Journal of Health, Population and Nutrition

RESEARCH

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The association between fruit and vegetable intake and the odds of asthma among children and adolescents

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Abstract

Background Previous epidemiological studies on the correlation between fruit and vegetable consumption and asthma, the majority of them were conducted in developed countries, have led to conflicting results. This study aimed to examine the relationship between fruit and vegetable intake and the risk of asthma among a large sample of children and adolescents.

Methods This cross-sectional study was conducted as part of the Global Asthma Network (GAN) on 7667 Iranian children and adolescents. Asthma and its related outcomes were measured using validated questionnaires. A food frequency method was used to assess the dietary intake. The association between fruit and vegetable intake and asthma and its related symptoms was examined using logistic regression.

Results After adjustment for all possible confounding variables, no significant association was found between fruit and vegetable intake and the odds of medication use for asthma and asthma confirmed by a doctor. However, an inverse significant trend was found between fruits intake and current asthma. After adjusting for age, sex, BMI, and the use of television and computers, participants who regularly consumed fruit had a 37% lower likelihood of experiencing wheezing in the past 12 months (OR = 0.63; 95% CI: 0.42–0.94, P trend = 0.001) compared to those who never or only occasionally consumed fruit. Additionally, individuals who reported consuming vegetables most or all days had a 38% reduced chance of wheezing in the past 12 months (OR = 0.62; 95% CI: 0.48–0.80, P trend < 0.001) compared to participants with infrequent vegetable intake. Participants with regular fruit and vegetable intake combined (OR = 0.50; 95% CI: 0.31–0.82, P trend < 0.001) had a 50% lower likelihood of wheezing in the past 12 months in comparison with those who never or only occasionally fruits and vegetables combined consumers.

Conclusion Our findings suggest that regular consumption of fruits and vegetables on most or all days has a protective effect against wheezing in the past 12 months. Future longitudinal studies should be conducted to confirm our findings.

Keywords Asthma, Fruits, Vegetables, Children, Adolescents

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Introduction

Affecting approximately 339 million children, adolescents, and adults globally, asthma is one of the prevalent chronic respiratory diseases; as1 out of every 10 children suffers from asthma; and many of them do not have access to medication [1–4]. The disease also imposes a large financial burden on the healthcare system and patients [5–7]. Asthma is usually identified by airway inflammation and symptoms like coughing, wheezing, and shortness of breath [8]. Uncontrolled asthma can lead to many problems for the patients, such as a low quality of life, an inappropriate quality of mental health, increased number of school absences, and low academic performance [9, 10].

Several factors including genetics, exposure to smoke and tobacco, air pollution, viral and bacterial infections, stress, poor socioeconomic status, occupational risk factors, obesity, as well as dietary intake might be related to asthma [11–13]. Several studies assessed the relationship between dietary and food group intake with asthma [14, 15]. A meta-analysis found that daily meat consumption might not affect the risk of asthma in children [16]. Another meta-analysis showed that there was no relationship between dairy products consumption and reduced asthma risk in children; moreover, this study mentioned that increased milk and dairy consumption was associated with a reduced risk of asthma among the non-Asian population [17]. Several epidemiological studies have proposed a protective relationship between fruits, vegetables, fish, and whole grain consumption and asthma in children [18–21]. Also, a Mediterranean diet which is rich in fruits and vegetables was shown to have beneficial effects on wheezing and asthma in children [22, 23]. A high intake of fruits and vegetables may offer protective benefits to the lungs against oxidative damage [24]. This protection is attributed to their rich antioxidant and anti-inflammatory properties, which include significant quantities of antioxidants, vitamins (notably vitamins C and E), β-carotene, minerals, and fiber [24]. The results of a cross-sectional study conducted on 690 children aged 7 to 18 in Greece showed that long-term consumption of fruits and vegetables in children with asthma is associated with reduced asthma progression and contributes to better management of asthma symptoms [20]. On the other hand, in a large cross-sectional study of schoolchildren in Taiwan, no significant association was found between fruit and vegetable consumption and physician-diagnosed asthma [25]. The meta-analysis conducted by Nurmatov et al. which combined the results of four cross-sectional studies found a relationship between increased fruit consumption and a decreased risk of wheezing in children aged 10 to 14 years [14]. In contrast, a pooled analysis of three studies indicated that there was no association between a higher intake of vegetables and odds of wheezing in children aged 10 to 14 years [14]. A cross-sectional study conducted in the Netherlands found that there was no significant association between total vegetables consumption and current wheezing; additionally, vegetable consumption was not significantly related to current asthma [21].

