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Lifestyle Changes and COVID-19 Infection: A Cross-Sectional Study

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ABSTRACT

Background: COVID-19 pandemic has evidently influenced people's lifestyle, particularly their health. In this study, the authors examined the association between dietary intake and lifestyle changes, and COVID-19 infection in adults living in Bojnurd, Iran. **Methods:** In this cross-sectional study conducted on 4425 adults from Bojnurd city, Iran, regarding changes in food consumption, physical activity, sleep duration, and the history of COVID-19 infection; data were collected online using a researcher-designed questionnaire. The associations between lifestyle changes and COVID-19 infection were assessed by multivariate- adjusted logistic regression models. **Results:** There were significant associations between lower odds of COVID-19, increased legumes consumption (OR: 0.76; 95% CI: 0.61, 0.96), and increased physical activity (OR: 0.74; 95% CI: 0.57, 0.95) during the pandemic; this was while increased intakes of refined grain (OR: 1.32; 95% CI: 1.06, 1.63), butter oil (OR: 1.34; 95% CI: 1.03, 1.73), processed meat (OR: 1.36; 95% CI: 1.01, 1.82), fast foods (OR: 1.65; 95% CI: 1.13, 2.40), honey (OR: 1.34; 95% CI: 1.10, 1.64), and coffee (OR: 1.61; 95% CI: 1.24, 2.09) were associated with higher odds of infection. Moreover, higher sleep duration (OR: 1.25; 95% CI: 1.02, 1.52), increased intake of multivitamins/minerals (OR: 1.66; 95% CI: 1.35, 2.05), vitamin D (OR: 1.22; 95% CI: 1.01, 1.47), and vitamin C (OR: 1.52; 95% CI: 1.26, 1.84) were significantly associated with higher odds of infection, compared to the cases with no change. **Conclusion**: Increased intake of refined grain and high-fat foods may be associated with lower odds of infection. However, the cross-sectional design of the present study precludes causal inferences.

Keywords: *Diet; COVID-19; Physical activity; Sleep habit; Cross-sectional studies*

Introduction

On December 2019, a new type of coronavirus disease broke out in Wuhan, China, and sparked a global pandemic, on March 11, 2020 (Silva, 2020, Song *et al.*, 2020). The disease was

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termed COVID-19, which predominantly attacks lungs (both upper and lower). Symptoms of the disease include fever, fatigue, body aches, cough, and shortness of breath (Pullen *et al.*, 2020). Globally, according to the latest report of World Health Organization (WHO) (Ammar *et al.*, 2020), as of 14 October 2022, 620 million people were infected, and 6.5 million died.

To prevent the spread of COVID-19, governments carried out sanitization and disinfectant protocols, and WHO advised home quarantine and maintaining social distance (Velavan and Meyer, 2020). Travel between high-risk cities was banned, and gatherings were limited. Subsequently, many jobs were shut down or virtualized, and online distance learning prevailed. Previous studies demonstrated that despite preventing the spread of the virus, these changes yielded detrimental effects on mental and physical health; lower physical/outdoor activities because of the time spent on home-cooked sweets, restricted access to grocery shopping centers causing lower consumption of fresh foods, altered sleep patterns, and feeling anxious due to the constant exposure to stressful news (Banerjee and Rai, 2020). Stress-coping behaviors may also develop habits like overeating, especially high-fat sugary foods and beverages (Koball *et al.*, 2012, Yannakoulia *et al.*, 2008). This condition may prevent individuals from having a healthy lifestyle.

Several studies investigated changes in lifestyle during the pandemic; they demonstrated that during COVID-19 people were more likely to eat unhealthy (Ammar *et al.*, 2020b, Scarmozzino and Visioli, 2020, Sidor and Rzymski, 2020) and canned foods (Janssen *et al.*, 2021). However, the situation may be quite different due to the raised public awareness about health and boosting immune systems. A study in Spain showed adherence to a Mediterranean diet was increased during the pandemic confinement, compared with previous habits (Rodríguez-Pérez *et al.*, 2020). In another study, physical activity (PA) was reduced by around 34%, although dietary habits remained stable or improved in older adults in Finland (Lehtisalo *et al.*, 2021).

