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Association between an individual dietary index based on the British Food Standard Agency Nutrient Profiling System and asthma symptoms

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Abstract

The role of diet in asthma is still debated. In France, a front-of-pack (FOP) nutrition label based on a modified Food Standards Agency Nutrient Profiling System/High Council for Public Health (FSAm-NPS/HCSP) has recently been implemented to help consumers to make healthier food choices during purchase. At the individual level, the FSAm-NPS dietary index (DI) has been shown to reflect the nutritional quality of the diet. The aim of the present study was to investigate the association between the FSAm-NPS DI and the asthma symptom score. In total, 34 323 participants (25 823 women and 8500 men) from the NutriNet-Santé cohort were included. The overall nutritional quality of the diet was assessed using the FSAm-NPS DI. Increasing FSAm-NPS DI reflects decreasing overall diet quality. Asthma was defined by the asthma symptom score (sum of five questions). Negative binomial regression was used to evaluate the association between the FSA-NPS DI and the asthma symptom score. Overall, mean participant's age was 54 ± 14 years, and about 27 % reported at least one asthma symptom. We observed a significant positive association between less healthy diet, as expressed by higher FSAm-NPS DI, and the asthma symptom score. The adjusted OR were 1·27 (95 % CI 1·17, 1·38) among women and 1·31 (95 % CI 1·13, 1·53) among men. Unhealthy food choices, as reflected by a higher FSAm-NPS DI, were associated with greater asthma symptoms. These results reinforce the relevance of public health approach to orient consumers towards healthier food choices by using a clear and easy-to-understand FOP nutrition label based on the FSAm-NPS, such as the Nutri-Score.

Key words: Asthma symptom score: Modified Food Standards Agency Nutrient Profiling System dietary index: Unhealthy food choices: Nutrient profiling systems: Dietary score: Nutrition policy

Asthma, one of the most common chronic diseases in the world, is estimated to affect more than 350 million people[1]. Asthma is a major public health concern, and identifying modifiable risks factors to improve asthma prevention is of major importance. Recent worldwide modifications in dietary habits – resulting in a decrease in diet quality, especially in western world, characterised by higher intakes of refined and pre-packaged foods with a poor nutritional quality and a low intake of fruits and vegetables – have been associated with increased prevalence of asthma[2].

In public health strategies aiming to tackle the deleterious consequences of poor diet, front-of-pack (FOP) nutrition labels have received growing attention to help consumers to make healthier choices at the point of purchase. Most of the FOP nutrition labelling relies on the nutritional quality of foods using a nutrient profiling system (NPS). Among the available nutrient profiling systems, NPS developed by the UK Food Standard Agency (named FSA-NPS) is one of the most scientifically validated systems in the European context[3–5]. It has been developed and validated initially in the British food environment[6], but previous studies have demonstrated its applicability to the French context after some modifications by the French High Council for Public Health (Haut Conseil de la Santé Publique; HCSP)[3,4,7,8].

For these reasons the modified Food Standards Agency Nutrient Profiling System (FSAm-NPS/HCSP) was used in France to underlie a FOP nutrition label, the Nutri-Score, which

Abbreviations: DI, dietary index; FOP, front-of-pack; FSA, Food Standards Agency; FSAm-NPS/HCSP, modified Food Standards Agency Nutrient Profiling System/High Council for Public Health; NPS, nutrient profiling system.

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was implemented in 2017. A dietary index (DI) based on the FSAm-NPS (FSAm-NPS DI) has been developed, reflecting the overall nutritional quality of the diet at the individual level, and employed to validate the algorithm used for the computation of the Nutri-Score[6,9]. Less healthy diets, as expressed by higher FSAm-NPS DI, have been associated with a higher risk of several chronic diseases, such as overall cancer[10], breast cancer[11], CVD[12,13], the metabolic syndrome[14] or weight gain and obesity[15].

To the best of our knowledge, no study has investigated the association between the overall nutritional quality of diet, based on a nutrient profiling system of food consumed, and asthma.

Thus, our aim was to investigate the association between the FSAm-NPS DI and the asthma symptom score in a large cohort of French adults.

Methods

Study population

Participants were a selection of volunteers from the NutriNet-Santé study[16], a prospective observational cohort study launched in May 2009 to evaluate the determinants of eating behaviours and the relationships between nutrition and chronic disease risk. Details of the NutriNet-Santé study are extensively described elsewhere[16]. Participants of the NutriNet-Santé study, all aged ≥18 years, gave electronic informed consent. All procedures have been approved by the institutional review board of the French Institute for Health and Medical Research (0000388FWA00005831) and the French Institutional Ethics Committee (CNIL numbers 908450 and 909216). The NutriNet-Santé Study is registered in ClinicalTrials.gov (NCT03335644).

