 (8.7)	10 (13.2)		8 (15.4)	10 (28.6)	
≥ 5 times/week	115 (56.4)	118 (53.9)		97 (84.4)	62 (81.6)		31 (59.6)	19 (54.3)	
Vegetables									
≤1 times/week	39 (19.1)	36 (16.4)	0.700	1 (0.9)	3 (3.9)	0.327 *	9 (17.3)	4 (11.4)	0.744*
2–4 times/week	54 (26.5)	64 (29.2)		4 (3.5)	4 (5.3)		12 (23.1)	10 (28.6)	
≥5 times/week	111 (54.4)	119 (54.3)		110 (95.7)	69 (90.8)		31 (59.6)	21 (60.0)	
Nuts and Seeds									
≤1 times/week	149 (73.0)	170 (77.9)	0.471	37 (32.2)	27 (35.5)	0.791	32 (61.5)	23 (65.7)	0.713
2–4 times/week	28 (13.7)	26 (11.9)		30 (26.1)	21 (27.6)		11 (21.2)	5 (14.3)	
≥5 times/week	27 (13.2)	22 (10.1)		48 (41.7)	28 (36.8)		9 (17.3)	7 (20.0)	
Vegetable oils									
≤1 times/week	58 (28.4)	76 (34.7)	0.380	17 (14.8)	14 (18.4)	0.777	18 (34.6)	11 (31.4)	0.792
2–4 times/week	48 (23.6)	48 (21.9)		9 (7.8)	5 (6.6)		11 (21.2)	6 (17.1)	
≥5 times/week	98 (48.0)	95 (43.4)		89 (77.4)	57 (75.0)		23 (44.2)	18 (51.4)	
Dairy									
≤1 times/week	35 (17.2)	33 (15.1)	0.250	77 (66.9)	42 (56.0)	0.093	21 (46.2)	7 (20.0)	0.044
2–4 times/week	45 (22.2)	64 (29.2)		17 (14.8)	9 (12.0)		11 (21.2)	11 (31.4)	
≥5 times/week	123 (60.6)	122 (55.7)		21 (18.3)	24 (32.0)		17 (32.7)	17 (48.6)	
Eggs									
≤1 times/week	65 (31.9)	67 (31.0)	0.975	75 (65.8)	42 (56.0)	0.246	14 (26.9)	10 (28.6)	0.729
2–4 times/week	71 (34.8)	75 (34.7)		21 (18.4)	14 (18.7)		19 (37.5)	15 (42.9)	
≥5 times/week	68 (33.3)	74 (34.3)		18 (15.8)	19 (25.3)		19 (36.6)	10 (28.6)	
Meats (red, processed, poultry, fish and seafood)									
≤1 times/week	13 (6.3)	7 (3.2)	0.140	0	0	NA	19 (36.5)	15 (42.9)	0.655*
2–4 times/week	54 (26.3)	48 (21.9)		0	0		33 (63.5)	20 (57.1)	
≥5 times/week	138 (67.4)	164 (74.9)		0	0		0	0	
Sweets and desserts									
≤1 times/week	87 (42.7)	65 (29.8)	0.005	46 (40.0)	25 (32.9)	0.605	24 (46.2)	12 (34.3)	0.399
2–4 times/week	54 (26.5)	87 (39.9)		33 (28.7)	25 (32.9)		14 (26.9)	9 (25.7)	
≥5 times/week	63 (30.9)	66 (30.3)		36 (31.3)	26 (34.2)		14 (26.9)	14 (40.0)	

*Fisher's exact test.
NA, not applicable.