Change in lifestyle can affect susceptibility to infectious diseases, primarily through affecting the immune system (Calder, 2020, Shi *et al.*, 2020). A large cohort study in UK reported higher incidence of COVID-19 in people who had sedentary lifestyles, smoked, and were obese (Hamer *et al.*, 2020). The results from a cross-sectional study also revealed higher rates of severe infection in patients with lower levels of PA, and less severity in patients with a healthier dietary pattern (Tavakol *et al.*, 2021).

In Iran, the severity of infection was more complicated due to the imposition of sanctions on people facing severe inflation and losing their jobs (Abdoli, 2020). So far, no study has investigated dietary intake and other risk factors in relation to COVID-19 infection. Therefore, the authors aimed to examine the changes in lifestyle (including diet, physical activity, sleep duration, and smoking) and their association with COVID-19 infection.

Materials and Methods

Study design and participants: The present cross-sectional study was conducted on adults from Bojnurd, Iran, in July 2021. No inclusion and exclusion criteria were applied, except for age (18 years old and above). Anyone interested in participating in the study, after watching a recorded video about the objectives of the survey and reading the informed consent, could access the questionnaire through an electronic link created by *survey.porsline.ir*. To avoid duplication of data, the authors asked only one adult person in each household to complete the questionnaire (preferably the head of the household). The study was conducted in agreement with the Helsinki declaration, and all data were collected anonymously and kept confidential. The questionnaire was available from May 4th for one month, and social networks (including Instagram, Telegram, WhatsApp, and Facebook) and emails were used to recruit for the study. For this purpose, the invitation video along with the link of the questionnaire were shared on the most visited pages/groups related to North Khorasan, such as news channels, medical channels, and COVID-19

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information channels on the social networks. Moreover, the announcement was released in the context of Roshd educational network, a designed platform for virtual education of students during the pandemic.

As old people use the internet less frequently than young individuals, participants were asked to interview with them and complete the questionnaire for relatives and acquaintances who did not have regular access to the internet.

Questionnaire: A 60-item self-administered questionnaire was designed, containing three sections: 1) socio-demographic characteristics, including age, sex, history of chronic disease, place of residence (urban/rural), education, sleep duration, weight change during the pandemic, income, marital status, living status, family size, and main source of income; 2) changes in lifestyle (PA, smoking, and sleep), and 3) dietary intake during and after the pandemic. They were also asked about whether their family members have been diagnosed with COVID-19. All the sections were based on multiple choice close-ended questions, except for age. Participants were asked to choose an option, based on the changes due to COVID-19 outbreak (decreased, increased, and unchanged).

Ethical considerations: This study was conducted in agreement with Helsinki declaration, and all the data were collected anonymously and kept confidentially. The study protocol was also approved by the Medical Ethics Committee of North Khorasan University of Medical Sciences (IR.NKUMS.REC.1400.026).

Data analyses: Descriptive statistics of the participants' characteristics are presented as frequency and percentages. Chi-square test was performed to analyze the difference between socio-demographic factors and COVID-19. Stepwise multivariate logistic regression analyses were performed to explore the associations between changes in dietary intake, PA, and sleep [(1) no change/constant, (2) increase, (3) decrease]) and confirmed/unconfirmed diagnosis of COVID-19. The results of logistic regression analyses were expressed as crude and adjusted model (age, sex, food purchasing power, marital status, household composition, family member, place of residence, income, main source of income, and education). For all analyses, p-values less than 0.05 were considered significant. All analyses were performed with SPSS for Windows, version 16 (Chicago, Illinois).

Results

From 4425 completed questionnaires, 97 were excluded due to incomplete information. 675 participants were diagnosed with COVID-19 since beginning of the pandemic. More than half of the participants were married (nearly 58%), and most of the households had 3-4 members. More than 90% of the participants lived in families with monthly incomes below the poverty line, whilst half of the participants reported no change in their weight during the pandemic. Other main characteristics of the participants with COVID-19 infection are described in **Table 1**.