Dietary data collection

At inclusion and twice a year thereafter, participants were invited to complete three non-consecutive, self-administered, web-based 24-h dietary records randomly allocated over a 2-week period, including 2 week-days and 1 weekend day. Self-administered, web-based, 24-h dietary records have been validated against urinary[17] and plasma biomarkers[18] and interview by a trained dietitian[19]. For the present study, to have a better estimate of dietary habits, we included participants who completed at least three 24-h dietary records since their inclusion till 2 years of follow-up. They reported all foods and beverages consumed at each eating occasion. Portion sizes for each food and beverage were estimated using validated photographs[20] or by indicating the exact quantity in grams or the volume in millilitres. Mean daily dietary alcohol and nutrient intakes were estimated using the NutriNet-Santé food composition table, which includes more than 3000 different items[21].

We also excluded underreporting participants identified on the basis of the method proposed by Black[22] using Schofield equations[23] and taking into account sex, age, height and weight, as well as physical activity level (PAL), number of 24-h records, intra-individual variabilities of reported energy intake and BMR, and intra-/inter-variabilities of PAL. However, it is important to note that the exclusion of subjects (online Supplementary Fig. S1) following the Goldberg cut-off point was not optimal due to its low sensitivity[22].

Modified Food Standards Agency Nutrient Profiling System dietary index computation

The FSAm-NPS score for all foods and beverages was computed based on their nutrient content for 100 g. Positive points (0–10) were allocated for the content of energy (kJ), total sugar (g), SFA (g), and Na (mg). Negative points (0–5) were allocated for the content of fruits, vegetables and nuts, fibres and proteins. FSAm-NPS scores for foods and non-alcoholic beverages were based on a discrete continuous scale ranging from −15 (most healthy) to +40 (less healthy). Thus, an increase in the score reflects a decreasing nutritional quality of the food or beverage item.

Specific modifications of the score for cheese, added fats and beverages were made to maintain a high consistency with the French nutritional recommendations, as proposed by the French HCSP, leading to the FSAm/HCSP algorithm[7].

The FSAm-NPS DI was computed at the individual level using arithmetic energy-weighted means. The corresponding equation has been described elsewhere[14]. Increasing FSAm-NPS DI reflects decreasing overall diet quality.

Respiratory data

To improve the respiratory characterisation in the cohort, a non-mandatory detailed questionnaire on respiratory health based on international standardised recommendations[24] was proposed in April 2016 to all the active participants (n 121 568). As June 2017, the survey was completed by 40 152 adults (online Supplementary Fig. S1).

We used the asthma symptom score[25,26], which has been previously proposed as a continuous measure of asthma in epidemiological studies. It is a validated score that has shown good predictive ability against outcomes related with asthma. The asthma symptom score is assessed on a scale from 0 to 5, with higher scores indicating a higher number of symptoms. It is based on the number of respiratory symptoms during the past 12 months: (1) breathless while wheezing, (2) woken up with chest tightness, (3) attack of shortness of breath at rest, (4) attack of shortness of breath after exercise and (5) woken by attack of shortness of breath.

'Ever asthma' was defined by at least one positive answer to the question 'Have you ever had asthma?' in main questionnaires, or by a positive answer to 'Have you ever had an asthma attack?' or 'Have you ever had an attack of shortness of breath at rest with wheezing' in the respiratory survey. Information about family history of asthma was also collected.

Allergic rhinitis was defined as a positive answer to the following questions: 'Have you ever had allergic rhinitis?' or 'Have you ever had hay fever?'

Covariate assessment

Baseline questionnaires provided information on socio-demographic[27] and anthropometric measurements,[28,29] including age and sex. Educational level was classified into four groups (<13, 14, 15–16 and ≥17 years), and smoking status into three groups (never smokers, ex-smokers, current smokers). Among ever smokers, pack-years were calculated to estimate the amount of tobacco smoke. BMI was calculated as weight (kg)/height^2 (in m^2) and categorised according to the WHO classification (<18·5, 18·5–24, 25–29, ≥30 kg/m^2)[30]. Physical activity was assessed using the short form of the French version of the International Physical Activity Questionnaire[31]. The latter allows estimating three levels of physical activity: vigorous (≥60 min/d), moderate (30–59 min/d), low (<30 min/d).

Statistical analysis

Analyses were conducted separately among men and women to take into account sex differences in the diet–asthma association[32].

Baseline characteristics of participants are reported as means and standard deviations or numbers and percentages according to sex-specific quintiles of the FSAm-NPS DI.

The asthma symptom score was considered as a continuous variable, and a negative binomial regression was performed to evaluate the association between quintiles of the FSAm-NPS DI and the asthma symptom score.

The following potential confounders were included in the main model: age, smoking, pack-years, educational level, leisure time physical activity, daily energy intake, alcohol intake (g/d, continuous), presence of allergic rhinitis and family history of asthma. Tests for linear trends were performed using quintiles of FSAm-NPS DI score as an ordinal variable.

