

Diet and asthma, allergic rhinoconjunctivitis and atopic eczema symptom prevalence: an ecological analysis of the International Study of Asthma and Allergies in Childhood (ISAAC) data

P. Ellwood*, M.I. Asher*, B. Björkstén[#], M. Burr[†], N. Pearce[‡], C.F. Robertson[§], and the ISAAC Phase One Study Group

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ABSTRACT: Several studies have suggested that the increasing prevalence of symptoms of asthma, rhinitis and eczema, could be associated with dietary factors. In the present paper, a global analysis of prevalence rates of wheeze, allergic rhinoconjunctivitis and atopic eczema was performed in relation to diet, as defined by national food intake data.

Analyses were based on the International Study of Asthma and Allergies in Childhood (ISAAC) data for 6–7 and 13–14 yr old children. Symptoms of wheeze, allergic rhinoconjunctivitis and atopic eczema symptom prevalence were regressed against per capita food intake, and adjusted for gross national product to account for economic development. Dietary data were based on 1995 Food and Agriculture Organisation of the United Nations data for 53 of the 56 countries that took part in ISAAC phase I (1994/1995).

The 13–14 year age group showed a consistent pattern of decreases in symptoms of wheeze (current and severe), allergic rhinoconjunctivitis and atopic eczema, associated with increased per capita consumption of calories from cereal and rice, protein from cereals and nuts, starch, as well as vegetables and vegetable nutrients. The video questionnaire data for 13–14 yr olds and the ISAAC data for 6–7 yr olds showed similar patterns for these foods.

A consistent inverse relationship was seen between prevalence rates of the three conditions and the intake of starch, cereals, and vegetables. If these findings could be generalised, and if the average daily consumption of these foods increased, it is speculated that an important decrease in symptom prevalence may be achieved.

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*Dept of Paediatrics, Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand, [#]Centre for Allergy Research, Karolinska Institute, Nobels väg 5, Stockholm, Sweden, [†]University of Wales College of Medicine, Temple of Peace and Health, Cathays Park, Cardiff, UK, [‡]Centre for Public Health Research, Massey University, Wellington Campus, Wellington, New Zealand and [§]Dept of Respiratory Medicine, Royal Children's Hospital, Flemington Rd, Parkville, Victoria, Australia.

Correspondence: Philippa Ellwood, ISAAC International Data Centre, Dept of Paediatrics, Faculty of Medical and Health Science, University of Auckland, Private Bag 92019, Auckland, New Zealand
Fax: 64 9 3737602

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The incidence of many noncommunicable diseases (NCDs) throughout the world, has been linked to diet [1], and there is a need for standardised multi-country studies of nutrition and disease [2]. Many nutritional

factors may influence disease, including changes to the production and availability of food, changing food preferences, increased supply of processed foods for consumption as well as supplies for food aid, use of

fertilisers and pesticides, land availability, increased prices of staple foods, urbanisation, migration, economic factors and market fluctuations [3–6]. Traditional nutritional patterns and patterns of health are changing as are other aspects of lifestyles of populations. Over the past few decades, "Westernization" has seen many countries moving away from the traditional diet of locally grown foods to a more western diet [4]. In some countries, these patterns have been shown to be linked to the increase of NCDs [5–7] including obesity, cardiovascular diseases and some cancers [1, 6, 8]. Others have reported a lower incidence of chronic disease to be associated with the consumption of a more traditional form of diet [9–12].

