Associations between pre-pregnancy obesity and asthma symptoms in adolescents

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ABSTRACT

Background The high prevalence of children's asthma symptoms, worldwide, is unexplained. We examined the relation between maternal pre-pregnancy weight and body mass index (BMI), and asthma symptoms in adolescents.

Methods Data from 6945 adolescents born within the Northern Finland Birth Cohort 1986 were used. Prospective antenatal and birth outcome data, including maternal pre-pregnancy weight and BMI, and asthma symptoms in adolescent offspring at age 15–16 years, were employed. Logistic regression analyses were performed to examine the associations between relevant prenatal factors and asthma symptoms during adolescence.

Results Current wheeze (within the past year) was reported by 10.6% of adolescents, and physician-diagnosed asthma by 6.0%. High maternal pre-pregnancy BMI was a significant predictor of wheeze in the adolescents (increase per kilogram per square metre unit; 2.7%, 95% CI 0.9 to 4.4 for ever wheeze; 3.5%, 95% CI 1.3 to 5.8 for current wheeze), and adjusting for potential confounders further increased the risk (2.8%, 95% CI 0.5 to 5.1; 4.7%, 95% CI 1.9 to 7.7, respectively). High maternal pre-pregnancy weight, in the top tertile, also significantly increased the odds of current wheeze in the adolescent by 20% (95% CI 4 to 39), and adjusting for potential confounders further increased the risk (OR=1.52, 95% CI 1.19 to 1.95). Results were similar for current asthma. Furthermore, these significant associations were observed only among adolescents without parental history of atopy but not among those with parental history of atopy.

Conclusions The association demonstrated here between maternal pre-pregnancy overweight and obesity, and asthma symptoms in adolescents suggests that increase in asthma may be partly related to the rapid rise in obesity in recent years.

INTRODUCTION

Prevalence of children's asthma symptoms has increased substantially, worldwide, since the 1970s,[1–10] although international differences between countries have reduced in the last decade.[11] Up to 37% of teenagers are affected by asthma symptoms, making it one of the most common chronic diseases in childhood.[12] Absence from school and limitations in activities are some of the common consequences of asthma. In 2004, the estimated cost of asthma symptoms among children in the European Union was €3000 million, indicating that asthma in children is a substantial disease burden for society.[13]

The reasons for the rise in asthma are obscure. A difference in diagnostic criteria over time is one explanation. Partly for this reason, the International Study of Asthma and Allergies in Childhood (ISAAC) set up uniform diagnostic criteria.[14] Research has shown that both genetic susceptibility and environmental factors contribute to symptoms.[15] Genetic predisposition is unlikely to have changed over such a short period so environmental factors are more likely to play an important role in the prevalence of asthma symptoms.

The prenatal environment is of special concern because disruptions during this critical stage of development can result in structural and functional disturbances evident in later life. Prenatal exposure to maternal smoking has been found to contribute to asthma and wheeze in children beyond the effect of postnatal environmental tobacco smoke.[16 17] Nonetheless, the rise in children's asthma symptoms is unlikely to be attributable to a higher prevalence of women smoking during pregnancy as the reverse is generally true in most Western societies.[15] In contrast, maternal weight entering pregnancy has increased dramatically in the last decades[18] and has been associated with a number of negative outcomes in infants and children.[19–22] Two recent cohort studies reported an association between increasing maternal pre-pregnancy body mass index (BMI) (in kilogram per square metre) and child wheeze.[23 24] One study found the association only for 8-year-olds with a prior disposition to asthma[23] and the other examined symptoms in 18-month-old infants.[24] Two further US studies showed the relationship in 3-year-olds, but only looked at urban populations.[25 26] Therefore, we investigated whether maternal pre-pregnancy weight and BMI contribute to the risk of developing asthma symptoms in light of other prenatal and life course exposures to better understand the nature of the associations. We studied a large cohort born in Northern Finland and prospectively followed from early pregnancy until adolescence. Use of this cohort gives a powerful opportunity to examine the associations because the population is homogeneous and stable over time without any marked increase in environmental pollutants. This geographical region was encompassed by ISAAC studies, which also provided us with the opportunity to monitor possible changes in prevalence of asthma symptoms.