The asthma symptom score has the potential to reveal asthma in individuals not previously identified as thus. Hence, we carried out a sensitivity analysis to highlight the strength of the score by inclusion of participants who had never previously reported symptoms of asthma since their inclusion in the NutriNet-Santé cohort till answered the respiratory survey. Furthermore, since diet quality is often associated with smoking habit, and to take into account potential residual confounding by cigarette smoking, we also conducted a sensitivity analysis stratified by smoking status. Finally, as diet affects BMI, and obesity is likely a risk factor for asthma, BMI might be a potential mediator in the diet–asthma association; thus we also performed a stratified analysis based on BMI.

To handle missing data, we used multiple imputations methods (n 10) according to a Markov chain–Monte Carlo approach[33]. Data were analysed using SAS version 9.4 (SAS Institute). All tests were two-sided, and a significance level of 0·05 was used.

Results

Participant characteristics

Among the 40 152 participants who filled in the non-mandatory, web-based questionnaire on respiratory health, we excluded those with less than three dietary records till their 2 years of follow-up (n 2122). The final sample included 34 323 participants (25 823 women and 8500 men) for which the FSAm-NPS DI could have been computed (online Supplementary Fig. S1). Overall, the average FSAm-NPS DI score was 6·1 (SD 2·2) in women and 6·0 (SD 2·1) in men. Mean participant age was 54 (SD 14) years (53 (SD 14) years for women and 59 (SD 13) years for men).

Participant characteristics are shown in Table 1 for women and Table 2 for men according to quintiles of the FSAm-NPS DI.

Both among women (Table 1) and men (Table 2), compared with participants with the lowest FSAm-NPS DI (quintiles 1, healthier diet), participants with the highest FSAm-NPS DI (quintiles 5, less healthy diet) were significantly younger, more likely to be current smokers, had higher educational level, practiced less intense physical activity, had higher energy intakes and reported more allergic rhinitis and less ever asthma. Among women only, participants with the lowest FSAm-NPS DI were more likely to be overweight or obese (Table 1).

Associations between the modified British Food Standards Agency Nutrient Profiling System dietary index and asthma symptom score

Associations between FSAm-NPS DI and the asthma symptom score are presented in Table 3 for women and men. Accordingly, 28 % of women and 25 % of men reported at least one asthma symptom. After adjusting for several potential confounders, we observed that a higher FSAm-NPS DI was positively and significantly associated with greater asthma symptoms both among women and men. OR for the highest FSAm-NPS DI (quintile 5) *v.* the lowest FSAm-NPS DI (quintile 1) was 1·27 (95 % CI 1·17, 1·38) in women and 1·31 (95 % CI 1·13, 1·53) in men.

Restricting analysis to participants without ever asthma (n 23 435 women and 7853 men) did not modify the observed associations, and similar associations were reported between the asthma symptom and the FSAm-NPS DI both among women (online Supplementary Table S1) and men (online Supplementary Table S2). After stratification by smoking status, associations remained significant and of similar magnitudes within each stratum among women (online Supplementary Table S3). Among men, the associations were significant only in never and former smokers (online Supplementary Table S4). Lastly, after stratification based on BMI, associations remained significant within each stratum among women (online Supplementary Table S5). Associations were still positive but were statistically significant only for participants with BMI < 25 kg/m^2 among men (online Supplementary Table S6).

Discussion

In this large cohort of French adults, a higher FSAm-NPS DI score, reflecting poorer food choices in the diet, was associated with a higher asthma symptom score. The association remained significant after adjusting for a wide range of potentially confounding variables and was also significant in participants without ever asthma.

To our knowledge, no other study has investigated the association between asthma and a dietary score based on a nutrient profiling system of the foods consumed. Indeed, the FSA score was initially developed to account for the nutrients for which a major concern has been raised regarding public health

Table 1. Characteristics of the participants, before imputation, according to the quintiles (Q) of the Food Standards Agency Nutrient Profiling System dietary index (FSA-NPS DI), among women (*n* 25 823) from the NutriNet-Santé study
(Mean values and standard deviations; numbers and percentages)

