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Fresh fruit intake and asthma symptoms in young British adults: confounding or effect modification by smoking?

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Fresh fruit intake and asthma symptoms in young British adults: confounding or effect modification by smoking? B.K. Butland, D.P. Strachan, H.R. Anderson. ©ERS Journals Ltd 1999.

ABSTRACT: Antioxidant vitamins have been postulated as a protective factor in asthma. The associations between the frequency of fresh fruit consumption in summer, and the prevalence of self-reported asthma symptoms were investigated.

The analysis was based on 5,582 males and 5,770 females, born in England, Wales and Scotland between March 3–9, 1958 and aged 33 yrs at the time of survey.

The 12-month period prevalence of wheeze and frequent wheeze were inversely associated with frequent intakes of fresh fruit and salad/raw vegetables and positively associated with smoking and lower social class. After adjustment for mutual confounding and sex, associations with smoking persisted, but those with social class and salad/raw vegetable consumption lost significance. The frequency of fresh fruit intake was no longer associated with wheeze after adjustment, but was inversely associated with frequent wheeze and speech-limiting attacks. The association with frequent wheeze differed significantly between smoking groups (never, former, current) and appeared to be confined to exsmokers and current smokers.

These findings support postulated associations between infrequent fresh fruit consumption and the prevalence of frequent or severe asthma symptoms in adults. Associations appeared to be restricted to smokers, with effect modification as a more likely explanation of this pattern than residual confounding by smoking.
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Recent decades have seen an increase in the prevalence of asthma and other atopic diseases within British children and young adults [1, 2]. The reason for this increase is unclear, but diet has been implicated [3] and further investigations into those factors which may prevent or initiate allergic symptoms are clearly required. Fresh fruit consumption is of particular interest as it is a rich source of vitamin C [4] which, owing to its antioxidant properties, may help to defend the body against airway inflammation and lung damage caused by tobacco smoke [5] and oxidant air pollutants such as ozone [6] and nitrogen dioxide [7].

The present study investigates the association between the frequency of fruit consumption and the prevalence of asthma symptoms in a British cohort study.

Materials and methods

All children born in England, Scotland and Wales between March 3–9, 1958 inclusive were targeted for study by the Perinatal Mortality Survey. Of these, 17,414 were recruited (98%) and followed-up at ages 7, 11, 16, 23 and 33 yrs by the National Child Development Study (NCDS) [8]. Late traces and immigrants (n=1,145) sharing the same birth week were identified at the first four follow-ups and added to the cohort, giving a total of 18,559. After exclusion of known deaths and emigrations a target sample of 16,455 was eligible for follow-up at 33 yrs of age [9].

Information at 33 yrs of age was obtained using interviewer administered questionnaires [9]. Cohort members were asked about their smoking habits, their consumption of fresh fruit in summer and their consumption of salads/raw vegetables in winter. The dietary variables were recorded on a six category frequency scale of "never", "less than once a week", "1 or 2 days a week", "3–6 days a week", "once a day" and "more than once a day". Social class was coded according to the Registrar General's 1991 classification [10]. Subjects were asked to report whether they had "ever had wheezing or whistling in the chest at any time in the past", whether these symptoms had occurred "at any time in the last 12 months" and if so "how many times... in the past 12 months". Those reporting past wheeze or responding positively to the question "Have you ever been told that you have asthma?" were asked whether over the past 12 months they had: 1) "used an inhaler or any other medicines prescribed by a doctor to treat your asthma or wheezing"; 2) had "any attacks of wheezing or asthma so severe that you could speak only one or two words at a time between breaths"; and 3) "been admitted overnight to hospital for treatment for wheezing or asthma".

Cross tabulations were performed using the Statistical Analysis System (SAS; SAS Institute, Cary, NC, USA) [11]. Epi Info [12] was used to calculate prevalence ratios and their 95% confidence intervals (CI), and logistic regression in SAS [11] was used to estimate prevalence odds

ratios, where prevalence odds is the ratio of prevalence to 1-prevalence.