Most research on the topic has been carried out in developed nations, yielding conflicting results. In contrast, the dietary intakes among Middle Eastern populations, particularly those from Iran, differ significantly [26, 27]. Dietary patterns identified in population-based studies in Iran vary according to the type of city. In a cross-sectional analysis of 10,693 Iranian adults from Yazd, a large urban city, a dietary pattern characterized by high intakes of confectionery, sugars, and snacks was observed [28]. Conversely, a sample of 4,834 Iranian adults from Isfahan identified three distinct dietary patterns: a Western dietary pattern, a fast-food dietary pattern, and an animal fat dietary pattern [29]. In the study conducted by Aghayan et al. [26], dietary changes among Iranians from 2006 to 2017 were evaluated. The results indicated a notable rise in the consumption of refined grains, solid fats, and simple sugars [26]. Conversely, dairy products intake significantly decreased [26]. Meanwhile, fruit and vegetable intake remained consistent throughout the study period [26]. Given these discrepancies and the absence of prior studies examining the correlation between fruit and vegetable intake and asthma within this geographical area, this investigation aimed to assess the link between fruit and vegetable consumption and both asthma and its symptoms in a large sample of school-aged children residing in Iran.

Methods

This cross-sectional study was performed among 7667 children aged 6–7 years and adolescents aged 13-14 years in early 2020 living in Yazd City, central Iran. This study was conducted as a part of the Global Asthma Network (GAN). The GAN is a multi-country, multicenter, epidemiological research that was conducted to evaluate the global trend of asthma over three decades as a continuation of the International Study of Asthma and Allergies in Childhood (ISAAC) Phase III [30]. Detailed information about the methodology, participants, and data collection of our study has been described elsewhere [31]. Briefly, due to the coincidence of the current study with the coronavirus outbreak, information was collected from school-aged children through online forms. This study included participants aged 6 to 7 and 13 to 14 years who held Iranian nationality. Individuals with non-Iranian nationality were excluded from participation. In this study, students were randomly chosen from 48 high schools and 36 elementary schools, both state and private, across two educational districts using a cluster sampling method. All

procedures in this study were conducted in compliance with the Helsinki Declaration. The GAN study among Iranian children and adolescents was ethically approved by the ethics committee of Shahid Sadoughi University (SSU) of Medical Sciences, Yazd, Iran (ethics approval code: IR.SSU.REC.1398.244). All parents whose children were included in the current study filled out an informed consent form. Ethical approval for the present study was also obtained from the ethics committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran (IR.SSU.SPH.REC.1400.138). Permission to carry out this study in the schools was obtained from the Department of Education of Yazd province.

Dietary assessment

The dietary intake of fruits and vegetables in the previous year was assessed using a multiple-choice food frequency questionnaire proposed by the GAN study [32]. Food groups included: Fruits, Vegetables, Potatoes, Legumes, Bread, Pasta, Rice, Olive oil, Sugar, Fast foods, soft drinks, and Snacks. The participants reported the frequency of their food consumption in three options (never or rarely/once or twice a week/often or daily). The FFQ was initially translated into Persian and subsequently reviewed by a panel of experts to verify its validity. After this evaluation, the questionnaire was back-translated into English and submitted to the GAN principals for their final approval. (Supplementary online materials).

Asthma and its symptoms confirmation

In this study, the GAN questionnaire was used to assess asthma and its symptoms. The questionnaire was designed based on the ISACC methodology [33]. The questions are related to allergic diseases and their risk factors. The following questions were used in this study: "use of asthma medication" and "asthma confirmed by a doctor", as well as wheezing in the past 12 months. Current asthma was ascertained by affirmative answers to the items "history of asthma confirmed by a doctor" and "wheezing in the past 12 months" and/or "use of asthma medication in the past 12 months" [34].

Assessment of other variables

The GAN online questionnaire was used to collect participants' self-reported weight, height, and other variables such as watching TV and computer use. The formula for calculating body mass index (BMI) was weight in kilograms divided by height per square meter.

Statistical analysis

Statistical analysis was conducted using STATA software version 14 (STATA Corp., Lakeway Drive, USA). The Kolmogorov–Smirnov test was employed to assess the normality of the data distribution. As a result, it was found that all numerical variables followed a normal distribution. The chi-square test and independent sample t-test were used to assess the difference in qualitative and quantitative variables, respectively, between participants with and without the desired outcomes.

Logistic regression was used to evaluate the association between fruit and vegetable intake and asthma confirmed by a doctor, current asthma, use of asthma medication, and wheezing in the past 12 months in crude and multivariable adjusted models. Model I was adjusted for age and sex, Model II was further adjusted for watching TV and computer use and the final model was additionally adjusted for BMI. A p-value < 0.05 was considered as statistically significant.

Results

General characteristics of the 7,667 participants who answered all questionnaires are summarized in Table 1. Participants with asthma confirmed by a doctor were older than those without this condition ($P < 0.001$). Also, subjects with the use of asthma medication were older than those without this condition ($P = 0.05$). The percentage of boys with asthma confirmed by a doctor was 58.02% and the percentage of boys without asthma confirmed by a doctor was 43.93%. The distribution of subjects in terms of age($P = 0.05$), ethnicity, and sex was significantly different among participants with the use of asthma medication ($P < 0.05$ for all).

As presented in Table 2, everyday consumption of bread was significantly higher in children without the use of asthma medication than those with this condition ($P = 0.02$). However, never consumption of fast food was significantly higher in children without the use of asthma medication than those with this condition ($P = 0.03$). Children without asthma confirmed by a doctor had a lower frequency of fast food and soft drinks intake than those with it.