Asthma, a chronic respiratory disease, is classified as an NCD but there has been little study of its relationship to dietary factors. Recent hypotheses have focused on potential relationships between food content and the airway inflammatory response [13, 14]. Decreased consumption of fruit and vegetables in the United Kingdom has been postulated to be associated with an increase in prevalence of asthma and rhinitis through their antioxidant properties, which may protect against inflammation [13, 15]. Similarly, increased consumption of linoleic acid, found in polyunsaturated fatty acids (PUFAs), is thought to be linked to asthma, eczema and allergic rhinitis [12, 16]. It is postulated that an increase in consumption of linoleic acid leads to an increase in the synthesis of prostaglandin- E_2 (PGE $_2$), resulting in allergic sensitisation [14]. More recently, a European investigation indicated an association between trans-fatty acids and the prevalence of childhood asthma, rhinitis and eczema [17]. Oily fish consumption has been associated with reduced risk of children having asthma and previous studies postulated that increased consumption of oily fish, rich in omega-3 fatty acids, reduces the synthesis of proinflammatory cytokines [18]. Migration and food aid (including processed food) have been associated with the rapid increase in asthma prevalence, suggesting a potent environmental factor [6, 19, 20]. Thus, in seeking explanations for the large world-wide variations in the prevalence of asthma, rhinitis and eczema, and the increases within populations over the last few decades, dietary factors are a potentially important field for study. The findings of an ecological analysis of the relationship between per capita food intake and the prevalence of symptoms of asthma, allergic rhinoconjunctivitis and atopic eczema are reported here.

Methods

Sources of data

Symptom prevalence data. The International Study of Asthma and Allergies in Childhood (ISAAC) programme [21], has reported major world-wide variation in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis and atopic eczema [22–25]. The methods have been described in detail elsewhere [21] and they are mentioned only briefly here. ISAAC Phase One studied a total of 721,601 children of two age groups (6–7 and 13–14 yr olds)

from 156 collaborating centres in 56 countries. Each centre was responsible for obtaining its own funding and obtained the necessary approval from an ethics committee before the start of the study. Three one-page core questionnaires on asthma, rhinitis and eczema symptoms for both age groups were used and an asthma symptoms video questionnaire used for the older age group. The basic question used for assessing asthma symptom prevalence was "Have you had wheezing or whistling in the chest in the last 12 months?" (current wheeze). The prevalence of asthma severity was assessed by using the question "In the last 12 months, how often, on average has your sleep been disturbed due to wheezing?" and identifying respondents who reported such sleep disturbance "one or more nights per week". The allergic rhinoconjunctivitis prevalence analyses were based on positive answers to two questions; "In the past 12 months have you had a problem with sneezing or a runny or blocked nose when you DID NOT have a cold or the flu?" If yes: "In the past 12 months has this nose problem been accompanied by itchy watery eyes?" The atopic eczema prevalence analyses used positive answers to three questions relating to an itchy rash: "Have you ever had an itchy rash which was coming and going for at least six months?" If yes: "Have you had this itchy rash at any time in the last 12 months?" If yes: "Has this itchy rash at any time affected any of the following places: the folds of the elbows, behind the knees, in front of the ankles, under the buttocks, or around the neck, ears, or eyes?" The older age group self completed the questions and also answered a video questionnaire, for which the first scene, wheezing at rest, was used for analysis. Questions for the younger age group were reworded accordingly and answered by the parent/guardian of the child.

Food Balance Sheets. We used the 1995 food balance sheet and food supply data, from the Food and Agriculture Organisation (FAOSTAT) website [26] to obtain comparative figures of food and nutrient intake among the large number of countries who took part in ISAAC Phase One. FAOSTAT data was obtained for 53 out of the 56 ISAAC countries (all except Oman, Singapore and Taiwan). FAOSTAT data describe amounts of food produced per country, and amounts exported and imported, but wastage is not accounted for. Food consumption per capita is calculated as the sum of food production and food imports, minus food exports, divided by the population, and the resulting food balance sheets subjected to rigorous internal and external consistency checks [26]. This information was analysed using an international Food and Nutrient database (www.healthnz.co.nz) which estimated per capita consumption of macro nutrients and micro nutrients in appropriate units or as a percentage of total energy consumption (%TEC) corrected for edibility obtained from food composition tables [27, 28].

Table 1. – Country food supply per capita per day; minimum and maximum range.