For descriptive purposes smoking information was categorized and represented as a seven-level factor. However, when adjusting prevalence odds ratios for potential confounders using logistic regression, smoking (measured at the level of individual cigarettes) was included in the model by three terms. The first representing a linear association between log odds and the amount smoked, the second allowing the gradient of the linear association to differ between current and exsmokers and the third allowing the gradient for exsmokers to vary linearly according to the number of years since giving up smoking. When investigating whether associations between symptoms and diet differed between the three smoking groups (*i.e.* smokers, exsmokers and nonsmokers), two further terms were added to the model: a three-level factor for smoking group, and an interaction term between smoking group and fresh fruit consumption.

Results

Response

Information on wheeze in the past 12 months at 33 yrs of age was available for 69% of the 16,455 (5,582 males and 5,770 females). Response rates for providing information on wheeze were virtually identical among those who did and did not report wheeze in the past 12 months when 23 yrs of age (77.8% (420/540) *versus* 77.6% (9,298/11,983)).

Potential risk factors

The prevalence of asthma symptoms is shown by sex in table 1 and by social class and smoking habit in table 2. The period prevalence of frequent wheeze (table 1) was slightly higher for males than females (prevalence ratio 1.16 (95% CI 1.02–1.32)) although males had a much lower prevalence of speech-limiting attacks (prevalence ratio 0.55 (0.41–0.73)) and a lower proportion of males reported using prescribed medication for asthma symptoms (prevalence ratio 0.75 (0.66–0.85))

The prevalences of wheeze and frequent wheeze were significantly related to social class (table 2) and increased by approximately 72% (prevalence ratio 1.72 (1.31–2.25)) and 60% (prevalence ratio 1.60 (1.05–2.42)) respectively between social classes I and V. The prevalence of wheeze was particularly high among those subjects for whom social class could not be defined.

There were strong associations with smoking (table 2). The 12-month period prevalences of wheeze and frequent wheeze were highest among current smokers and appeared to increase with the increasing number of cigarettes smoked. In particular, heavy smokers ($\geq$20 cigarettes·day^{-1}) were three times more likely to wheeze and wheeze frequently than subjects who had never smoked. Exsmokers appeared to form an intermediate category where prevalence increased according to the number of cigarettes, but also decreased with increasing time since quitting.

There were strong negative associations between the dietary variables and wheezing (table 3), although associations with salad/raw vegetable intake were less convincing owing to high prevalences in the small group consuming salads more than once a day. The period prevalence of wheeze and frequent wheeze decreased stepwise with increasing fresh fruit consumption. The prevalence of speech-limiting attacks was approximately halved among those who ate fresh fruit in summer compared to those who did not, although there was no significant decreasing trend with increasing frequency of consumption.

The confounding effects of smoking

Fresh fruit intake in summer was strongly related to smoking habit. Of those who reported never eating fresh fruit, 60% were current smokers compared to only 24% among those reporting more than daily consumption. A similar trend was observed with increasing frequency of salad/raw vegetable intake in winter where the proportion of current smokers decreased from 45% among nonconsumers to 29% among frequent consumers (more than once a day). It is clear that observed associations between asthma symptoms and diet may be positively confounded by smoking. This was investigated firstly by restricting the analysis to lifelong nonsmokers. Within this subgroup, having adjusted for sex, no significant associations were found between the frequency of fresh fruit intake and asthma symptoms (table 4). Similarly, there were no significant associations between wheeze or frequent wheeze and salad/raw vegetable intake (p=0.803 and p=0.607, respectively).