The association between fruit and vegetable intake and asthma confirmed by a doctor is shown in Table 3 and the associations found in the final model are provided in Fig. 1, A-C. There was no significant association between fruit and vegetable intake and asthma confirmed by a doctor.

A significant inverse trend was found in the association between fruit intake and current asthma in the crude model. This trend was still significant after adjusting potential confounders (P_{trend}=0.02). There was no significant association between vegetable intake and current asthma (Fig. 1, D-F). Also, this null association was seen after pooling the fruit and vegetable consumption together (Table 4).

The association between fruit and vegetable intake and the use of asthma medications is shown in Table 5 and no significant association was observed in crude

Table 1 General characteristics of the subjects according to asthma

Variables	Asthma confirmed by a doctor		*p*-value	Use of asthma medication		*p*-value
	Without (*n*=7343)	With (*n*=324)		Without (*n*=7476)	With (*n*=191)	
Sex						
Male	3226 (43.93)	188 (58.02)	**<0.001**	3296 (44.09)	118 (61.7)	**<0.001**
Female	4117 (56.07)	136 (41.98)		4180 (55.9)	73 (38.2)	
Age (years)	10.9±3.37	11.7±2.94	**<0.001**	10.9±3.36	11.3±3.16	0.05
BMI (kg/m$^{2)}$	18.9±10.4	19.1±4.18	0.35	18.97±10.3	18.73±3.97	0.37
Ethnicity			0.13			**0.003**
Kord	38 (0.52)	5 (1.54)		38 (0.51)	5 (2.62)	
Turk	73 (0.99)	2 (0.62)		74 (0.99)	1 (0.52)	
Persian	7064 (96.2)	311 (95.9)		7192 (96.2)	183 (95.8)	
Lor	62 (0.84)	4 (1.2)		64 (0.86)	2 (1.05)	
Arab	55 (0.75)	1 (0.31)		56 (0.75)	0 (0.0)	
Balooch	51 (0.69)	1 (0.31)		52 (0.70)	0 (0.0)	
Physical activity (watch TV and computer use)			0.38			0.29
2–4 h	3945 (53.7)	163 (50.3)		4016 (53.7)	92 (48.1)	
5–8 h	2463 (33.5)	103 (34.8)		2506 (33.5)	70 (36.6)	
9–14 h	935 (12.7)	48 (14.8)		954 (12.7)	29 (15.1)	

Values are mean (SD) or percentages

[a]χ^2 Test for ordinal qualitative variables and t-test for continuous variables

Statistically significant p-values ($p < 0.05$) are presented in bold text

and multivariable adjusted models (Fig. 2, A-C). Crude and multivariable-adjusted odds ratios for wheezing in the past 12 months is indicated in Table 6. In the crude model, individuals who consumed fruit daily or almost daily had significantly lower odds of experiencing wheezing in the past 12 months compared to those who did not consume fruit or did so only occasionally (OR = 0.66; 95% CI: 0.44–0.98, Ptrend = 0.001). After adjusting for confounding variables such as age, sex, television and computer use, and BMI in the final model, it was found that participants who consumed fruit on most or all days were 37% less likely to experience wheezing in the past 12 months compared to those who rarely or never consumed fruit (OR = 0.63; 95% CI: 0.42–0.94, Ptrend = 0.001). Likewise, in the crude model, subjects who consumed vegetables on most or all days had lower odds of wheezing in the past 12 months (OR = 0.62; 95% CI: 0.48–0.80, Ptrend < 0.001). After further adjustment for confounding variables such as age, sex, television and computer use, and BMI in the third model, it was found that those who consumed vegetables daily or almost daily had a 38% lower chance of wheezing in the past 12 months compared to those who rarely or never consumed vegetables (OR = 0.62; 95% CI: 0.48–0.80, Ptrend < 0.001). Additionally, when the combined intake of fruits and vegetables was evaluated, participants who consumed both on most or all days had a significantly lower likelihood of wheezing in the past 12 months according to the crude model (OR = 0.51; 95% CI: 0.31–0.82, Ptrend < 0.001) compared to those who consumed them occasionally or not at all. After adjusting for confounders such as age, sex, television and computer use, and BMI in the third model, it was found that individuals who consumed both fruits and vegetables daily or almost daily had a 50% lower chance of wheezing in the past 12 months compared to those who rarely or never consumed them (OR = 0.50; 95% CI: 0.31–0.82, Ptrend < 0.001) (Fig. 2, D-F).

Discussion

In this cross-sectional study, the relationship between fruit and vegetable intake and asthma and its related outcomes in children and adolescents was investigated. Our findings showed that the intake of vegetables and fruits was inversely associated with wheezing in the 12 past months. Also, there was a significant inverse trend between the intake of fruits and current asthma.