Diet variable intake per day	Country range			
	Minimum value		Maximum value	
Kilocalories (kCal)	1602	Ethiopia	4013	USA
Protein (%TEC)	8	Thailand & Nigeria	14	Albania
Protein (g)	48	Thailand	119	Italy
Carbohydrate (%TEC)	42	Austria	74	India
Carbohydrate (g)	311	Ethiopia	587	Morocco
Total Fat (%TEC)	13	Ethiopia	43	Belgium
Total Fat (g)	24	Ethiopia	181	Belgium
Saturated Fat (%TEC)	4	Ethiopia & Morocco	19	Belgium
PUFA (%TEC)	3	Indonesia	12	South Africa
MUFA (%TEC)	3	Ethiopia	18	Greece
Vegetables (%TEC)	0.3	Ethiopia	3	Greece
Vegetables (g)	18	Ethiopia	470	Lebanon
Vit A from vegetables (µg)	30	Ethiopia	739	Lebanon
Vit E from vegetables (mg)	0.1	Ethiopia	5	Greece
Calcium from vegetables (mg)	6	Ethiopia	130	Korea
Protein from vegetables (g)	0.5	Costa Rica	6	Greece
Vegetable MUFA (%TEC)	0.01	Many countries	0.05	Greece and Lebanon
Vegetable PUFA (%TEC)	0.01	Ethiopia	0.2	Lebanon
Vegetable saturated fat (%TEC)	0.01	Many countries	0.08	Lebanon
Starch (g)	121	Thailand	366	Algeria
Calories from cereal/rice (%TEC)	21	Germany	72	Ethiopia
Protein from cereals/nuts (g)	27	Finland	79	Morocco
Soya oil (g)	0.0	Nigeria	56	USA
Olive oil (g)	0.0	Many countries	51	Greece

%TEC: percent of total energy consumption; PUFA: polyunsaturated fatty acids; MUFA: monounsaturated fatty acids.

Data analysis

The data for the three conditions and dietary variables were entered onto a computer and analysed using PC SAS (SAS Institute, Cary, NC, USA). Analyses of dietary variables were performed both by units of kg and by %TEC. The results given are for %TEC unless otherwise stated, to enable a focus on dietary patterns rather than total food intake (which may be more prone to inaccuracies due to wastage or miss reporting). Mixed model regression analyses were carried out to incorporate the different structure of each of the data sets, with FAOSTAT data representing whole countries and ISAAC data using centres within countries. All analyses were repeated with gross national product (GNP) in the model to account for the level of economic development of countries, a factor related to symptom prevalence [29]. The analysis did not examine combinations and interactions of the diet variables.

Results

There were 53 countries with both FAOSTAT and ISAAC data with a wide range of per capita food supply. TEC (expressed as kilocalorie (kCal) for consistency with the data obtained from FAOSTAT) ranged from 1602–4013 kCal·day⁻¹; protein 48–119 g·day⁻¹ (5–14%TEC); carbohydrate from 311–587 g·day⁻¹ (42–74%TEC) and fat 24–181 g·day⁻¹ (13–43%TEC). Table 1 shows these and the range of other dietary variables.

The results of the regression analysis for the

13–14 yr age group are shown in table 2. For kCal and protein, a negative pattern of association with wheeze (current and severe), allergic rhinoconjunctivitis and atopic eczema was seen, significantly negative between kCal and atopic eczema. Carbohydrate showed a negative association, except with atopic eczema, which became positive. Fat and saturated fat showed a generally consistent positive association (GNP adjusted data).

Starch (g), total fibre (g), calories from cereal and rice (%TEC), protein from cereals and nuts (g), total seafood (g), and all fresh/frozen fish (g), showed a consistent negative association with current and severe wheeze, allergic rhinoconjunctivitis and atopic eczema. These negative associations were significant between starch and current wheeze; total fibre and current wheeze; calories from cereal and rice and current/severe wheeze and allergic rhinoconjunctivitis; protein from cereals and nuts and current wheeze, allergic rhinoconjunctivitis and atopic eczema; total seafood and severe wheeze; all fish and severe wheeze. The strongest findings were for calories from cereals and rice. Figure 1 shows the %TEC of calories from cereals and rice by country, ranging from 21% (Germany) to 72% (Ethiopia). Figure 2 plots, for the 13–14 year age group, the percentage of current wheeze against calories from cereals and rice as %TEC, expressed as averaged country data. As an example, an increase in calories from cereal and rice of 10%TEC was associated with a decrease of 3.2% (3.1% if not adjusted for GNP) for current wheeze, 0.4% (0.2%) for severe wheeze, 2.4% (1.9%) for allergic rhinoconjunctivitis and 0.6% (0.9%) for atopic eczema.