The multivariate adjusted model revealed a significant association between lower odds of COVID-19, increased legumes consumption (OR: 0.76; 95% CI: 0.61, 0.96), and increased PA (OR: 0.74; 95% CI: 0.57, 0.95) during the pandemic. This was while the increased intake of refined grain (OR: 1.32; 95% CI: 1.06, 1.63), butter oil (OR: 1.34; 95% CI: 1.03, 1.73), processed meat (OR: 1.36; 95% CI: 1.01, 1.82), fast foods (OR: 1.65; 95% CI: 1.13, 2.40), honey (OR: 1.34; 95% CI: 1.10, 1.64), and coffee (OR: 1.61; 95% CI: 1.24, 2.09) was associated with higher odds of infection. There was also a significant relationship between increased sleep duration and higher odds of infection (OR: 1.25; 95% CI: 1.02, 1.52). Furthermore, it was found that participants with an increased intake of multivitamins/ minerals (OR: 1.66; 95% CI: 1.35, 2.05), vitamin D (OR: 1.22; 95% CI: 1.01, 1.47), and vitamin C (OR: 1.52; 95% CI: 1.26, 1.84) was associated with higher odds of COVID-19 infection, compared to participants who did not change their intake (**Table 2**).

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Table 1. Characteristics of the questionnaires regarding COVID -19 infection.

Variables	COVID-19 non-infected	COVID-19 infected	Total	P-value[a]
Sex				
Male	924 (25.4)[b]	159 (23.6)	1083 (25.3)	0.31
Female	2714 (74.6)	516 (76.4)	3230 (74.6)	
Physical activity duration per day (min)				0.003
Less than 30	1108 (30.9)	249 (37.8)	1357 (32.0)	
30-60	1194 (33.3)	190 (28.9)	1384 (32.6)	
60-120	803 (22.4)	129 (19.6)	932 (22.0)	
More than 120	481 (13.4)	90 (13.7)	571 (13.5)	
Sleep duration (hour)				0.073
Less than 2	141 (3.9)	16 (24.0)	157 (3.6)	
2-4	89 (2.4)	12 (1.8)	101 (2.3)	
4-6	246 (6.7)	59 (8.8)	305 (7.1)	
6-8	1405 (38.5)	250 (37.1)	1655 (38.3)	
8-10	1463 (40.1)	269 (39.9)	1732 (40.1)	
More than 10	305 (8.4)	68 (10.1)	373 (8.6)	
Using the electronic devise (hour)				<0.001
Less than 2	1110 (30.7)	165 (24.7)	1275 (29.7)	
2-4	1020 (28.2)	182 (27.3)	1202 (28.0)	
4-6	677 (18.7)	128 (19.2)	805 (18.8)	
6-8	446 (12.3)	102 (15.3)	548 (12.8)	
8-10	215 (5.9)	43 (6.4)	258 (6.0)	
More than 10	151 (4.2)	47 (7.0)	198 (4.6)	
Smoking				0.045
I never smoked	2626 (85.9)	522 (89.8)	3148 (86.5)	
I have been smoking since the past	156 (5.1)	16 (2.8)	172 (4.7)	
Decreased	209 (6.8)	33 (5.7)	242 (6.7)	
Increased	67 (2.2)	10 (1.7)	77 (2.1)	
Weight change during the pandemic				0.034
Without change	1820 (49.8)	301 (44.6)	2121 (49.0)	
Decreased	490 (13.4)	93 (13.8)	583 (13.5)	
Increased	1344 (36.8)	281 (41.6)	1625 (37.5)	
Food intake during pandemic				0.008
Without change	2297 (62.9)	389 (57.9)	2686 (62.1)	
Decreased	475 (13.0)	86 (12.7)	561 (13.0)	
Increased	879 (24.1)	200 (29.6)	1079 (24.9)	
Marital status				<0.001
Single	1540 (42.4)	189 (27.9)	1729 (40.1)	
Married	2035 (56.0)	464 (68.4)	2499 (57.9)	
Widowed	19 (0.5)	5 (0.7)	24 (0.6)	
Divorced	41 (1.1)	20 (2.9)	61 (1.4)	
Household composition				<0.001
Couple and children	1926 (52.7)	452 (66.9)	2378 (54.9)	
Living with parents	1666 (45.6)	199 (29.4)	1865 (43.1)	
One person	32 (0.9)	12 (1.8)	44 (1.0)	
Extended family	19 (0.5)	8 (1.2)	27 (0.6)	
Nonfamily households	10 (0.3)	5 (0.7)	15 (0.3)	
Family size (number)				<0.001
≤ 2	121 (3.3)	44 (6.5)	165 (3.8)	
3-4	2205 (60.3)	439 (64.8)	2644 (61)	
5-6	1237 (33.8)	179 (26.4)	1416 (32.7)	
7 ≤	95 (2.6)	15 (2.2)	110 (2.5)	