	Q1 (*n* 5164)		Q2 (*n* 5165)		Q3 (*n* 5165)		Q4 (*n* 5165)		Q5 (*n* 5164)		
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*P*
FSA-NPS DI											
Mean	3·0		5·0		6·2		7·3		9·2		
SD	1·2		0·4		0·3		0·4		1·0		
Age (years)											<0·0001
Mean	57·6		56·6		53·8		50·5		44·9		
SD	12·5		12·6		13·1		13·2		12·9		
Smoking											<0·0001
Never smokers	2636	51·1	2830	54·8	2823	54·7	2782	53·9	2956	57·2	
Former smokers	2032	39·4	1822	35·3	1789	34·6	1694	32·8	1381	26·7	
Current smokers	496	9·6	513	9·9	553	10·7	689	13·3	826	16·0	
Missing	0	0·0	0	0·0	0	0·0	0	0·0	1	0·0	
Pack-years among ever smokers											<0·0001
Mean	12·7		11·5		10·5		10·7		10·9		
SD	14·2		13·4		12·1		11·8		12·2		
Educational level											<0·0001
≤13 years	1131	21·9	993	19·2	906	17·5	779	15·1	619	12·0	
14 years	808	15·7	841	16·3	795	15·4	813	15·7	846	16·4	
15–16 years	1656	32·1	1588	30·8	1741	33·7	1710	33·1	1731	33·5	
≥17 years	1535	29·7	1698	32·9	1678	32·5	1832	35·5	1933	37·4	
Missing	34	0·7	45	0·9	45	0·9	30	0·6	36	0·7	
Leisure time physical activity											<0·0001
High	1820	35·2	1621	31·4	1519	29·4	1300	25·2	1156	22·4	
Moderate	1927	37·3	2091	40·5	2049	39·7	2097	40·6	2083	40·3	
Low	806	15·6	884	17·1	996	19·3	1139	22·1	1303	25·2	
Missing	611	11·8	569	11·0	601	11·6	629	12·2	622	12·0	
Total daily energy (kcal)*											<0·0001
Mean	1597		1735		1792		1867		1934		
SD	334		334		349		368		403		
Alcohol intake (g/d)											<0·0001
Mean	5·8		7·0		6·9		6·6		5·5		
SD	8·7		9·3		9·1		8·1		7·6		
BMI (kg/m^2)											<0·0001
Mean	23·8		23·5		23·4		23·4		23·3		
SD	4·6		4·2		4·2		4·5		4·7		
BMI											<0·0001
<18·5 kg/m^2	337	6·5	274	5·3	247	4·8	298	5·8	338	6·6	
18·5–24·9 kg/m^2	3225	62·5	3401	65·9	3491	67·6	3480	67·4	3472	67·2	
25·0–29·9 kg/m^2	1089	21·1	1038	20·1	993	19·2	925	17·9	806	15·6	
≥30·0 kg/m^2	480	9·3	410	7·9	380	7·4	400	7·7	458	8·9	
Missing	33	0·6	42	0·8	54	1·1	62	1·2	90	1·7	
Allergic rhinitis	2012	39·0	2093	40·5	2160	41·8	2261	43·8	2351	45·5	<0·0001
Family history of asthma	545	10·6	495	9·6	529	10·2	542	10·5	553	10·7	0·36
Asthma symptom score†											<0.0001
Mean	0·38		0·38		0·42		0·43		0·48		
SD	0·80		0·79		0·80		0·83		0·88		
Asthma symptom score†											<0·0001
0	3876	75·1	3827	74·1	3698	71·6	3678	71·2	3545	68·7	
1	880	17·0	937	18·1	1033	20·0	1039	20·1	1081	20·9	
2–5	408	7·9	401	7·8	434	8·4	448	8·7	538	10·4	
Ever asthma‡	515	10·0	585	11·3	594	11·5	580	11·2	709	13·7	<0·0001

* To convert kcal to kJ, multiply by 4·184.
† Number of respiratory symptoms during the past 12 months: (1) breathless while wheezing, (2) woken up with chest tightness, (3) attack of shortness of breath at rest, (4) attack of shortness of breath after exercise, and (5) woken by attack of shortness of breath. Each item is scored from 0 to 1, and the total asthma symptom score ranges from 0 to 5.
‡ Defined by at least one positive answer to the question 'Have you ever had an asthma attack?' in main questionnaires (baseline or follow-up), and by a positive answer to 'Have you ever had an asthma attack?' or 'Have you ever had an attack of shortness of breath at rest with wheezing' in the respiratory survey (2016).

significance, but not specifically asthma. In this context, in France, several studies have reported significant associations between the FSAm-NPS DI and increased risks of cancer[10,11], CVD[12,13], the metabolic syndrome[14] and obesity[15].

The FSAm-NPS DI, based on the FSAm-NPS of the foods consumed, has been shown to reflect the nutritional quality of the diet[6,9]. Still, few studies have been conducted to assess the association between overall nutrition diet quality and asthma. A study conducted in the USA in a large cohort of women reported no association between overall nutritional diet quality assessed by the Alternative Healthy Eating Index (AHEI-2010) and the risk of adult-onset asthma[34]. However, the authors used a

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Table 2. Characteristics of the participants, before imputation, according to the quintiles (Q) of the Food Standards Agency Nutrient Profiling System dietary index (FSA-NPS DI), among men (*n* 8500) from the NutriNet-Santé study
(Mean values and standard deviations; numbers and percentages)