For vegetables (g and %TEC), and vegetable derived

Table 2. – Regression analysis of the International Study of Asthma and Allergies in Childhood (ISAAC) (13–14 year age group) symptom prevalence data and diet variables.

Diet variable	Coefficient	Lower 95% CI	Upper 95% CI	p-value
Current wheeze				
Kilocalories (kCal)	-0.0008 (0.03)	-0.006 (-0.001)	0.004 (0.007)	0.747 (0.138)
Protein%*	-0.3 (0.2)	-1.7 (-1.32)	1.2 (1.67)	0.728 (0.819)
Carbohydrate%*	-0.2 (-0.3)	-0.5 (-0.53)	0.2 (-0.09)	0.356 (0.008)
Fat%*	0.2 (0.4)	-0.2 (0.11)	0.6 (0.62)	0.311 (0.006)
Saturated fat all%*	0.6 (1)	-0.1 (0.36)	1.4 (1.55)	0.102 (0.003)
Vegetables g/day	-0.02 (-0.01)	-0.04 (-0.03)	-0.001 (0.011)	0.041 (0.337)
Vegetables %*	-3.1 (-2.3)	-5.9 (-5.35)	-0.3 (0.76)	0.035 (0.146)
Vitamin A from vegetables µg·day ⁻¹	-0.01 (-0.006)	-0.03 (-0.02)	-0.001 (0.007)	0.040 (0.347)
Starch g·day ⁻¹	-0.05 (-0.06)	-0.08 (-0.09)	-0.014 (-0.028)	0.008 (0.0004)
Calories from cereal/rice %*	-0.3 (-0.3)	-0.5 (-0.43)	-0.2 (-0.2)	0.0005 (0.0001)
Protein from cereals/nuts g·day ⁻¹	-0.3 (-0.4)	-0.5 (-0.6)	-0.124 (-0.2)	0.002 (0.0001)
Total fibre g·day ⁻¹	-0.2 (-0.2)	-0.36 (0.411)	-0.009 (-0.046)	0.044 (0.018)
Wheeze disturbing sleep				
kCal	-0.00009 (-0.00005)	-0.001 (-0.0007)	0.0008 (0.0006)	0.833 (0.876)
Protein%*	-0.1 (-0.1)	-0.4 (-0.37)	0.1 (0.11)	0.295 (0.302)
Carbohydrate%*	-0.003 (-0.001)	-0.061 (-0.04)	0.06 (0.04)	0.930 (0.943)
Fat%*	0.02 (0.01)	-0.04 (-0.03)	0.09 (0.06)	0.491 (0.634)
Saturated fat all%*	0.03 (0.02)	-0.1 (-0.09)	0.2 (0.13)	0.640 (0.708)
Vegetables g/day	0.002 (-0.001)	-0.005 (-0.005)	0.002 (0.002)	0.397 (0.415)
Vegetables %*	-0.2 (-0.2)	-0.8 (-0.74)	0.286 (0.279)	0.381 (0.380)
Vitamin A from vegetables µg·day ⁻¹	-0.001 (-0.001)	-0.004 (-0.003)	0.001 (0.001)	0.286 (0.306)
Starch g·day ⁻¹	-0.002 (-0.002)	-0.009 (-0.008)	0.0039 (0.0037)	0.458 (0.497)
Calories from cereal/rice %*	-0.04 (-0.02)	-0.1 (-0.04)	-0.01 (0.004)	0.023 (0.102)