Table 1. – Sex-specific period prevalences of symptoms and treatment as reported by the study subjects at 33 yrs of age

	Male			Female			All^{+}		
	Total	n	%	Total	n	%	Total	n	%
Any wheezing or whistling in the chest in the past 12 months	5582	996	17.8	5770	1059	18.4	11354	2056	18.1
Frequent ($\geq$5 times) wheezing or whistling in the chest in the past 12 months*	5529	439	7.9	5739	393	6.8	11270	833	7.4
Speech-limiting attacks of asthma or wheezing over the past 12 months***	5390	70	1.3	5550	131	2.4	10942	201	1.8
Use of medication prescribed for asthma or wheezing, in the past 12 months***	5390	362	6.7	5553	499	9.0	10945	862	7.9
Hospital admission for wheezing or asthma in the past 12 months	5391	15	0.3	5548	23	0.4	10941	38	0.3

Test for sex difference in period prevalence. *: p<0.05; ***: p<0.001; $^{+}$: includes subjects with no information on sex.

Table 2. – Twelve-month period prevalence for reported treatment and symptoms of wheezing illness by social class and smoking

	Wheezing		Frequent (≥5 times) wheezing		Speech-limiting attacks		Medication	
	n	%	n	%	n	%	n	%
Social class*								
Missing	81	21.8	41	11.1	10	2.8	39	11.0
Not defined	23	26.7	7	8.2	0	0.0	2	2.4
I Professional	71	13.2	34	6.3	5	1.0	34	6.5
II Managerial and technical	577	16.6	231	6.7	60	1.8	261	7.8
IIINM Skilled (nonmanual)	394	16.3	138	5.7	39	1.7	186	7.9
IIIM Skilled (manual)	419	19.4	177	8.3	36	1.7	142	6.8
IV Partly skilled	378	20.8	155	8.7	40	2.3	153	8.8
V Unskilled	113	22.6	50	10.1	11	2.3	45	9.4
Chi-squared test for trend (excluding "not defined" and "missing")	p<0.001		p<0.001		p=0.080		p=0.168	
Smoking history								
Missing	17	16.7	9	8.9	1	1.1	7	7.4
Never smoked	659	12.1	274	5.0	88	1.7	407	7.7
Exsmoker for >5 yrs†								
<20 cigarettes·day^{-1}	87	12.3	25	3.6	8	1.2	49	7.1
≥20 cigarettes·day^{-1}	69	13.3	30	5.8	7	1.4	41	8.1
Exsmoker for <5 yrs‡								
<20 cigarettes·day^{-1}	64	15.0	26	6.1	6	1.5	35	8.5
≥20 cigarettes·day^{-1}	83	19.8	42	10.1	9	2.3	30	7.5
Current smoker								
<10 cigarettes·day^{-1}	130	19.0	44	6.5	14	2.1	63	9.6
10–19 cigarettes·day^{-1}	323	27.0	105	8.9	22	2.0	76	6.8
≥20 cigarettes·day^{-1}	624	33.7	278	15.3	46	2.6	154	8.8
Chi-squared test for heterogeneity (excluding "missing")	p<0.001		p<0.001		p=0.159		p=0.350	

*: If social class of cohort member missing or not defined then coded according to social class of partner; †: quit aged 27 yrs or younger; ‡: quit aged 28 yrs or older.

Results for the never smoked (adjusted for sex) were then compared with those for current smokers (adjusted for sex and amount smoked) and those for exsmokers (adjusted for sex, amount smoked and age since quitting). In the case of frequent wheeze and speech-limiting attacks, the negative association with fresh fruit intake appeared to be confined to current smokers and exsmokers (table 4), although a statistical interaction was only significant for frequent wheeze (Chi-squared=6.694, degrees-of-freedom=2, p=0.035). For salad/raw vegetable consumption, there was little evidence of an association with wheeze or frequent wheeze in any of the three smoking groups (data not shown).

Independent effects

Returning to the full data set, logistic regression models were used to investigate the extent to which observed associations between the two dietary variables and asthma symptoms or treatment were confounded by sex, social class and each other as well as by smoking habit. Associations between diet and the recent use of prescribed medication for asthma or wheezing remained nonsignificant regardless of adjustment for confounders (table 5).

Adjusting for sex had little impact on associations between diet and wheeze or frequent wheeze, but a negative trend in the prevalence of speech-limiting attacks with the increasing frequency of fresh fruit intake became slightly more pronounced and reached statistical significance (p=0.006).