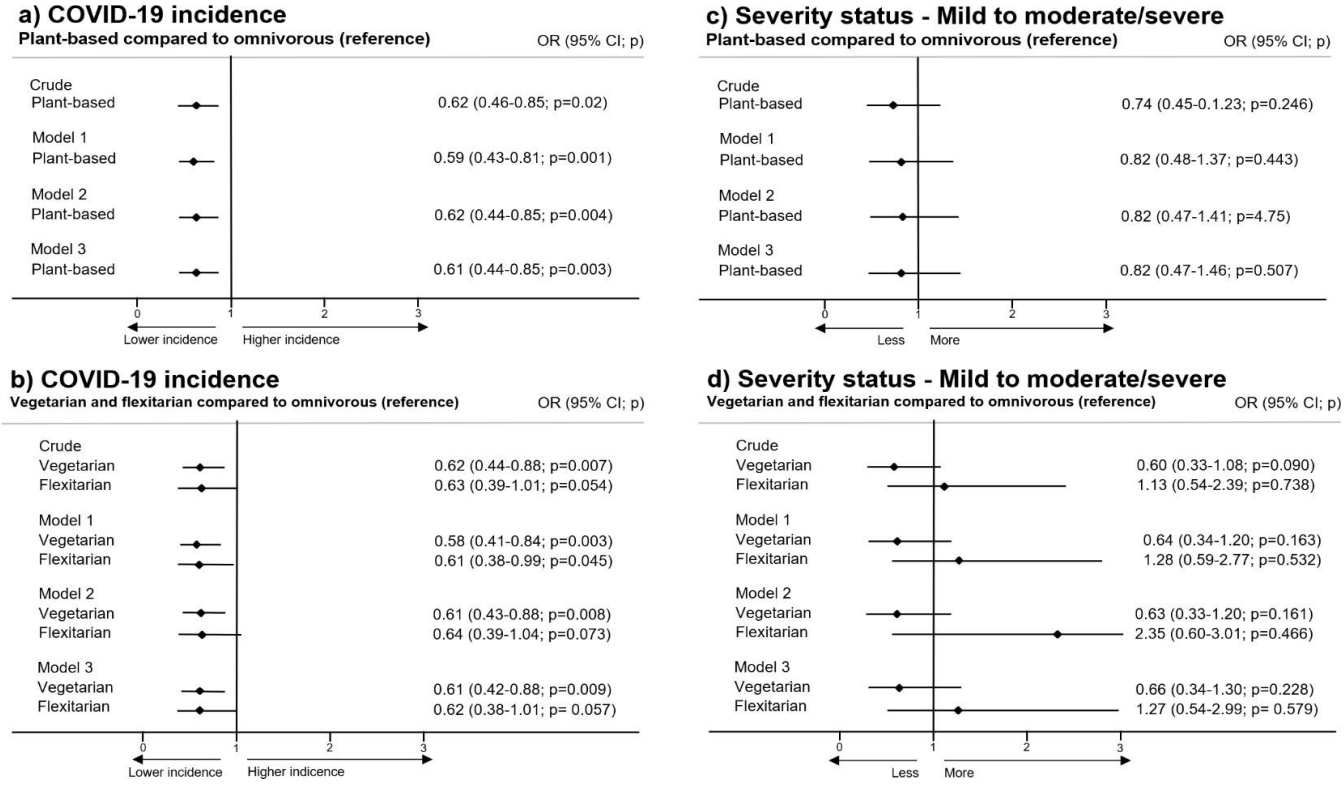

Figure 2 Rate of incidence of COVID-19 and severity status according to dietary pattern. Logistic regression models considered as dependent variables: COVID-19 incidence (no as the reference), and severity status (mild as the reference). Model 1 – adjusted for sex (women or men), age (continuous variable in years), ethnicity (white, mixed race, black, Asian or indigenous) and educational level (elementary and high school, university level or postgraduate). Model 2 – adjusted for covariates in model 1 plus smoking status (yes or no), physical activity practice (yes or no) and body mass index (continuous variable in kg/m^2). Model 3 – adjusted for covariates in model 2 plus presence of pre-existing medical conditions (yes or no), restriction of personal contact and vaccine (yes or no). Vegetarian group includes vegan and lacto-ovo-vegetarian.

in the plant-based group and specifically also in the vegetarian group. Therefore, until we have additional knowledge, this is the first study to report a lower incidence of COVID-19 associated with the vegetarian diet.

In another prospective cohort study,[9] it was found that a healthy, plant-based dietary pattern was associated with lower risk and severity of COVID-19. Recently, in Taiwan, the association between dietary patterns and the greater severity of COVID-19 in hospitalised patients was observed only in the group of patients aged 65 years and older who followed an omnivorous diet compared with a vegetarian dietary pattern.[16]

Differences in the findings with respect to other studies could be related to geographical and temporal situations. Our study was carried out during the months of March to July 2022. At the beginning of the research, in March, Brazil registered more than 29.6 million confirmed cases and about 657 000 deaths from COVID-19. In this initial period of the research, more cases of the delta variant were identified, representing 43.54% of cases, the gamma variant 30.41%, omicron 25.50%, alpha 0.54% and beta 0.01%.[17] In July 2022, at the end of the survey, Brazil recorded more than 33.5 million confirmed cases and around 676 000 deaths from COVID-19, demonstrating an accumulated incidence rate of more than 15 000 cases per 100 000 inhabitants, and an accumulated mortality rate of 319.7 deaths per 100 000 inhabitants.