Protein from cereals/nuts g·day ⁻¹	-0.03 (-0.02)	-0.06 (-0.06)	0.01 (0.01)	0.143 (0.175)
Total fibre g·day ⁻¹	-0.002 (-0.002)	-0.035 (-0.034)	0.03 (0.029)	0.882 (0.881)
Allergic Rhinconjunctivitis				
kCal	-0.0002 (0.002)	-0.005 (-0.002)	0.004 (0.005)	0.930 (0.391)
Protein%*	-1.1 (-0.9)	-2.4 (-2.18)	0.2 (0.46)	0.100 (0.205)
Carbohydrate%*	-0.08 (-0.2)	-0.4 (-0.36)	0.2 (0.05)	0.619 (0.156)
Fat%*	0.2 (0.2)	-0.2 (-0.01)	0.5 (0.45)	0.301 (0.072)
Saturated fat all%*	0.2 (0.4)	-0.5 (-0.15)	1.0 (0.98)	0.523 (0.153)
Vegetables g/day	-0.02 (-0.01)	-0.04 (-0.03)	0.002 (0.01)	0.083 (0.246)
Vegetables %*	-2.7 (-2.3)	-5.4 (-5)	-0.05 (0.42)	0.051 (0.102)
Vitamin A from vegetables µg·day ⁻¹	-0.01 (-0.007)	-0.02 (-0.02)	0.0012 (0.0048)	0.085 (0.258)
Starch g·day ⁻¹	-0.02 (-0.03)	-0.05 (-0.06)	0.014 (0.004)	0.266 (0.100)
Calories from cereal/rice %*	-0.2 (-0.2)	-0.41 (-0.31)	-0.076 (-0.075)	0.007 (0.003)
Protein from cereals/nuts g·day ⁻¹	-0.2 (-0.2)	-0.4 (-0.39)	-0.02 (-0.05)	0.039 (0.012)
Total fibre g·day ⁻¹	-0.07 (0.28)	-0.24 (-0.26)	0.096 (0.074)	0.399 (0.277)
Atopic Eczema				
kCal	-0.003 (-0.0002)	-0.005 (-0.002)	-0.0006 (0.0019)	0.016 (0.860)
Protein%*	-0.4 (-0.2)	-1.1 (-0.92)	0.4 (0.62)	0.341 (0.699)
Carbohydrate%*	0.09 (-0.07)	-0.1 (-0.19)	0.3 (0.05)	0.294 (0.261)
Fat%*	-0.08 (0.09)	-0.3 (-0.04)	0.1 (0.23)	0.442 (0.184)
Saturated fat all%*	0.1 (0.3)	-0.3 (0.01)	0.5 (0.64)	0.599 (0.047)
Vegetables g/day	-0.02 (-0.01)	-0.03 (-0.02)	-0.01 (-0.0004)	0.001 (0.046)
Vegetables %*	-2.3 (-1.9)	-3.7 (-3.44)	-0.9 (0.39)	0.002 (0.017)
Vitamin A from vegetables µg·day ⁻¹	-0.01 (-0.007)	-0.02 (-0.01)	-0.0045 (-0.0002)	0.001 (0.048)
Starch g·day ⁻¹	-0.006 (-0.01)	-0.02 (-0.03)	0.013 (0.0033)	0.560 (0.119)
Calories from cereal/rice %*	-0.06 (-0.09)	-0.2 (-0.16)	0.039 (-0.025)	0.246 (0.011)
Protein from cereals/nuts g·day ⁻¹	-0.1 (-0.2)	-0.2 (-0.25)	-0.015 (-0.055)	0.028 (0.003)
Total fibre g·day ⁻¹	-0.03 (-0.05)	-0.12 (-0.148)	0.063 (0.046)	0.523 (0.307)