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Income (million Rial)			<0.001
< 1	588 (16.5)	54 (8.2)	642 (15.2)
1-2	822 (23.0)	86 (13.0)	908 (21.5)
3-5	1036 (29.0)	228 (34.5)	1264 (29.9)
6- 8	496 (13.9)	124 (18.8)	620 (14.7)
8-10	338 (9.5)	81 (12.3)	419 (9.9)
10-15	177 (5.0)	60 (9.1)	237 (5.6)
15- 20	58 (1.6)	14 (2.1)	72 (1.7)
20 ≥	52 (1.5)	13 (2.0)	65 (1.5)

[a]: Chi-square test; [b]: n(%)

Table 2. The association between dietary and lifestyle factors and COVID-19 infection.

Food groups	Participants/ event (Number)	Crude	Model 1	Model 2
Dairy	4326/ 674			
No Change	2938/ 470	1	1	1
Decreased	555/ 100	1.13 (0.88, 1.45)	1.13 (0.88, 1.45)	1.21 (0.93, 1.57)
Increased	833/ 104	0.75 (0.59, 0.95)	0.76 (0.60, 0.96)	0.85 (0.66, 1.09)
Cookies and sweets	4322/ 675			
No Change	2632/ 397	1	1	1
Decreased	1047/ 156	0.94 (0.76, 1.16)	0.94 (0.76, 1.16)	0.94 (0.75, 1.17)
Increased	643/ 122	1.27 (1.00, 1.60)	1.27 (1.00, 1.60)	1.21 (0.95, 1.54)
Refined grain	4323/ 673			
No change	3052/ 460	1	1	1
Decreased	315/ 52	0.95 (0.67, 1.33)	0.96 (0.68, 1.35)	1.19 (0.83, 1.71)
Increased	956/161	1.14 (0.93, 1.40)	1.15 (0.94, 1.41)	**1.32 (1.06, 1.63)**
Red meat	4315/ 674			
No change	2817/ 457	1	1	1
Decreased	807/ 110	0.79 (0.62, 1.00)	0.79 (0.62, 1.00)	0.93 (0.73, 1.20)
Increased	691/ 107	1.02 (0.81, 1.30)	1.03 (0.82, 1.31)	1.18 (0.92, 1.51)
Poultry	4319/ 672			
No change	2804/ 446	1	1	1
Decreased	755/ 105	0.81 (0.64, 1.03)	0.82 (0.64, 1.05)	0.97 (0.75, 1.25)
Increased	760/ 121	0.99 (0.79, 1.24)	1.00 (0.79, 1.25)	1.11 (0.88, 1.41)
Egg	4321/ 674			
No change	2800/ 436	1	1	1
Decreased	556/ 90	1.01 (0.78, 1.31)	1.02 (0.78, 1.32)	1.23 (0.94, 1.62)
Increased	965/ 148	0.96 (0.78, 1.19)	0.97 (0.79, 1.21)	0.99 (0.79, 1.23)
Fish	4318/ 671			
No change	2868/ 477	1	1	1
Decreased	993/ 133	0.76 (0.61, 0.94)	0.76 (0.61, 0.94)	0.81 (0.65, 1.02)
Increased	457/ 61	0.77 (0.57, 1.04)	0.77 (0.57, 1.04)	0.77 (0.56, 1.05)
Salty snacks	4316/ 674			
No change	2371/ 381	1	1	1
Decreased	1322/ 177	0.80 (0.65, 0.98)	0.81 (0.66, 0.99)	0.91 (0.73, 1.12)
Increased	623/ 116	1.19 (0.94, 1.51)	1.19 (0.94, 1.51)	1.22 (0.95, 1.57)
Olive and olive oil	4297/ 673			
No change	3399/ 539	1	1	1
Decreased	525/ 74	0.86 (0.65, 1.13)	0.87 (0.66, 1.14)	0.94 (0.71, 1.25)
Increased	373/ 60	0.92 (0.67, 1.25)	0.93 (0.68, 1.27)	0.84 (0.61, 1.15)
Butter oil	4310/ 671			
No change	3111/ 475	1	1	1
Decreased	648/ 96	0.91 (0.71, 1.17)	0.92 (0.72, 1.18)	1.06 (0.82, 1.38)
Increased	551/100	1.20 (0.94, 1.54)	1.21 (0.95, 1.55)	**1.34 (1.03, 1.73)**