Several studies conducted on the relationship between fruit and vegetable consumption and asthma and its symptoms have shown that high fruit and vegetable consumption has a protective effect against asthma [35, 36]. Moreover, the results of the diet and asthma in 598 Dutch school-children showed that there was no significant relationship between the consumption of citrus fruits and total vegetables and the odds of recent asthma [21]. Tessa et al. [25] performed a study on 2290 children in Taiwan and observed that vegetable consumption was not associated with asthma-related symptoms and fruit consumption was only associated with wheezing without cold. Likewise, A cross-sectional study was conducted on 700 children in Athens and it was shown no significant relationship between fruit and vegetable consumption and asthma symptoms [37]. Variations in study results can be attributed to factors such as sample size, geographical location, dietary habits, age, and the methods used for collecting food data.

The results of a systematic review and meta-analysis of observational studies showed that there was a relationship between high consumption of fruits and vegetables and reduced risk of wheezing in children [3]. The results of this systematic review, which included 26 cross-sectional studies, 4 case-control studies, and 12 cohort studies, also showed that total fruit (RR = 0.90; 95%CI, 0.86–0.94) and vegetable (RR = 0.91; 95%CI, 0.82–1.00) consumption has been associated with a 10% and 9% lower risk of asthma in children respectively [3]. Additionally, in the study by Farchi et al. involving 4104 Italian children aged 6–7 years, the results suggested that summer tomato consumption was associated with a 51% decreased likelihood of wheezing in the past 12 months (OR = 0.49; 95%CI, 0.31–0.80) [38].

There is a connection between oxidative stress and the pathogenesis of many diseases, including acute respiratory distress syndrome, idiopathic pulmonary fibrosis, chronic obstructive pulmonary disease, and asthma [39–41]. An imbalance of oxidants and antioxidants and oxidative stress occurs due to the activation of inflammatory cells, which leads to an increase in the amount of reactive oxygen species (ROS) [42, 43]. An increase in the production of (ROS) is related to an increase in the severity of asthma [44]. Antioxidants may play a role in reducing airway inflammation by protecting the airways from endogenous and exogenous sources of oxidants [3].

Fruits and vegetables are good sources of vitamin C and E [45]. Vitamin C plays a role in preventing the progression of asthma by restraining prostaglandins and reducing C-reactive protein (CRP) levels [46, 47]. Vitamin E may also have a protective effect due to its role in suppressing oxidative stress [48]. Fruits and vegetables are rich sources of bioactive compounds such as vitamins, minerals, and polyphenols that have antioxidant and immunomodulating properties and can strengthen endogenous antioxidant systems and eliminate free radicals produced in the inflammatory process [3]. Additionally, Fruits and vegetables have a great content of fiber, which can help balance the microbiome and may influence the immune response and respiratory diseases [49]. High consumption of various vegetables is linked with a reduction in the risk of asthma in school-aged children

Table 2 Daily food of subjects according to asthma

Variables	Asthma confirmed by a doctor		*p*-value	Use of asthma medication		*p*-value
	Without (*n*=7343)	With (*n*=324)		Without (*n*=7476)	With (*n*=191)	
Fruits						
Never	252 (3.4)	16 (4.9)	0.25	257 (3.4)	11 (5.7)	0.22
Weekly	1250 (17.0)	60 (18.5)		1277 (17.0)	33 (17.2)	
Every day	5841 (79.5)	248 (76.5)		5942 (79.4)	147 (76.9)	
Vegetables						
Never	1858 (25.3)	88 (27.1)	0.51	1895 (25.3)	51 (26.7)	0.15
Weekly	4040 (55.0)	180 (55.5)		4107 (54.9)	113 (59.1)	
Every day	1445 (19.6)	56 (17.2)		1474 (19.7)	27 (14.1)	
Potatoes						
Never	415 (5.6)	16 (4.9)	0.82	422 (5.6)	9 (4.7)	0.70
Weekly	4711 (64.1)	212 (65.4)		4803 (64.2)	120 (62.8)	
Every day	2217 (30.1)	96 (29.6)		2251 (30.1)	62 (32.4)	
Legumes						
Never	270 (3.6)	16 (4.9)	0.43	277 (3.7)	9 (4.7)	0.75
Weekly	4275 (58.2)	191 (58.9)		4357 (58.2)	109 (57.0)	
Every day	2798 (38.1)	117 (36.1)		2842 (38.0)	73 (38.2)	
Pasta						
Never	1840 (25.0)	89 (27.4)	0.31	1877 (25.1)	52 (27.2)	0.60
Weekly	5121 (69.7)	214 (66.0)		5208 (69.6)	127 (66.4)	
Every day	382 (5.2)	21 (6.4)		391 (5.2)	12 (6.2)	
Bread						
Never	124 (1.69)	5 (1.54)	0.22	127 (1.7)	2 (1.0)	**0.02**
Weekly	346 (4.71)	22 (6.79)		351 (4.7)	17 (8.9)	
Every day	6873 (93.6)	297 (91.6)		6998 (93.6)	172 (90.0)	
Rice						
Never	121 (1.65)	4 (1.2)	0.56	122 (1.6)	3 (1.5)	0.32
Weekly	962 (13.1)	37 (11.4)		981 (13.1)	18 (9.4)	
Every day	6260 (85.2)	283 (87.3)		6373 (85.2)	170 (89.0)	
Olive oil						
Never	5056 (68.8)	218 (67.2)	0.55	5148 (68.8)	126 (65.9)	0.27
Weekly	1582 (21.5)	69 (21.3)		1611 (21.5)	40 (20.9)	
Every day	705 (9.6)	37 (11.4)		717 (9.5)	25 (13.0)	
Fast food						
Never	4148 (56.4)	160 (49.3)	**0.03**	4217 (56.4)	91 (47.6)	**0.03**
Weekly	2931 (39.9)	152 (46.9)		2989 (39.9)	94 (49.2)	
Every day	264 (3.6)	12.(3.7)		270 (3.6)	6 (3.1)	
Sugar						