Results are presented as adjusted for GNP (unadjusted). *: % of total energy consumption; GNP: Gross national product; CI: confidence interval.

nutrients of vitamin A (µg), E (mg), saturated fat (%TEC), calcium (mg) and protein (g), consistent negative associations were seen with all three conditions. These negative associations were significant for vegetables (g) and current wheeze and atopic eczema; vegetables (%TEC) and current wheeze, allergic rhinconjunctivitis and atopic eczema; vegetable derived nutrients, vitamin A and current wheeze, atopic

eczema; vitamin E and atopic eczema; saturated fat and current wheeze, allergic rhinconjunctivitis and atopic eczema; calcium and current wheeze, atopic eczema; protein and current wheeze, atopic eczema. For example, an increase of vegetable consumption by 100 g (country range 18–470 g·day⁻¹) was associated with a decrease of current wheeze by 2% (1% unadjusted for GNP) and atopic eczema by 2% (1%).

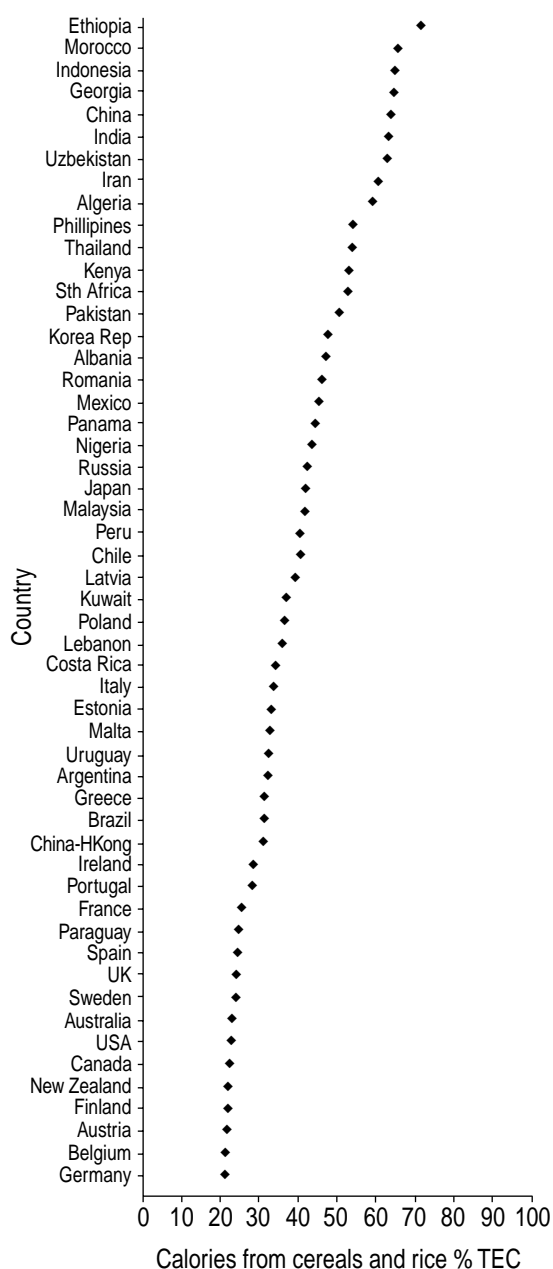


Fig. 1. – Ranked consumption of calories from cereal and rice in percentage of total energy consumption (%TEC) by country.

There was no association between total monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) intake %TEC, as well as MUFA and PUFA from vegetable oils and animals, for current wheeze, severe wheeze, allergic rhinoconjunctivitis and atopic eczema. However, significant negative associations were seen between MUFA from vegetables and current wheeze, atopic eczema and PUFA from vegetables and current wheeze, allergic rhinoconjunctivitis and atopic eczema (GNP adjusted).

For oils, olive oil (g) showed a negative association with current wheeze, severe wheeze and allergic rhinoconjunctivitis, becoming significantly negative with atopic eczema. Soya oil (g) was positively associated

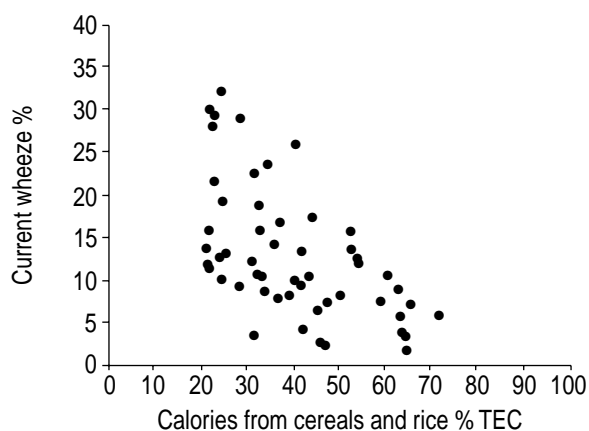


Fig. 2. – Current wheeze (%) against consumption of calories from cereal and rice (%TEC), 13–14 yr data. Each point represents a country, averaged from centre data.

with all three conditions and significantly positive with severe wheeze.