	Q1 (*n* 1700)		Q2 (*n* 1700)		Q3 (*n* 1700)		Q4 (*n* 1700)		Q5 (*n* 1700)		
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*P*
FSA-NPS DI											
Mean	3·1		4·9		6·0		7·1		8·9		
SD	1·0		0·4		0·3		0·3		1·0		
Age (years)											<0·0001
Mean	63·7		62·8		61·3		57·7		50·3		
SD	11·5		11·7		12·4		13·5		13·9		
Smoking											<0·0001
Never smokers	639	37·6	617	36·3	663	39·0	703	41·4	887	52·2	
Former smokers	908	53·4	916	53·9	868	51·1	763	44·9	571	33·6	
Current smokers	153	9·0	167	9·8	169	9·9	234	13·8	242	14·2	
Missing	0	0·0	0	0·0	0	0·0	0	0·0	0	0·0	
Pack-years among ever smokers											<0·0001
Mean	17·1		18·2		15·3		16·8		16·1		
SD	16·6		18·1		13·7		16·3		16·0		
Educational level											<0·0001
≤13 years	484	28·5	452	26·6	448	26·4	407	23·9	313	18·4	
14 years	184	10·8	219	12·9	224	13·2	191	11·2	221	13·0	
15–16 years	398	23·4	368	21·7	392	23·1	381	22·4	480	28·2	
≥17 years	622	36·6	652	38·4	628	36·9	716	42·1	683	40·2	
Missing	12	0·7	9	0·5	8	0·5	5	0·3	3	0·2	
Leisure time physical activity											<0·0001
High	749	44·1	738	43·4	669	39·4	616	36·2	559	32·9	
Moderate	547	32·2	563	33·1	573	33·7	595	35·0	601	35·4	
Low	226	13·3	248	14·6	287	16·9	328	19·3	406	23·9	
Missing	178	10·5	151	8·9	171	10·1	161	9·5	134	7·9	0·01
Total daily energy (kcal)*											<0·0001
Mean	2061		2222		2297		2353		2417		
SD	457		447		453		472		515		
Alcohol intake (g/d)											<0·0001
Mean	14·5		17·3		16·7		16·9		13·1		
SD	16·5		17·1		15·8		16·2		14·0		
BMI (kg/m²)											0·01
Mean	24·9		25·3		25·0		25·0		24·8		
SD	3·7		3·7		3·5		3·6		4·0		
BMI											0·002
<18·5 kg/m²	18	1·1	5	0·3	15	0·9	15	0·9	28	1·7	
18·5–24·9 kg/m²	963	56·7	900	52·9	935	55·0	921	54·2	975	57·4	
25·0–29·9 kg/m²	573	33·7	626	36·8	603	35·5	632	37·2	550	32·4	
≥30·0 kg/m²	146	8·6	167	9·8	145	8·5	132	7·8	146	8·6	
Missing	0	0·0	2	0·1	2	0·1	0	0·0	1	0·1	
Atopy	469	27·6	504	29·7	522	30·7	523	30·8	510	30·0	
Family history of asthma	112	6·6	140	8·2	118	6·9	116	6·8	125	7·4	0·37
Asthma symptom score†											0·05
Mean	0·32		0·38		0·39		0·40		0·39		
SD	0·72		0·78		0·81		0·82		0·80		
Asthma symptom score†											
0	1319	77·6	1271	74·8	1274	74·9	1270	74·7	1258	74·0	
1	269	15·8	295	17·4	281	16·5	284	16·7	302	17·8	
2–5	112	6·6	134	7·9	145	8·5	146	8·6	140	8·2	
Ever asthma‡	136	8·0	140	8·2	162	9·5	168	9·9	204	12·0	<0·0001

* To convert kcal to kJ, multiply by 4·184.
† Number of respiratory symptoms during the past 12 months: (1) breathless while wheezing, (2) woken up with chest tightness, (3) attack of shortness of breath at rest, (4) attack of shortness of breath after exercise, and (5) woken by attack of shortness of breath. Each item is scored from 0 to 1, and the total asthma symptom score ranges from 0 to 5.
‡ Defined by at least one positive answer to the question 'Have you ever had an asthma attack?' in main questionnaires (baseline or follow-up), and by a positive answer to 'Have you ever had an asthma attack?' or 'Have you ever had an attack of shortness of breath at rest with wheezing' in the respiratory survey (2016).

dichotomous definition of asthma, which, compared with the asthma symptom score, may not correctly reflect phenotypic variability in asthma[25,26]. In contrast, using data from the French prospective Epidemiological study on the Genetics and Environment of Asthma study, but using the asthma symptom score as a continuous definition of asthma, Li *et al.* reported a significant association between a higher overall nutritional diet quality measured by the AHEI-2010 and improvement in asthma symptoms in never smokers[35]. We also described on the NutriNet-Santé cohort that scores reflecting a healthier diet (AHEI-2010, MED-LITE and Programme National Nutrition Santé Guideline Score (PNNS-GS)) were associated with a statistically significant decreased risk of asthma symptoms[36]. Our results are consistent with mechanistic studies regarding the associations between nutritional factors and asthma. First, studies have been conducted on the role of fruits and vegetables