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Processed meat	4300/ 674			
No change	2607/ 414	1	1	1
Decreased	1305/ 181	0.88 (0.72, 1.07)	0.88 (0.73, 1.08)	0.92 (0.75, 1.13)
Increased	388/ 79	1.32 (1.00, 1.75)	1.34 (1.01, 1.77)	**1.36 (1.01, 1.82)**
Fast food	4291/ 671			
No change	2321/ 334	1	1	1
Decreased	1761/ 287	1.13 (0.94, 1.35)	1.13 (0.94, 1.35)	1.00 (0.83, 1.21)
Increased	209/ 50	1.73 (1.21, 2.46)	1.78 (1.25, 2.54)	**1.65 (1.13, 2.40)**
Alcoholic drinking	3970/ 624			
No change	3426/ 549	1	1	1
Decreased	446/ 55	0.78 (0.57, 1.07)	0.78 (0.75, 1.07)	1.01 (0.73, 1.40)
Increased	98/ 20	1.24 (0.71, 2.16)	1.28 (0.73, 2.23)	1.39 (0.76, 2.54)
Energetic drinks	4123/ 650			
No change	3408/ 535	1	1	1
Decreased	527/ 88	1.09 (0.84, 1.41)	1.10 (0.85, 1.42)	1.30 (0.99, 1.71)
Increased	188/ 27	0.97 (0.63, 1.51)	0.99 (0.64, 1.54)	1.13 (0.71, 1.79)
Sweet beverage	4284/ 669			
No change	2467/ 406	1	1	1
Decreased	1323/ 175	0.77 (0.63, 0.93)	0.77 (0.63, 0.94)	0.83 (0.67, 1.02)
Increased	494/ 88	1.00 (0.77, 1.31)	1.02 (0.78, 1.33)	1.09 (0.82, 1.45)
Water	4315/ 673			
No change	2274/ 362	1	1	1
Decreased	233/ 32	0.86 (0.58, 1.28)	0.87 (0.58, 1.29)	1.11 (0.73, 1.68)
Increased	1808/ 279	0.90 (0.76, 1.08)	0.91 (0.76, 1.09)	0.95 (0.79, 1.15)
Tea	4310/ 672			
No change	2554/ 378	1	1	1
Decreased	412/ 56	0.87 (0.63, 1.21)	0.89 (0.64, 1.22)	1.15 (0.82, 1.61)
Increased	1344/ 238	1.19 (1.00, 1.44)	1.20 (0.99, 1.44)	1.13 (0.93, 1.37)
Coffee	4245/ 666			
No change	3198/ 474	1	1	1
Decreased	576/ 84	1.01 (0.78, 1.31)	1.01 (0.78, 1.31)	1.17 (0.89, 1.54)
Increased	471/ 108	1.66 (1.30, 2.12)	1.70 (1.32, 2.17)	**1.61 (1.24, 2.09)**
Nuts	4296/ 671			
No change	2567/ 398	1	1	1
Decreased	750/ 106	0.89 (0.70, 1.13)	0.89 (0.70, 1.13)	0.96 (0.75, 1.23)
Increased	979/ 167	1.07 (0.87, 1.32)	1.07 (0.87, 1.32)	0.99 (0.79,1.23)
Honey	4319/ 671			
No change	2660/ 377	1	1	1
Decreased	538/ 73	0.93 (0.70, 1.24)	0.94 (0.71, 1.25)	1.10 (0.82, 1.47)
Increased	1121/ 221	1.54 (1.27, 1.86)	1.53 (1.26, 1.85)	**1.34 (1.10, 1.64)**
Fruits	4325/ 673			
No change	1896/ 292	1	1	1
Decreased	499/ 64	0.74 (0.54, 1.00)	0.74 (0.55, 1.01)	0.91 (0.66, 1.26)
Increased	1930/ 317	1.03 (0.86, 1.24)	1.04 (0.86, 1.24)	1.05 (0.87, 1.27)
Vegetable	4322/ 675			
No change	2438/ 387	1	1	1
Decreased	519/ 86	0.97 (0.74, 1.27)	0.97 (0.74, 1.28)	1.09 (0.82, 1.45)
Increased	1365/ 202	0.86 (0.71, 1.04)	0.86 (0.71, 1.04)	0.87 (0.71, 1.06)
Beans	4328/ 676			
No change	3065/ 512	1	1	1
Decreased	297/ 43	0.78 (0.54, 1.13)	0.79 (0.55, 1.14)	1.01 (0.69, 1.49)
Increased	966/ 121	0.73 (0.59, 0.91)	0.73 (0.59, 0.91)	**0.76 (0.61, 0.96)**
Physical activity	4244/ 658			
No change	1357/ 249	1	1	1
Decreased	1384/ 190	0.74 (0.60, 0.91)	0.74 (0.60, 0.91)	0.79 (1.63, 0.98)
Increased	932/ 129	0.71 (0.56, 0.91)	0.72 (0.56, 0.92)	**0.74 (0.57, 0.95)**
Smoking	3639/ 581			
No change	3320/ 538	1	1	1