The video questionnaire showed generally the same pattern of associations as for current wheeze. Although most were insignificant, significant negative associations were seen with starch and protein from cereals and nuts. For example, a 50 g increase in starch was associated with a 1.4% (1.6% unadjusted for GNP) decrease in symptoms from the video questionnaire.

The 6–7 yr age group (data not shown), showed the same pattern as for the 13–14 yr age group data. Significant negative associations were seen between starch (g) and current wheeze and atopic eczema; calories from cereal and rice (%TEC) and current wheeze and severe wheeze; as well as significant negative associations between fat (g), vitamin E from vegetables (mg), PUFA (%TEC); olive oil (g); oleic fat (%TEC); total fibre (g) and atopic eczema. For example a 10%TEC increase of calories from cereals and rice was associated with a 2.8% decrease in current wheeze and a 50 g increase of starch with a 2.7% decrease. A significant positive association was seen between soya oil and current wheeze and severe wheeze (GNP adjusted).

Discussion

This world wide analysis of food intake and symptoms of asthma, allergic rhinoconjunctivitis and atopic eczema has shown, for the 13–14 yr age group, a consistent negative association between all three atopic conditions and kCals, protein, vegetables and specific vegetable nutrients (vitamin A, Vitamin E, protein, MUFA, PUFA and saturated fats), starch, calories from cereal and rice, total fibre, protein from cereals and nuts, total seafood, all fish (fresh and frozen) and olive oil. There were no consistent associations for other foods. The video questionnaire results showed similar, but weaker, associations with the diet variables. For the 6–7 yr age group the negative and positive associations generally remained as for the older age group, but were also weaker. This may indicate that the diet of 13–14 year old children is more accurately reflected in the average per capita per day

intake of food and may account for the stronger associations seen for the older age group.

The analysis used reliable data from standardised sources (ISAAC and FAOSTAT). FAOSTAT data must be interpreted with care, however, as its accuracy depends on the reliability of the underlying statistics of population, supply and utilisation of foods and of their nutritive value. Food balance data provide direct information about the availability of foods, but only indirect information about dietary intake. Furthermore, FAOSTAT is at times, updated retrospectively when more reliable information becomes available. An example would be 1995 census data for a country becoming available in 1999, allowing legitimate changes to the data (already submitted) to be made, or perhaps food groups being separated as more accurate country data becomes available. The associations seen therefore may change slightly once the FAOSTAT data is updated.

The limitations of ecological analyses are well known [30]. In particular, an association at the country level may be due to complex biases and may not apply at the individual level, since dietary variations between countries are likely to reflect broader cultural and environmental differences and may not be directly causal. Nevertheless, an ecological approach has certain advantages in examining possible relationships between diet and disease. In so far as diet varies more widely between countries than within them, associations may be detectable when comparisons are made between different countries that would not be evident within any one country [31]. Ecological studies also avoid the regression dilution bias that arises in studies of individuals whose diet varies over time.

There was a large between country variability within some food groups, as shown in table 1, illustrating the minimum and maximum range of country food supply per capita per day. There was over a 1500 fold difference between the two countries at the extreme for olive oil consumption, a 25 fold difference for the two countries at the extremes for vegetable consumption and nearly a 3 fold difference for the two countries at the extremes for calories from cereal and rice. The between country variability of calories from cereal and rice, as illustrated in figure 1, shows the country with the lowest consumption (Germany, 21%TEC) to the country with the highest consumption (Ethiopia 72%TEC). Although the country range is relatively small, the analysis showed a significant negative association with current and severe wheeze, allergic rhinoconjunctivitis and atopic eczema.