The extra effects of adjusting for smoking were particularly marked. The negative associations of salad/raw vegetable intake with wheeze and frequent wheeze lost statistical significance (p=0.142 and p=0.186, respectively) as did the association between speech-limiting attacks and fresh fruit intake (p=0.071). The association between fresh fruit consumption and wheeze appeared to be completely explained by smoking (p=0.227) with odds ratios for all intake categories close to 1. The extra confounding effects of social class for associations with fresh fruit were minimal (table 5).

After final adjustment for salad/raw vegetable consumption, the negative trend between frequent wheeze and fresh fruit intake, although weakened slightly, persisted (p=0.019) and that with speech-limiting attacks became significant (p=0.034). The association with frequent wheeze differed significantly (test for a statistical interaction: Chi-squared=6.634, degrees-of-freedom=2, p=0.036) between smoking groups (never, ex, current) and appeared to be confined to current and exsmokers, although among current smokers there was no evidence to suggest that the percentage reduction in risk associated with a one category rise in fresh fruit intake, increased with increasing number of cigarettes smoked (test for a statistical interaction: Chi-squared=0.116, degrees-of-freedom=1, p=0.733). The odds ratio (95% CI) for frequent wheeze comparing those eating fresh fruit more than once a day with nonconsumers was

Table 3. – Twelve-month period prevalence for reported treatment and symptoms of wheezing illness by frequency of fruit eating in summer and salad/raw vegetable eating in winter

	Wheezing		Frequent (≥5 times) wheezing		Speech-limiting attacks		Medication	
	n*	%	n	%	n	%	n	%
Fresh fruit in summer								
Never	96	25.2	57	15.1	15	4.1	34	9.2
<1 day a week	258	22.6	125	11.1	21	1.9	89	8.1
1 or 2 days a week	430	20.1	166	7.8	37	1.8	161	7.8
3–6 days a week	311	17.8	127	7.3	31	1.8	131	7.8
Once a day	620	15.8	234	6.0	62	1.6	294	7.7
More than once a day	340	16.9	124	6.2	35	1.8	153	7.9
Chi-squared test for trend	p<0.001		p<0.001		p=0.075		p=0.559	
Salads or raw vegetables in winter								
Never	341	22.5	159	10.6	36	2.5	127	8.8
<1 day a week	634	18.7	242	7.2	49	1.5	266	8.1
1 or 2 days a week	660	16.6	256	6.5	69	1.8	276	7.2
3–6 days a week	239	16.9	101	7.2	17	1.3	111	8.2
Once a day	145	16.7	55	6.3	20	2.4	65	7.7
More than once a day	36	21.4	20	12.0	10	6.3	17	10.6
Chi-squared test for trend	p<0.001		p=0.006		p=0.359		p=0.577	

*: One subject reported current wheeze but provided no information on the frequency of fruit eating in summer or salad/raw vegetable eating in winter.

estimated as 0.98 (0.41–2.37) for the never smoked, 0.59 (0.19–1.86) for exsmokers and 0.59 (0.36–0.97) for current smokers.

The previously strong associations of social class with wheeze and frequent wheeze lost significance after adjustment for sex, smoking and dietary variables (p=0.171 and p=0.419, respectively), as did the association between frequent wheeze and sex (p=0.840). The prevalences of wheeze, prescribed medication use and speech-limiting attacks after adjustment were significantly higher for females than males (p=0.012, p<0.001, p<0.001, respectively).

The strong associations between smoking history, wheeze and frequent wheeze persisted after adjustment for other factors (test for heterogeneity: both p<0.001). In addition all four outcomes, including speech-limiting attacks and prescribed medication were positively associated with the number of cigarettes smoked (p<0.0001; p< 0.0001; p=0.0066; p=0.028). For wheeze and frequent wheeze the percentage increase in risk per cigarette was lower for exsmokers than current smokers (p<0.0001; p< 0.0001), and within exsmokers, it increased with age of giving up (p<0.0001; p=0.0006).