Table 2 (continued)

Variables	Asthma confirmed by a doctor		*p*-value	Use of asthma medication		*p*-value
Never	1693 (23.0)	70 (21.6)	0.60	1717 (22.9)	46 (24.0)	0.86
Weekly	4065 (55.3)	177 (54.6)		4140 (55.3)	102 (53.4)	
Every day	1585 (21.5)	77 (23.7)		1619 (21.6)	43 (22.5)	
Soft drink						
Never	4105 (55.9)	151 (46.6)	**0.004**	4161 (55.6)	95 (49.7)	0.20
Weekly	2612 (35.5)	140 (43.2)		2672 (35.7)	80 (41.8)	
Every day	626 (8.5)	33 (10.1)		643 (8.6)	16 (8.3)	
Snacks						
Never	3762 (51.2)	159 (49.0)	0.25	3817 (51.0)	104 (54.4)	0.37
Weekly	3073 (41.8)	135 (41.6)		3137 (41.9)	71 (37.1)	
Every day	508 (6.9)	30 (9.2)		522 (6.9)	16 (8.3)	

Values are percentages

Statistically significant p-values ($p < 0.05$) are presented in bold text

[50]. Our study found a significant association between the consumption of fruits and vegetables and the incidence of wheezing in the past 12 months. However, no such association was observed for asthma confirmed by a doctor, current asthma, or the use of asthma medication. The high nutrient content of fruits and vegetables, including vitamin C, flavonoids, and carotenoids, may explain these results [45, 51]. Studies have shown that a higher intake of vitamin C can reduce the risk of wheezing [52, 53], and decrease airway hyperresponsiveness [54], which can improve lung function [55]. Flavonoids have anti-inflammatory effects, suppressing NF-κB signaling and reducing the expression of proinflammatory markers [56]. Carotenoids have antioxidant properties that may help reduce airway inflammation and support lung function in asthmatic patients [57]. Lycopene, a carotenoid found in fruits and vegetables, has been shown to alleviate oxidative stress and improve asthma-related symptoms, such as airway muscle tightening, bronchial hyperresponsiveness (BHR), and excessive mucus production [58]. Furthermore, the consumption of fruits and vegetables has been positively correlated with improved lung function in children with asthma, as indicated by higher forced expiratory volume in 1 s (FEV1) and forced vital capacity (FVC) [59]. Diet and nutritional supplementation are widely recognized as popular forms of complementary and alternative medicine for the treatment of asthma [60]. Studies have shown that Mediterranean-style diets, which focus on plant-based foods, are associated with a reduction in asthma symptoms in children with asthma [61, 62]. Furthermore, research has demonstrated an inverse relationship between adherence to the Mediterranean diet and the risk factors for noncommunicable diseases, such as cardiovascular disease and type 2 diabetes, in the Iranian population [63–65].

The findings of this study indicate that fruit and vegetable consumption may have beneficial effects on asthma-related symptoms, such as wheezing in the past 12 months. This provides valuable insights for researchers and policymakers to establish guidelines encouraging higher fruit and vegetable intake. Evidence from studies conducted in Iran shows that the country's dietary patterns are undergoing a transition [66]. To achieve a sustainable dietary pattern, it is essential to increase fruits and vegetables consumption [66].

This study has several strengths. One notable strength of this study is the large number of participants, which enhances its statistical power. Additionally, both genders were included in the analysis. Another strength is the use of valid questionnaires for data collection. However, the present study also has several limitations. In this study, subjects' dietary intake was estimated using the FFQ, which is prone to reporting bias and misclassification of participants [67, 68]. Moreover, FFQ used in this study

Table 3 Association between fruits and vegetables intake and asthma confirmed by a Doctor