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Decreased	242/ 33	0.94 (0.64, 1.39)	0.95 (0.65, 1.41)	1.35 (0.89, 2.05)
Increased	77/ 10	0.57 (0.24, 1.33)	0.59 (0.25, 1.39)	0.55 (0.21, 1.42)
Social media	4319/ 670			
No change	1174/ 170	1	1	1
Decreased	339/ 29	0.58 (0.38, 0.90)	0.59 (0.38, 0.91)	0.75 (0.48, 1.18)
Increased	2806/ 471	1.15 (0.94, 1.40)	1.15 (0.94, 1.40)	1.11 (0.90, 1.37)
Sleep duration	4317/ 673			
No change	2453/ 363	1	1	1
Decreased	552/ 85	1.05 (0.80, 1.38)	1.06 (0.81, 1.38)	1.17 (0.88, 1.54)
Increased	1312/ 225	1.17 (0.97, 1.41)	1.18 (0.98, 1.43)	**1.25 (1.02, 1.52)**
Intake of multivitamin-mineral intake	4256/ 667			
No change	3055/ 435	1	1	1
Decreased	368/ 43	0.81 (0.57, 1.16)	0.82 (0.58, 1.17)	1.02 (0.71, 1.49)
Increased	833/ 189	1.80 (1.47, 2.19)	1.80 (1.48, 2.20)	**1.66 (1.35, 2.05)**
Intake of vitamin D supplement	4283/ 671			
No change	2496/ 350	1	1	1
Decreased	406/ 46	0.79 (0.57, 1.12)	0.80 (0.57, 1.12)	1.03 (0.72, 1.47)
Increased	1381/ 275	1.49 (1.25, 1.79)	1.50 (1.24, 1.78)	**1.22 (1.01, 1.47)**
Intake of vitamin A supplement	4260/ 666			
No change	3115/ 480	1	1	1
Decreased	351/ 46	0.82 (0.58, 1.16)	0.83 (0.59, 1.18)	1.06 (0.74, 1.53)
Increased	794/ 140	1.14 (0.91, 1.41)	1.14 (0.92, 1.42)	1.11 (0.88, 1.40)
Intake of vitamin C supplement	4275/ 664			
No change	2681/ 358	1	1	1
Decreased	355/ 48	1.00 (0.71, 1.40)	1.02 (0.72, 1.43)	1.31 (0.92, 1.88)
Increased	1239/ 258	1.72 (1.43, 2.06)	1.72 (1.43, 2.07)	**1.52 (1.26, 1.84)**
Intake of omega-3 supplement	4238/ 659			
No change	3281/ 509	1	1	1
Decreased	374/ 50	0.84 (0.61, 1.17)	0.84 (0.61, 1.18)	1.11 (0.79, 1.58)
Increased	583/ 100	1.19 (0.93, 1.51)	1.20 (0.94, 1.52)	1.11 (0.86, 1.43)

Model 1: Adjusted for age and sex; Model 2: Adjusted for age, sex, food purchasing power, marriage status, household composition, family member, place of residence, income, main source of income, and education

Discussion

This paper examined the association between lifestyle factors and COVID-19 infection in Bojnurd, Iran. The increased consumption of legumes and increased PA was negatively associated with the odds of COVID-19 infection. However, increased consumption of refined grain, butter oil, processed meats, fast foods, honey, caffeine, and more sleep duration contributed to higher odds of COVID-19 infection. Surprisingly, higher intake of multivitamin, vitamin D, and vitamin C supplements was associated with higher odds of infection.