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Table 3. Associations between quintiles (Q) of the Food Standards Agency Nutrient Profiling System dietary index (FSA-NPS DI) and asthma symptom score among women and men from the NutriNet-Santé study (*n* 34 323)
(Numbers of participants; mean values and standard deviations; odds ratios and 95 % confidence intervals)

		Q2		Q3		Q4		Q5		
	Q1	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	$P_{\text{for trend}}$
Women (*n* 25 823)										
n	5164	5165		5165		5165		5164		
FSA-NPS DI										
Mean	3·0	5·0		6·2		7·3		9·2		
SD	1·2	0·4		0·3		0·4		1·0		
OR*	1·00 (Reference)	1·01	0·94, 1·09	1·10	1·02, 1·19	1·15	1·06, 1·24	1·30	1·20, 1·40	<0·0001
OR†	1·00 (Reference)	1·01	0·94, 1·10	1·10	1·02, 1·19	1·12	1·04, 1·21	1·27	1·17, 1·38	<0·0001
Men (*n* 8500)										
n	1700	1700		1700		1700		1700		
FSA-NPS DI										
Mean	3·1	5·0		6·1		7·2		9·1		
SD	1·1	0·4		0·3		0·3		1·0		
OR*	1·00 (Reference)	1·16	1·01, 1·35	1·21	1·04, 1·40	1·24	1·07, 1·44	1·25	1·07, 1·45	0·003
OR†	1·00 (Reference)	1·09	0·94, 1·26	1·22	1·06, 1·41	1·22	1·06, 1·41	1·31	1·13, 1·53	0·0004

* Models were adjusted for age.
† Models were further adjusted for smoking, pack-years (among ever smokers), educational level, leisure time physical activity, total daily energy, alcohol intake, allergic rhinitis and family history of asthma.

and dietary fibres[6], which are major components of the FSAm-NPS DI, in explaining the diet–asthma association, at least partly. Secondly, studies have also been conducted on the potential role of salt, another component of the FSAm-NPS DI, on asthma and other chronic lung disease, such as chronic bronchitis[37]. In fact, high salt intake was reported to be risky for lung inflammation through a specific activation state in the macrophages, termed M(Na)[38]. In line with these findings, a case–control study conducted in Australia using an *a priori* score, which reflected the inflammatory potential of overall diet, the Dietary Inflammatory Index (DII), reported greater DII score in participants with ever asthma[39]. Finally, a recent study reported that lower SCFA production, end-products of fermentation of dietary fibres (mainly from fruits, vegetables or legumes), which can lead to an imbalanced gut microbiota[40], was associated with increased airway inflammation[41].

This study has some limitations that need to be pointed out. First, our results should be extrapolated with caution since participants from the NutriNet-Santé cohort were all volunteers involved in a long-term study that investigated the association between nutrition and health, with overall more health-conscious behaviours and higher socio-professional and educational levels[42]. Moreover, it has been observed that participants from the NutriNet-Santé cohort reported higher intake of healthy foods compared with participants from a representative French population-based study[42]. As unhealthy dietary behaviours are underrepresented in our study, the strength of the diet–asthma association is likely weakened in our sample compared with the general population. Second, the respiratory data used in the analysis were collected cross-sectionally and limit the conclusions that could be drawn with regard to causality. However, the association was also significant in participants without ever asthma. Third, we used self-reported questionnaires to gather data, which are inherently prone to biases[43] and might have led to misclassification and possibly weakening of associations. However, self-reported questionnaires are frequently used in population studies for epidemiological purposes, and objective validation studies performed in the NutriNet-Santé cohort supported the accuracy of self-reports as a measure of diet[17,18] and anthropometrics[28]. In addition, the FSAm-NPS DI was also validated against food consumption, nutrient intake and biomarkers of nutritional status in several studies[6,9,44]. In addition, the observational data may also be subject to residual confounding although we adjusted for several potential confounders. Fourth, since the overall nutritional quality of the diet has been associated with chronic obstructive pulmonary disease (COPD), potential overlaps between COPD and asthma might contribute to the association. However, since similar results were observed among never smokers, overlap between COPD and asthma was less likely in our study.

The key strengths of our study are the large sample size that allowed us to account for several potential confounders and to have sufficient statistical power to investigate stratified associations. Furthermore, we used validated tools to assess asthma symptoms[25,26], and dietary data were assessed by repeated 24-h dietary records (at least three) that reflect usual dietary behaviors.