Fruit & vegetable intake				
	Never or only occasionally	**Once or twice per week**	**Most or all days**	**P_{trend}**
	0R (95% CI)	**0R (95% CI)**	**0R (95% CI)**	
Fruits				
No. of with/without asthma	12/256	62/1248	250/5839	
Crude	1.00	1.05 (0.56-1.99)	0.91 (0.50-1.65)	0.36
Model 1	1.00	0.97 (0.51-1.84)	0.84 (0.46-1.52)	0.28
Model 2	1.00	0.97 (0.51-1.84)	0.84 (0.46-1.53)	0.28
Model 3	1.00	0.97 (0.51-1.84)	0.84 (0.46-1.52)	0.28
Vegetables				
No. of with/without asthma	94/1852	171/4049	59/1442	
Crude	1.00	0.83 (0.64-1.07)	0.80 (0.57-1.12)	0.16
Model 1	1.00	0.83 (0.64-1.08)	0.77 (0.55-1.08)	0.12
Model 2	1.00	0.83 (0.64-1.08)	0.78 (0.56-1.09)	0.12
Model 3	1.00	0.83 (0.64-1.08)	0.78 (0.55-1.09)	0.12
Fruit & vegetables				
No. of with/without asthma	8/150	121/2474	195/4719	
Crude	1.00	0.83 (0.40-1.72)	0.81 (0.39-1.68)	0.67
Model 1	1.00	0.80 (0.39-1.67)	0.76 (0.36-1.59)	0.48
Model 2	1.00	0.81 (0.39-1.68)	0.76 (0.37-1.60)	0.50
Model 3	1.00	0.81 (0.39-1.68)	0.76(0.36-1.59)	0.49

Model 1: adjusted for age and sex

Model 2: Model 1 + TV & computer use

Model 3: Model 2 + BMI

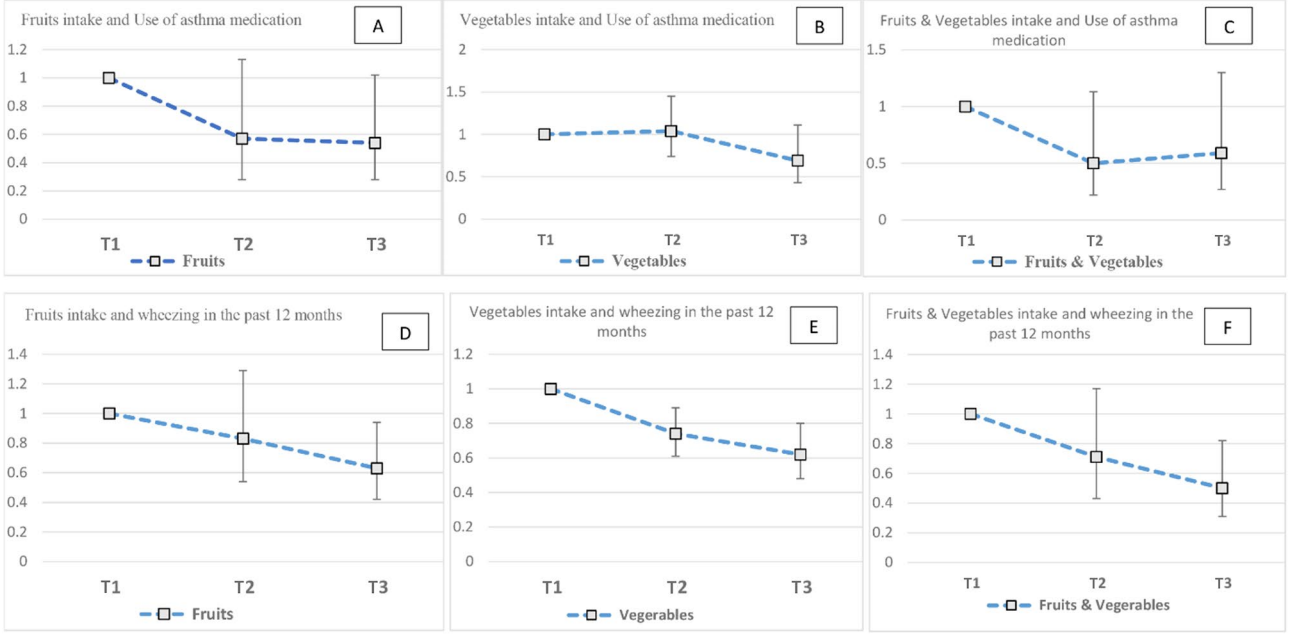

Fig. 1 The odds ratios and 95% confidence intervals (CIs) for asthma confirmed by doctor across tertiles of fruits intake (**A**), vegetables intake (**B**), fruits and vegetables intake (**C**) as well as the odds ratios and 95% confidence intervals (CIs) for asthma confirmed by doctor across tertiles of fruits intake (**D**), vegetables intake (**E**), fruits and vegetables intake (**F**). All associations were adjusted for age, sex, TV & computer use and BMI. (Y-axis = The odds ratios and 95% confidence intervals (CIs); X-axis = tertiles of fruits intake, vegetables intake, fruits and vegetables intake)

assessed a limited number of food items. Additionally, only data on age, gender, BMI, watching TV, and using the computer was collected through the questionnaire. Consequently, we were unable to measure and adjust for other potential confounders, such as air and household pollution, which may have significant effects. The asthma data in this study was self-reported. To validate our findings, laboratory tests or a doctor's diagnosis would be

Table 4 The association between fruits and vegetables intake and likelihood of current asthma