Adequate nutrition is essential for strengthening the immune system and may improve protection against COVID-19 infection and its complications (Calder and Jackson, 2000, EFSA Panel on Dietetic Products and Nutrition and Allergies, 2016, Keusch, 2003, Watson, 1984). It is well known that under nutrition with insufficient energy, protein, and nutrient intake is related to poor immune function (Katona and Katona-Apte, 2008), while over nutrition is associated with impaired lung function (Dietz and Santos-Burgoa, 2020, Melo *et al.*, 2014), secretion of inflammatory mediators (Hauner, 2005), and cytokine storm, leading to acute respiratory syndrome and organs dysfunction (Muscogiuri *et al.*, 2020). A balanced diet to meet nutritional needs, containing both plant-based foods and animal resources, in

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accordance with healthy nutritional guidelines, can improve immune responses and help body to fight against infection (Cena and Calder, 2020).

In concordance with some previous studies (Abdulah and Hassan, 2020, Kim *et al.*, 2021), this study revealed a significant association between higher consumption of legumes and lower odds of COVID-19 infection. Legumes are solid sources of protein, dietary fiber, as well as nutraceutical compounds (Singh *et al.*, 2017). Indeed, there are several sources of evidence supporting the beneficial effect of legumes on obesity (Kim *et al.*, 2016), diabetes mellitus (Becerra-Tomás *et al.*, 2018), dyslipidemia (Ha *et al.*, 2014), high blood pressure, and CVD (Grosso *et al.*, 2017).

There was also a significant association between increased PA and lower odds of COVID-19 infection. A similar finding was observed in a study with 48,440 participants, where inactivity was positively linked with severe COVID-19 infection (Sallis *et al.*, 2021). PA is acknowledged as an indispensable part of healthy lifestyle; although, it is suggested higher PA may increase pro-inflammatory cytokines in muscles, but not in the circulation (Peake *et al.*, 2015). Regular PA has been shown to enhance immune response, lung capacity, muscle strength, mental health (Buitrago-Garcia *et al.*, 2020), and reduce systemic inflammation (Sallis *et al.*, 2021), lockdown-induced emotional stress (Celorio-Sardà *et al.*, 2021) and COVID-19 complications (Nieman and Wentz, 2019). On the other hand, it is plausible that people who are more active are leaner, and therefore, follow a healthier lifestyle, compared with less active individuals.

A positive association was observed between increased intake of refined grains, honey, processed meats, fast food, and butter oil, and higher odds of COVID-19 infection. It has been well established that adherence to a diet rich in refined carbohydrates and saturated fats is associated with obesity, metabolic syndrome, cardiovascular damage, and inflammation, which can predispose individuals to infections, as well as COVID-19 (Butler and Barrientos, 2020). A study demonstrated that higher consumption of sugary drinks was associated with higher odds of COVID-19 infection (Abdulah and Hassan, 2020). Indeed, accumulating evidence suggests that chronic consumption of high-glycemic carbohydrates and saturated or trans fats contribute to higher circulating levels of pro-inflammatory cytokines such as CRP, IL-6 and TNF-α (Bulló *et al.*, 2013, Clarke *et al.*, 2008, Liu *et al.*, 2002, Mozaffarian *et al.*, 2004). Moreover, Higher intake of honey was significantly related to increased risk of COVID-19 infection. On the contrary, several studies have reported beneficial effects of honey on COVID-19 via interaction on the entrance of the virus into the host cells (Abedi *et al.*, 2021). Moreover, immune-boosting benefits of honey may be defined by its immunomodulatory, anti-thrombotic, anti-inflammation, and anti-oxidative properties (Hossain *et al.*, 2020). The main explanation of the results may be related to, so-called, 'food fraud' in Iran regarding the honey industry, as it has been reported that available samples are artificially altered by feeding sugar and syrup of C4 origin to bees (Khansaritoreh *et al.*, 2021). Moreover, energy intake and other potential confounding factors were not assessed in the present study, which makes it difficult to draw a firm association.