In conclusion, our results suggest that unhealthy food choices, as reflected by a higher FSAm-NPS DI, were associated with greater asthma symptoms. Thus, these results reinforce the relevance of a public health approach to help consumers make healthier food choices by using a clear and easy-to-understand FOP nutrition label based on the FSAm-NPS, such as the Nutri-Score, which has been recently implemented in France.

Supplementary material

For supplementary materials referred to in this article, please visit https://doi.org/10.1017/S0007114519000655

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We have no conflict of interest to declare.

References

1. Vos T, Allen C, Arora M, *et al.* (2016) Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* **388**, 1545–1602.
2. Garcia-Larsen V, Del Giacco SR, Moreira A, *et al.* (2016) Asthma and dietary intake: an overview of systematic reviews. *Allergy* **71**, 433–442.
3. Julia C, Kesse-Guyot E, Ducrot P, *et al.* (2015) Performance of a five category front-of-pack labelling system – the 5-colour nutrition label – to differentiate nutritional quality of breakfast cereals in France. *BMC Public Health* **15**, 179.
4. Julia C, Ducrot P, Péneau S, *et al.* (2015) Discriminating nutritional quality of foods using the 5-color nutrition label in the French food market: consistency with nutritional recommendations. *Nutr J* **14**, 100.
5. Julia C & Hercberg S (2017) Nutri-Score: evidence of the effectiveness of the French front-of-pack nutrition label. *Ernahrungs Umschau* **64**, 181–187.
6. Julia C, Touvier M, Méjean C, *et al.* (2014) Development and validation of an individual dietary index based on the British Food Standard Agency nutrient profiling system in a French context. *J Nutr* **144**, 2009–2017.
7. Haut Conseil de la Santé Publique (2015) Opinion on information regarding the nutritional quality of foodstuffs. HCSP Paris. https://www.hcsp.fr/explore.cgi/avisrapportsdomaine?clefr=519 (accessed December 2018).
8. Julia C, Kesse-Guyot E, Touvier M, *et al.* (2014) Application of the British Food Standards Agency nutrient profiling system in a French food composition database. *Br J Nutr* **112**, 1699–1705.
9. Julia C, Méjean C, Touvier M, *et al.* (2016) Validation of the FSA nutrient profiling system dietary index in French adults-findings from SUVIMAX study. *Eur J Nutr* **55**, 1901–1910.
10. Donnenfeld M, Julia C, Kesse-Guyot E, *et al.* (2015) Prospective association between cancer risk and an individual dietary index based on the British Food Standards Agency Nutrient Profiling System. *Br J Nutr* **114**, 1702–1710.
11. Deschasaux M, Julia C, Kesse-Guyot E, *et al.* (2017) Are self-reported unhealthy food choices associated with an increased risk of breast cancer? Prospective cohort study using the British Food Standards Agency nutrient profiling system. *BMJ Open* **7**, e013718.
12. Adriouch S, Julia C, Kesse-Guyot E, *et al.* (2016) Prospective association between a dietary quality index based on a nutrient profiling system and cardiovascular disease risk. *Eur J Prev Cardiol* **23**, 1669–1676.
13. Adriouch S, Julia C, Kesse-Guyot E, *et al.* (2017) Association between a dietary quality index based on the food standard agency nutrient profiling system and cardiovascular disease risk among French adults. *Int J Cardiol* **234**, 22–27.
14. Julia C, Fézeu LK, Ducrot P, *et al.* (2015) The nutrient profile of foods consumed using the British food standards agency nutrient profiling system is associated with metabolic syndrome in the SU.VI.MAX Cohort. *J Nutr* **145**, 2355–2361.
15. Julia C, Ducrot P, Lassale C, *et al.* (2015) Prospective associations between a dietary index based on the British Food Standard Agency nutrient profiling system and 13-year weight gain in the SU.VI.MAX cohort. *Prev Med* **81**, 189–194.
16. Hercberg S, Castetbon K, Czernichow S, *et al.* (2010) The Nutrinet-Santé Study: a web-based prospective study on the relationship between nutrition and health and determinants of dietary patterns and nutritional status. *BMC Public Health* **10**, 242.
17. Lassale C, Castetbon K, Laporte F, *et al.* (2015) Validation of a Web-based, self-administered, non-consecutive-day dietary record tool against urinary biomarkers. *Br J Nutr* **113**, 953–962.
18. Lassale C, Castetbon K, Laporte F, *et al.* (2016) Correlations between fruit, vegetables, fish, vitamins, and fatty acids estimated by web-based nonconsecutive dietary records and respective biomarkers of nutritional status. *J Acad Nutr Diet* **116**, 427–438.e5.
19. Touvier M, Kesse-Guyot E, Méjean C, *et al.* (2011) Comparison between an interactive web-based self-administered 24 h dietary record and an interview by a dietitian for large-scale epidemiological studies. *Br J Nutr* **105**, 1055–1064.
20. Le Moullec N, Deheeger M, Preziosi P, *et al.* (1996) Validation of the photo manual used for the collection of dietary data in the SU.VI.MAX. study. *Cah Nut Diét* **31**, 158–164.
21. Etude Nutrinet-Santé (2013) *Table de Composition des Aliments de L'étude Nutrinet-Santé (Nutrinet-Santé Study Food Composition Database)*. Paris: Economica.
22. Black AE (2000) Critical evaluation of energy intake using the Goldberg cut-off for energy intake: basal metabolic rate. A practical guide to its calculation, use and limitations. *Int J Obes Relat Metab Disord* **24**, 1119–1130.
23. Schofield WN (1985) Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr* **39**, Suppl. 1, 5–41.
24. Burney PG, Luczynska C, Chinn S, *et al.* (1994) The European community respiratory health survey. *Eur Respir J* **7**, 954–960.
25. Pekkanen J (2005) Operational definitions of asthma in studies on its aetiology. *Eur Respir J* **26**, 28–35.
26. Sunyer J, Pekkanen J, Garcia-Esteban R, *et al.* (2007) Asthma score: predictive ability and risk factors. *Allergy* **62**, 142–148.
27. Vergnaud A-C, Touvier M, Méjean C, *et al.* (2011) Agreement between web-based and paper versions of a socio-demographic questionnaire in the NutriNet-Santé study. *Int J Public Health* **56**, 407–417.