In this final period of the survey, the variant of most concern in the country was omicron, which represented 38.51% of confirmed cases, followed by delta representing 35.66%, gamma 25.39%, alpha 0.44% and beta <0.01%.[18] According to data from the Brazilian Ministry of Health, the presence of three waves of COVID-19, as well as the effect of immunisation on the reduction of mortality in the second and third waves, was attributed to the delta and omicron variants, respectively. The national and centralised command of the pandemic confrontation did not occur; thus, public administrators took the lead in their territories. The overwhelming effect of the pandemic could have been minimised, if there had been a coordinated participation of three spheres of the Brazilian Unified Health System administration, in the joint governance of the fight against the pandemic.[19]

It is interesting that in our study when we analysed three dietary groups, we found that the lower incidence of COVID-19 in the plant-based group compared with omnivorous group was due mainly to the vegetarian group. On the other hand, the frequency of food group consumption in the omnivorous group was like that in the flexitarian group. Flexitarians are closer to the

omnivorous group regarding food consumption and lack of protection. Therefore, we can associate the differences in the vegetarian group with differences in food group consumption: a higher consumption of cereals, fruits, vegetables, nuts and seeds, vegetable oils, and a lower consumption of dairy, eggs and meats. In addition, we speculate that the trend of the lower severity of COVID-19 associated with the vegetarian group observed in the crude model could not reveal any difference as observed in other studies in a larger sample size taking into account that this group did not reach the calculated sample.

Adults with excess weight were at even greater risk during the COVID-19 pandemic: being obese increases the risk of severe illness from COVID-19. In a recent meta-analysis, it was observed that being overweight increased the risk of COVID-19-related hospitalizations, whereas obesity increased the risk of both COVID-19-related hospitalizations and death.[20] In our study, we found that BMI and the prevalence of overweight and obesity was higher in the omnivorous group than in the plant-based group. Vegetarians had lower BMI, prevalence of overweight, obesity and metabolic syndrome.[21] However, after the adjustment of BMI in the logistic regression the difference of lower diagnosis of COVID-19 in plant-based and vegetarian groups remained, suggesting that the difference in incidence of COVID-19 could be associated with other factors present in the diet. On other hand, physical activity also relates to a lower likelihood of adverse COVID-19 outcomes. In a meta-analysis, it was found that, those who engaged in regular physical activity had a lower risk of infection, hospitalisation, severe COVID-19 illness and COVID-19-related death than their inactive peers.[22] In addition, in our study, after the adjustment for physical activity the lower incidence of COVID-19 remained in the plant-based and vegetarian group.

To explain the associations observed in our study, we must examine the relation between immunity and foods. The immune system uses a range of defence mechanisms to combat infections; therefore, it is necessary to have an adequate amount of antioxidant enzymes, vitamins and peptides; without them, the capability of the immune system will be jeopardised.[23] Due to the high intake of some key nutrients and phytochemicals in groups following plant-based diets, it is plausible that a difference in immune status might be observed between plant-based and omnivorous dietary patterns. Plant-based dietary patterns are rich in antioxidants, phytosterols and polyphenols, which positively affect several cell types implicated in the immune function[24] and exhibit direct antiviral properties.[25] We have demonstrated lowered leucocytes and lowered neutrophils[26] in vegetarian individuals. Furthermore, NK cell activity of peripheral blood lymphocytes has been shown to be elevated in plant-based populations compared with that in omnivorous populations.[27]

There is agreement that an appropriately planned vegetarian diet is healthy, nutritionally adequate and might provide health benefits for the prevention and treatment of certain diseases.[28] Furthermore, vegetarian people are at reduced risk of chronic diseases of high morbidity and mortality, including ischaemic heart disease, type 2 diabetes, hypertension, certain types of cancer and obesity.[29–31] In this study, our findings of the lower incidence of COVID-19 in plant-based and vegetarian groups remained after controlling for differences in pre-existing conditions. In light of these findings and other studies and because of the importance of identifying factors that can influence the incidence of COVID-19 we recommend the practice of these dietary patterns.

This study has several limitations. First, as an observational study, we are unable to confirm a direct causal association between diet and COVID-risk or infer specific mechanisms. Second, the fact that we combined the vegan and lacto-ovo-vegetarian groups could have influenced the results owing to some differences reported in the food composition. However, several studies have shown that both groups have the same results. Individuals with those diets have reduced risk of certain health conditions, including cardiovascular diseases, type 2 diabetes and obesity.[28] which increase the risk of severity of COVID-19. In addition, in other studies about dietetic patterns, due to the low number of participating vegans, these were pooled with the lacto-ovo-vegetarians.[32] Third, the self-reported nature online of the dietary questionnaire is prone to measurement error and bias. Nevertheless, it is encouraging that the responses on the food frequency questionnaire reflected intake of food groups consistent with self-reported dietary patterns. Fourth, participants in our study were required to rely on their memory when answering questions about pre-existing diseases and symptoms during COVID-19. This can introduce bias; however, it would be the same limitation for all the dietetic groups. Fifth, our study might not have included individuals with more severe COVID-19 illness or who might have died of COVID-19 before the administration of the dietary questionnaire.

CONCLUSION

Our study provides evidence that individuals with a plant-based diet and mainly a vegetarian diet had a lower incidence of COVID-19 even after accounting for important variables like physical activity, BMI and pre-existing conditions. Those who reported following plant-based diets or vegetarian diets had a higher intake of vegetables, legumes and nuts, and lower intake of dairy and meats. Our results suggest that a plant-based diet and mainly vegetarian diet may be considered for protection against infection with COVID-19.

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