Another contradictory result of this study was higher odds of COVID-19 infection in association with increased caffeinated-drinks consumption. Conversely, in the UK Biobank, daily consumption of 2-3 cups of coffee was associated with lower risk of COVID-19 compared to 1 cup per day (Vu *et al.*, 2021). Caffeinated-drinks (including coffee, types of tea) provide a large amount of polyphenols, and empirical evidence supports its anti-inflammatory properties (Barcelos *et al.*, 2020, Oyewole, 2015, Santana-Gálvez *et al.*, 2017) via decrease in inflammatory factors, such as CRP and IL- 6 (Wang *et al.*, 2012). However, the observed association in this study might be confounded by added sugar or high-fat milk in the drinks, thereby, reducing its health benefits.

During COVID-19 pandemic, the use of

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supplements increased all over the world as a strategy to boost immunity (Hamulka *et al.*, 2021). Sufficient levels of anti-oxidant vitamins, such as vitamin D and vitamin C, can decrease cytokine storm, which occurs in COVID-19 and is related to severe cases (Holford *et al.*, 2020, Jain *et al.*, 2020). Increased intake of nutritional supplements was associated with higher odds of infection; however, no form of causal association can be drawn, and the higher consumption of nutritional supplements may be due to treatment protocols in infected individuals.

It seems that quarantine measures put in place following the COVID-19 pandemic has disturbed sleep patterns. Furthermore, social distancing, working from home, and virtual education, all engender longer sleep periods (Smit *et al.*, 2021). A cross-sectional study which presented the effect of lockdown on sleep duration, demonstrated that sleeping hours increased in more than 40 percent of children during restriction (Kaditis *et al.*, 2021). According to the results of a longitudinal study, sedentary behaviors and sleep duration increased; while PA was lower among Hong-Kong-based adults during quarantine (Zheng *et al.*, 2020). Conversely, some studies have reported sleep deprivation due to increased stress and anxiety during COVID-19 lockdown (Celorio-Sardà *et al.*, 2021, Pérez-Rodrigo *et al.*, 2020, Voitsidis *et al.*, 2020). Both sleep deprivation and long sleep duration are associated with impaired immune response (Besedovsky *et al.*, 2012, Bryant *et al.*, 2004). However, those who experience long sleeping hours are probably less active, and follow an unhealthier lifestyle than those with healthy sleep cycles. It should be noted that the present study cannot discern causal inferences, and it may be because people who became infected slept more due to their medications.

This was the first study to examine the association between lifestyle changes and COVID-19 infection in Iran. Despite the novelty of this work, there were some limitations; the primary one was its cross-sectional design, which precludes causal inferences, and it is not clear whether the changes happened before or after the infection. Second, evaluation of lifestyle was based on a self-reported qualitative questionnaire, and results may have been influenced by over-reporting or under-reporting of the respondents. Third, COVID-19 pandemic may have caused a change in respondent's behavior, but also increased the potential for recall bias. In addition, there are several confounding factors which were not considered, including compliance with COVID-19 health and safety protocols. Finally, the limitations related to online surveys may result in bias; the difficulty of reaching those who did not have Internet access, not knowing how to fill out the electronic questionnaire, being illiterate, lack of quality random sampling, and not having time to fill out a 60-item questionnaire, which caused some participants to quit.

Conclusion

This cross-sectional study demonstrates for the first time that dietary intake and lifestyle factors may be associated with increased or decreased odds of COVID-19 infections in an Iranian population. However, more research is needed to draw firm conclusions.

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Conflict of interest

Authors declared no conflict of interest.

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Authors' contributions

Toupchian O and Abdollahi S contributed to the study's conception and design. Soltani S, Hosseini-Marnani E, Eslami F, Poorbarat S, Heshmati J, and Rajabzade R prepared, collected, and analyzed data. The first draft of the manuscript was written by Toupchian O, and edited by Cain C.T. Clark. All the authors read and approved of the final manuscript.

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