	Never or only occasionally	Once or twice per week	Most or all days	P_{trend}
	0R (95% CI)	**0R (95% CI)**	**0R (95% CI)**	
Fruits				
No. with/without current asthma	3/244	10/1212	22/5693	
Crude	1.00	0.67 (0.18-2.45)	0.31 (0.09-1.05)	**0.01**
Model 1	1.00	0.83 (0.22-3.09)	0.37 (0.11-1.28)	**0.01**
Model 2	1.00	0.84 (0.22-3.10)	0.37 (0.11-1.28)	**0.02**
Model 3	1.00	0.85 (0.23-3.14)	0.38 (0.11-1.30)	**0.02**
Vegetables				
No. with/without asthma	11/1798	20/3943	4/1408	
Crude	1.00	0.82 (0.39-1.73)	0.46 (0.14-1.46)	0.20
Model 1	1.00	0.81 (0.39-1.71)	0.54 (0.17-1.72)	0.30
Model 2	1.00	0.82 (0.39-1.73)	0.55 (0.17-1.75)	0.31
Model 3	1.00	0.83 (0.39-1.74)	0.56 (0.17-1.79)	0.33
Fruit & vegetables				
No. with/without asthma	2/143	21/3679	12/3327	
Crude	1.00	0.4 (0.09-1.75)	0.25 (0.05-1.16)	0.08
Model 1	1.00	0.41 (0.09-1.79)	0.29 (0.06-1.33)	0.15
Model 2	1.00	0.41 (0.09-1.80)	0.29 (0.06-1.34)	0.16
Model 3	1.00	0.4 (0.09-1.77)	0.29 (0.06-1.33)	0.16

Model 1: adjusted for age and sex

Model 2: Model 1 + TV & computer use

Model 3: Model 2 + BMI

Statistically significant p-values ($p < 0.05$) are presented in bold text

Table 5 Association between fruits and vegetables intake and use of asthma medication

Fruit & vegetable intake				
	Never or only occasionally	**Once or twice per week**	**Most or all days**	**P_{trend}**
	0R (95% CI)	**0R (95% CI)**	**0R (95% CI)**	
Fruits				
No. of with/without asthma	11/257	33/1277	147/5942 11/257	
Crude	1.00	0.60 (0.30-1.21)	0.57 (0.30-1.08)	0.19
Model 1	1.00	0.56 (0.27-1.13)	0.52 (0.28-0.99)	0.12
Model 2	1.00	0.56 (0.28-1.13)	0.53 (0.28-1.00)	0.13
Model 3	1.00	0.57 (0.28-1.15)	0.54 (0.28-1.02)	0.14
Vegetables				
No. of with/without asthma	51/1895	113/4107	27/1474	
Crude	1.00	1.02 (0.73-1.42)	0.68 (0.42-1.09)	0.15
Model 1	1.00	1.03 (0.73-1.44)	0.68 (0.42-1.09)	0.16
Model 2	1.00	1.03 (0.74-1.45)	0.68 (0.42-1.10)	0.17
Model 3	1.00	1.04 (0.74-1.45)	0.69 (0.43-1.11)	0.18
Fruit & vegetables				
No. of with/without asthma	6/152	71/2524	114/4800	
Crude	1.00	0.53 (0.23-1.20)	0.68 (0.31-1.48)	0.52
Model 1	1.00	0.49 (0.22-1.12)	0.60 (0.27-1.31)	0.83
Model 2	1.00	0.49 (0.21-1.12)	0.59 (0.27-1.30)	0.85
Model 3	1.00	0.50 (0.22-1.13)	0.59 (0.27-1.30)	0.87