Discussion

In this large, nationwide sample of young British adults, the reduced 12-month period prevalence of wheeze associated with frequent fruit consumption in summer was completely explained by smoking habit. The association between fruit eating and smoking was particularly marked with the proportion of current smokers, increasing dramatically from 24% among frequent consumers to 60%

Table 4. – Prevalence odds ratio (OR) (95% confidence intervals (CI)) for reported symptoms of wheezing illness by frequency of fruit eating in summer, within smoking groups

Smoking habit	Fresh fruit in summer	Wheezing		Frequent wheezing (≥5 times)		Speech-limiting attacks	
		OR	95% CI	OR	95% CI	OR	95% CI
Never smoked*	Less than one day a week	1.00	Baseline	1.00	Baseline	1.00	Baseline
	1–6 days a week	0.77	0.58–1.03	0.79	0.51–1.22	1.12	0.49–2.58
	At least once a day	0.80	0.61–1.05	0.88	0.58–1.33	0.90	0.40–2.02
Chi-squared test for trend†		p=0.281		p=0.964		p=0.544	
Exsmoker‡	Less than one day a week	1.00	Baseline	1.00	Baseline	1.00	Baseline
	1–6 days a week	1.01	0.66–1.54	0.65	0.38–1.12	0.24	0.08–0.74
	At least once a day	0.80	0.53–1.22	0.42	0.24–0.72	0.42	0.16–1.07
Chi-squared test for trend†		p=0.109		p=0.003		p=0.310	
Current smoker#	Less than one day a week	1.00	Baseline	1.00	Baseline	1.00	Baseline
	1–6 days a week	1.03	0.85–1.25	0.75	0.58–0.97	0.82	0.47–1.43
	At least once a day	0.94	0.77–1.14	0.64	0.49–0.84	0.65	0.36–1.17
Chi-squared test for trend†		p=0.882		p=0.005		p=0.103	

*: The analysis is based on at least 5,312 lifelong nonsmokers and adjusts for sex; †: tests for trend based on variables with six rather than three categories; ‡: the analysis is based on at least 2,005 exsmokers and adjusts for sex, amount smoked and age since quitting. #: the analysis is based on at least 3,521 current smokers and adjusts for sex and amount smoked.

Table 5. – Multiple logistic regression analysis for symptoms and medication by fruit intake, adjusting for the confounding effects of sex, smoking habit, social class and salad/raw vegetable consumption