It is striking that when adjusted for GNP, the negative association of total calories, protein, vegetables, vegetable fats and vegetable micronutrients, starch, total fibre, calories from cereal and rice, protein from cereals and nuts, total seafood, all fish and olive oil was consistent for symptoms of all three conditions, asthma, allergic rhinoconjunctivitis and atopic eczema. There was no consistent pattern for any other food category, so it seems unlikely that these findings simply reflect systematic bias or confounding by other unknown dietary factors. Do these foods have a protective effect in the expression of symptoms of these conditions? A possibility for the association seen between vegetables and vegetable micronutrients is that

this could be due to their antioxidant effects. In particular, Vitamins A and E are known antioxidants that are essential in the lung defence mechanisms against reactive oxidant propagation, inhibitor of oxidant propagation and scavenging of hydroxyl radicals and singlet oxygen [13]. These antioxidant defences may be important in reducing airway inflammation and lung permeability in response to cigarette smoke, air pollutants and ozone [13], and may also prove to be important in allergic rhinoconjunctivitis and atopic eczema. Although vitamin C may have similar properties [32], no consistent association was found in this analysis. However, it would be premature to focus on specific micronutrients at this stage. By analogy, there is clear evidence that vegetable consumption is a negatively associated cancer risk, but interventions based on specific micronutrient supplementation have been ineffective [33]. Thus, other potential mechanisms for a possible protective effect of vegetables also deserve attention. One such possibility is indicated by differences in the intestinal microflora between countries with a high and low prevalence of allergies [34] and between allergic and nonallergic children [35].

Of interest is the strong negative association between calories from cereal and rice and protein from cereal and nuts and the three atopic conditions. Throughout human development dietary patterns have evolved and now vary greatly in different parts of the world. The diet of economically developed countries and urban areas of the developing world are now relatively low in cereals, tubers and other starchy foods and relatively high in sugar, fat, protein of animal origin, salt, meat, dairy produce and alcohol. Plant based carbohydrate-rich diets have been associated with lower rates of other NLDs [9, 10, 11, 33, 36] and it is of interest that this association has been found for asthma, allergic rhinoconjunctivitis and atopic eczema. Although it is speculated that antioxidants contained in cereal, rice and vegetables may be a reason for this protective effect, other mechanisms need to be explored.

Recent exploration of PUFA and the potential for promoting allergic sensitisation and asthma [14, 16, 37], found a positive relationship. The present analysis saw a significant association between vegetable derived PUFA and decreased symptom prevalence of the three conditions, as well as vegetable derived MUFA and decreased symptom prevalence of current wheeze and atopic eczema. Similarly, a relationship between the consumption of oily fish and asthma symptoms in children [18], and fish intake and lung function [38] have been observed, although clinical studies (of fish oil supplements) have not shown the expected benefits on airway functioning [39, 40]. The present analysis showed a consistent negative association between total seafood and all fish (fresh and frozen) and the three conditions, although insignificant except for severe wheeze.

In summary, the consistent findings of a negative association between starch, calories from cereals and rice, protein from cereals and nuts and vegetables and symptoms of asthma, allergic rhinoconjunctivitis and atopic eczema, especially in the older age group, warrants further exploration. Antioxidant effects may be important, although other explanations, such as

effects on the intestinal microflora, should also be explored. There has been little exploration of the association between starchy foods and these conditions and although it is generally acknowledged that a diet containing large amounts of fruit and vegetables is associated with improved health, the association with cereal should be explored further. From this analysis, it is speculated that, if the daily per capita amount of calories from cereal and rice consumed were to be increased by 10% of total energy consumption, it may be possible to achieve a 3.2% decrease in the prevalence of current wheeze, a 0.4% decrease in severe wheeze, a 2.4% decrease in allergic rhinoconjunctivitis and a 0.6% decrease in atopic eczema. The relationship seen between the intake of cereals, starch and vegetables and symptom prevalence of asthma, allergic rhinoconjunctivitis and atopic eczema is strong enough to be explored further in strategies for prevention of these conditions. However it is likely that other nondietary factors are also of importance.

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