Model 1: adjusted for age and sex

Model 2: Model 1 + TV & computer use

Model 3: Model 2 + BMI

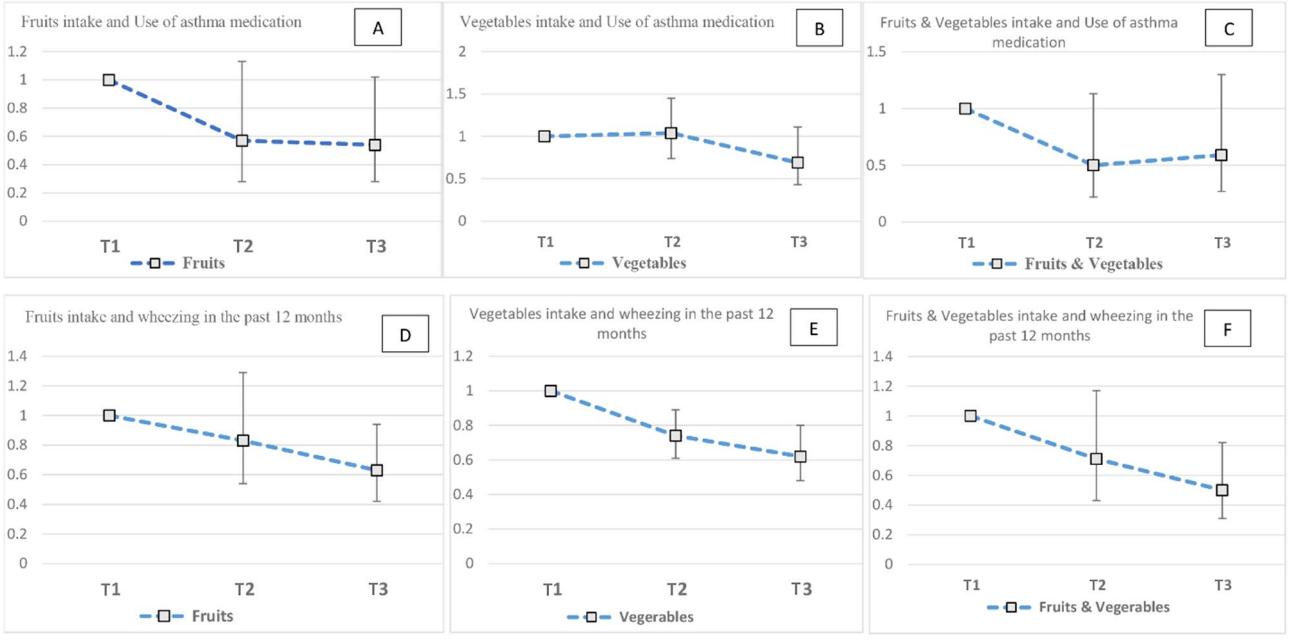

Fig. 2 The odds ratios and 95% confidence intervals (CIs) for asthma medication use (**A**-**B**) and wheezing (**D**-**F**) across tertiles of fruits, vegetables, and fruits and vegetables intake, adjusted for age, sex, TV & computer use and BMI. (Y-axis = The odds ratios and 95% confidence intervals (CIs); X-axis = tertiles of fruits intake, vegetables intake, fruits and vegetables intake)

Table 6 Association between fruits and vegetables intake and wheezing in the past 12 months

Fruit & vegetable intake				
	Never or only occasionally	**Once or twice per week**	**Most or all days**	**P_{trend}**
	0R (95% CI)	**0R (95% CI)**	**0R (95% CI)**	
Fruits				
No. of with/without asthma	29/239	128/1182	452/5637	
Crude	1.00	0.89 (0.58-1.36)	0.66 (0.44-0.98)	**0.001**
Model 1	1.00	0.82 (0.53-1.26)	0.61 (0.40-0.90)	**<0.001**
Model 2	1.00	0.83 (0.54-1.28)	0.63 (0.42-0.94)	**0.001**
Model 3	1.00	0.83 (0.54-1.29)	0.63 (0.42-0.94)	**0.001**
Vegetables				
No. of with/without asthma	196/1750	315/3905	98/1403	
Crude	1.00	0.72 (0.59-0.86)	0.62 (0.48-0.80)	**<0.001**
Model 1	1.00	0.72 (0.59-0.87)	0.60 (0.46-0.77)	**<0.001**
Model 2	1.00	0.74 (0.61-0.89)	0.62 (0.48-0.80)	**<0.001**
Model 3	1.00	0.74 (0.61-0.89)	0.62 (0.48-0.80)	**<0.001**
Fruit & vegetables				
No. of with/without asthma	20/138	250/2345	339/4575	
Crude	1.00	0.73 (0.45-1.19)	0.51 (0.31-0.82)	**<0.001**
Model 1	1.00	0.70 (0.43-1.15)	0.48 (0.29-0.78)	**<0.001**
Model 2	1.00	0.71 (0.43-1.17)	0.50 (0.31-0.82)	**<0.001**
Model 3	1.00	0.71(0.43-1.17)	0.50 (0.31-0.82)	**<0.001**

Model 1: adjusted for age and sex

Model 2: Model 1 + TV & computer use

Model 3: Model 2 + BMI

Statistically significant p-values ($p < 0.05$) are presented in bold text

necessary. Furthermore, since this study is cross-sectional, it does not show an established cause-and-effect relationship. Therefore, it is highly recommended to conduct culturally sensitive and resource-appropriate randomized control trials to confirm our findings.

Conclusion

In summary, our results showed that regular consumption of fruits and vegetables on most or all days might be associated with a lower likelihood of wheezing in the past 12 months. Studies with robust designs such as cohort or trial design are required to support the current findings in the future.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41043-025-00820-7.

Supplementary Material 1

Acknowledgements
We are grateful to the education department and the participants for their cooperation in this study. The authors would like to thank the Research Development Center of Shahid Sadoughi Hospital, Shahid Sadoughi University of Medical Sciences, for their close collaboration and scientific input.

Author contributions
ZN, NB, and ASA participated in the study design. AE, AR, KR and BS analysis and drafted the initial version. NB and ASA supervised the study. ASA and SMHB helped in data analysis. BS implemented comments and suggestions from the co-authors. All authors edited and reviewed the final version of the manuscript.

Data availability
The dataset of the present study is available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare no competing interests.

Financial support
This study was financially supported by Shahid Sadoughi University of Medical Science.

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Received: 30 October 2024 / Accepted: 9 March 2025
Published online: 02 April 2025

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