Adjusted for	Fresh fruit in summer	Wheezing (n=10,791)		Frequent wheezing (≥5 times) (n=10,712)		Speech-limiting attacks (n=10,409)		Medication (n=10,412)	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sex (Model 1)	Never	1.00	Baseline	1.00	Baseline	1.00	Baseline	1.00	Baseline
	<1 day a week	0.86	0.65–1.14	0.68	0.48–0.97	0.48	0.24–0.96	0.93	0.60–1.44
	1 or 2 days a week	0.73	0.56–0.95	0.47	0.33–0.65	0.40	0.21–0.76	0.83	0.55–1.25
	3–6 days a week	0.64	0.49–0.84	0.46	0.33–0.65	0.42	0.22–0.80	0.88	0.58–1.33
	Once a day	0.54	0.42–0.70	0.36	0.26–0.50	0.32	0.17–0.58	0.80	0.54–1.19
	More than once a day	0.58	0.44–0.76	0.39	0.27–0.55	0.35	0.19–0.67	0.81	0.53–1.22
Chi-squared test for trend		p<0.001		p<0.001		p=0.006		p=0.201	
Model 1 plus smoking history (Model 2)	Never	1.00	Baseline	1.00	Baseline	1.00	Baseline	1.00	Baseline
	<1 day a week	1.03	0.77–1.38	0.82	0.57–1.18	0.52	0.26–1.04	0.95	0.61–1.47
	1 or 2 days a week	0.98	0.74–1.29	0.62	0.44–0.88	0.46	0.24–0.87	0.86	0.57–1.30
	3–6 days a week	0.98	0.73–1.30	0.70	0.48–1.00	0.51	0.26–0.98	0.92	0.60–1.40
	Once a day	0.88	0.67–1.15	0.58	0.41–0.82	0.40	0.21–0.74	0.85	0.57–1.27
	More than once a day	0.98	0.73–1.30	0.64	0.44–0.92	0.45	0.23–0.88	0.85	0.56–1.30
Chi-squared test for trend		p=0.227		p=0.007		p=0.071		p=0.378	
Model 2 plus social class (Model 3)	Never	1.00	Baseline	1.00	Baseline	1.00	Baseline	1.00	Baseline
	<1 day a week	1.04	0.77–1.39	0.83	0.57–1.20	0.52	0.26–1.05	0.96	0.62–1.48
	1 or 2 days a week	0.99	0.75–1.30	0.63	0.44–0.89	0.46	0.24–0.88	0.86	0.57–1.31
	3–6 days a week	0.99	0.74–1.32	0.70	0.49–1.01	0.52	0.27–1.00	0.93	0.61–1.42
	Once a day	0.88	0.67–1.16	0.59	0.42–0.83	0.40	0.22–0.75	0.85	0.57–1.28
	More than once a day	0.99	0.74–1.32	0.65	0.45–0.94	0.46	0.24–0.89	0.86	0.57–1.32
Chi-squared test for trend		p=0.261		p=0.008		p=0.078		p=0.408	
Model 3 plus salad/raw vegetable consumption (Model 4)	Never	1.00	Baseline	1.00	Baseline	1.00	Baseline	1.00	Baseline
	<1 day a week	1.06	0.79–1.43	0.88	0.61–1.27	0.56	0.28–1.14	0.98	0.63–1.52
	1 or 2 days a week	1.02	0.77–1.36	0.67	0.47–0.95	0.49	0.26–0.96	0.90	0.59–1.37
	3–6 days a week	1.04	0.77–1.39	0.76	0.52–1.10	0.58	0.29–1.15	0.98	0.63–1.50
	Once a day	0.93	0.70–1.23	0.64	0.45–0.91	0.43	0.22–0.81	0.91	0.60–1.38
	More than once a day	1.04	0.77–1.40	0.68	0.46–1.00	0.41	0.20–0.83	0.91	0.58–1.40
Chi-squared test for trend		p=0.462		p=0.019		p=0.034		p=0.629	

OR: odds ratio; CI: confidence interval.

among nonconsumers. The existence of a strong link between vitamin C or fruit consumption and cigarette smoking is well documented [13–17]. Low levels of serum vitamin C among smokers may simply reflect higher levels of vitamin metabolism [14, 15], but other studies reporting associations with dietary intake suggest that smokers may also be exercising a preference against fresh fruit [16, 18].

The association between fruit eating and frequent wheeze, although weakened, persisted after adjustment for other factors including smoking; and the association with speech-limiting attacks reached statistical significance due to adjustment for sex and salad/raw vegetable consumption. Results after adjustment suggested that an increase in the frequency of fresh fruit intake from never to more than once a day was associated with a 32% decrease overall in the odds of frequent wheeze (2% among the never smoked and 41% among smokers) and a 59% decrease overall in the odds of speech-limiting attacks. There were no significant associations between symptoms and the frequency of salad/raw vegetable consumption in winter, although this may in part be due to a lack of power, with only 1.5% of the cohort reporting frequent consumption.

Evidence of an association between low vitamin C or fresh fruit intake and respiratory symptoms in adults comes from the Second United States National Health and Nutrition Examination Survey (NHANES II) [19], a study of middle-aged males in the Netherlands [20] and a Scottish case-control study [21], although other large epidemiological investigations have failed to find such an association including the American Nurses Health Study (NHS) [22] and the British Health and Lifestyle Survey [23]. Evidence for an association between vitamin C or fresh fruit intake and lung function in adults and children is more consistent [21, 23–26] and it has been suggested that vitamin C along with other antioxidants might play a role in protecting the lungs from damage by tobacco smoke [5], ozone [6] and nitrogen dioxide [7]. Under this hypothesis, stronger associations between fruit eating and symptoms among smokers compared to lifelong nonsmokers would be expected. There was some suggestion of this in the present data especially for frequent wheeze, where the difference reached statistical significance.