28. Lassale C, Péneau S, Touvier M, *et al.* (2013) Validity of web-based self-reported weight and height: results of the Nutrinet-Santé study. *J Med Internet Res* **15**, e152.
29. Touvier M, Méjean C, Kesse-Guyot E, *et al.* (2010) Comparison between web-based and paper versions of a self-administered anthropometric questionnaire. *Eur J Epidemiol* **25**, 287–296.
30. World Health Organization (2000) Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organ Tech Rep Ser* **894**, 1–253.
31. Hagströmer M, Oja P & Sjöström M. (2006) The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutr* **9**, 755–762.
32. Fuseini H & Newcomb DC (2017) Mechanisms driving gender differences in asthma. *Curr Allergy Asthma Rep* **17**, 19.
33. Yuan YC (2000) Multiple imputation for missing data: Concepts and new development. In *Proceedings of the Twenty-Fifth Annual SAS Users Group International Conference*. Cary, NC: SAS Institute, p. 267.
34. Varraso R, Chiuve SE, Fung TT, *et al.* (2015) Alternate Healthy Eating Index 2010 and risk of chronic obstructive pulmonary disease among US women and men: prospective study. *BMJ* **350**, h286–h286.
35. Li Z, Kesse-Guyot E, Dumas O, *et al.* (2017) Longitudinal study of diet quality and change in asthma symptoms in adults, according to smoking status. *Br J Nutr* **117**, 562–571.
36. Andrianasolo RM, Kesse-Guyot E, Adjibade M, *et al.* (2018) Associations between dietary scores with asthma symptoms and asthma control in adults. *Eur Respir J* **52**, 1702572.
37. Suadicani P, Hein HO & Gyntelberg F (2011) High salt intake and risk of chronic bronchitis: The Copenhagen Male Study—A 10-year followup. *ISRN Pulmonology* **2011**, 257979.
38. Zhang W-C, Zheng X-J, Du L-J, *et al.* (2015) High salt primes a specific activation state of macrophages, M(Na). *Cell Res* **25**, 893–910.
39. Wood LG, Shivappa N, Berthon BS, *et al.* (2015) Dietary inflammatory index is related to asthma risk, lung function and systemic inflammation in asthma. *Clin Exp Allergy* **45**, 177–183.
40. McKenzie C, Tan J, Macia L, *et al.* (2017) The nutrition-gut microbiome-physiology axis and allergic diseases. *Immunol Rev* **278**, 277–295.
41. Halnes I, Baines K, Berthon B, *et al.* (2017) Soluble fibre meal challenge reduces airway inflammation and expression of GPR43 and GPR41 in asthma. *Nutrients* **9**, 57.
42. Andreeva VA, Deschamps V, Salanave B, *et al.* (2016) Comparison of dietary intakes between a large online cohort study (Etude NutriNet-Santé) and a nationally representative cross-sectional study (Etude Nationale Nutrition Santé) in France: addressing the issue of generalizability in E-epidemiology. *Am J Epidemiol* **184**, 660–669.
43. Rosenman R, Tennekoon V & Hill LG. (2011) Measuring bias in self-reported data. *Int J Behav Healthc Res* **2**, 320–332.
44. Deschamps V, Julia C, Salanave B, *et al.* (2015) Score de qualité nutritionnelle des aliments de la Food Standards Agency appliqué aux consommations alimentaires individuelles des adultes en France (Nutritional Quality Score for Foods from the Food Standards Agency applied to individual food consumption by adults in France). *Bull Epidémiol Hebd* **24–25**, 466–475.

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