It has been suggested that healthy lifelong nonsmokers who eat less fruit may be more likely to live with smokers or have been brought up by parents who smoked [23]. However, with little evidence of an association between fresh fruit eating and either frequent wheeze or speech-limiting attacks among the large subset (>5,000) of lifelong nonsmokers (table 4), confounding by passive smoking seems an unlikely explanation of the current findings. Associations confined to smokers, though consistent with the antioxidant hypothesis could indicate residual confounding by active smoking. However, when modelling smoking in the logistic regression analysis all available information was used, including the number of individual cigarettes smoked. Further, although it was not possible to adjust for

length of time smoked among current smokers, or for other aspects of smoking habit, such as depth of inhalation, the authors′ adjustment was adequate to completely remove an apparently spurious association between wheeze and fresh fruit intake.

It is possible that those eating more fruit may not only smoke less but have a higher total energy intake and that fresh fruit intake is merely a marker for some other food source that contains the "real" protective factor. Total energy intake was not measured as part of this study and could not be allowed for in the analysis. However, if fresh fruit is acting as a marker, these data suggest that it is not for salads or raw vegetables. It is also of interest to note that the Zutphen study [20] which reported an inverse association between fruit consumption and chronic non-specific lung disease in middle-aged males, did so after adjustment for confounders including total calories.

Another problem with inferring causality, despite a plausible biological mechanism, is that subjects may change their diet on experiencing symptoms [19, 22], possibly removing fruit such as melon, which has been linked with allergic symptoms among sufferers of hay fever [27]. However, this would not explain associations confined to smokers. Changes in behaviour may not only have created spurious associations but masked real ones. In the NHS study [22], the authors found evidence that nurses with respiratory symptoms started to take vitamin supplements prior to a diagnosis of asthma. In the present study, vitamin C was not measured directly but the frequency of fresh fruit consumption was used instead; although it is still possible that some symptomatics altered their fresh fruit intake in order to boost their vitamin C load.

If the association with fresh fruit is real, it cannot be certain that its effect is due to vitamin C. Certain types of fresh fruit contain high levels of other free radical scavengers such as carotenes and flavonoids that may also be involved [4, 20, 22]. Unfortunately with no information on the type of fruit eaten or portion size this is not an issue that can be addressed in the current analysis.

Why an association with frequent wheeze and speech-limiting attacks should be detected, but not with wheeze in general, is unclear. Frequent wheeze and speech-limiting attacks are used in the NCDS as measures of symptom severity and may be more specific indicators of asthma. Indeed of those reporting speech-limiting attacks 84% also reported using inhalers or taking other prescribed medications for asthma or wheezing and 74% reported having been told at some point that they had asthma. For frequent wheeze the percentages were 53% and 46%, respectively, compared with 41% and 32% among those reporting wheeze in general. However, there was a lack of association between fresh fruit intake and medication. This persisted after adjustment for smoking and social class suggesting that socioeconomic variations in use of prescribed medication for asthma or wheezing (table 2) do not obscure a true inverse association of fresh fruit intake and treated disease. One possible explanation is that a protective effect of fresh fruit in smokers relates to oxidant challenges to the airway [5–7] which may be more important in the exacerbation of asthma symptoms than in initiation of disease.

In conclusion, an association between the frequency of fresh fruit consumption and the prevalence of persistent or severe asthma symptoms was found. The association between fresh fruit intake and frequent wheeze differed significantly between smoking groups and appeared to be largely confined to current smokers and exsmokers. Based on these data, effect modification was a more likely explanation of this statistical interaction than residual confounding by smoking. Thus, associations between diet and respiratory disease as indicated by fresh fruit consumption, are more evident among smokers, which is consistent with a protective antioxidant effect.

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