METHODS

The Northern Finland Birth Cohort 1986 (NFBC1986) consists of all births between 1 July 1985 and 30 June 1986 in the two northernmost provinces of Finland, Oulu and Lapland, totalling 9432 live births (response rate: 99%). The purpose was to prospectively study medical and psychological health outcomes. The ethics committee of Northern Ostrobotnia Hospital District approved the study, and both parents and adolescents gave written informed consent.

Pregnant women were recruited at their first prenatal visit on the 12th gestational week when a questionnaire on maternal demographics, social background, education level, disease history, and lifestyle including parental smoking was distributed. Women returned the form by 24th gestational week if still pregnant. Women reported smoking status for themselves and the expectant father. Data from official medical records, recorded by midwives at first antenatal visit, included maternal pre-pregnancy weight, height, and disease history for both parents. During the visit, women reported their weight before pregnancy, 38% stated their height, but the rest were measured. Pre-pregnancy BMI before was calculated (in kilogram per square metre). Data on birth outcomes (eg, birth weight and gender) were transferred to the research database at the time of delivery.

We obtained self-report data on asthma symptoms from adolescents aged 15–16 years including questions drawn from the ISAAC questionnaire. The main outcome variables 'ever wheeze', 'current wheeze', 'wheeze severity', 'ever asthma', and 'current asthma' were derived from the questions 'Have you ever had asthma?', 'Have you ever had wheezing or whistling in the chest?' (No; Yes, in the past 12 months; Yes, but not in the past 12 months), and How often have you had episodes of wheezing respiration during the past 12 months? (never; 1–3 times; 4–12 times; more that 12 times). The last question was used to derive the severity of wheezing, and 'current' was defined as having had symptoms in the past 12 months.

Potential confounders were identified by examining the association between each exposure variable, and adolescents' asthma symptoms, as well as maternal pre-pregnancy weight. The significant confounders were social class at birth, marital status at birth, maternal education, maternal asthma, birth weight, parental smoking during gestation, and adolescents' BMI at age 15 years, which have been established.[27] We tested and found that adolescents' current smoking or gender did not confound the associations.

Questionnaire to parents of adolescents aged 15 years included questions on biological mothers' and fathers' history of asthma, allergic rhinitis, and eczema using the question 'Have any of the following been diagnosed in the biological mother/father?' which identified parental history of atopy.

We received completed questionnaires from 7344 (response rate: 80%) adolescents, but some denied permission to use the responses for research, resulting in a sample of 6945. There were no differences in asthma and wheeze characteristics between adolescents who denied permission to use the responses and those who agreed.

Statistical analysis

We calculated the prevalence of asthma and wheezing in order to compare our findings with the previous results from the ISAAC done in the same geographical area. Logistic regression was used to investigate associations between prenatal factors (exposure variables) and adolescents' wheezing or asthma. The main outcomes were whether adolescents had 'ever' or 'current' asthma or wheeze and current wheeze severity. The results are reported for wheezing, in the main paper (and for asthma in supplementary tables) to facilitate comparability with other studies. The symptoms are more comparable indicators of respiratory disorder because of varying diagnostic criteria of the asthma. We performed unadjusted and adjusted analyses, and further stratified the data by parental history of atopy to explore potential interactions. Covariates in the regression models were all categorical except for birth weight and adolescents' BMI at age 15 years (continuous). The severity of adolescents' wheezing in the past year was used in ordinal regression where the categories were coded as 0=never, 2=1–3 times, 8=4–12 times, 14=more than 12 times. The analyses were conducted by SP using SPSS V.18.0.

RESULTS

At age 15–16 years, the prevalence of 'ever wheeze' and 'current wheeze' was 20.4% and 10.6%, respectively, and prevalence of 'ever asthma' was 11.5% (10.6% when confirmed by a doctor), and 6.0% had 'current asthma' (supplementary table 1). The association between reported doctor-diagnosed and self-reported ever asthma was very strong (χ^2 (1)=4005.5, p<0.0005), with 96.0% of doctor-diagnosed was also self-reported and 77.0% of self-reported was also doctor-diagnosed.

The demographics, history of allergies/asthma, smoking exposure, and maternal pre-pregnancy weight were examined in relation to asthma symptoms. There were no differences in the characteristics (sex, region, socioeconomic status at birth) of adolescents with or without missing data (not shown).

Table 1 shows the prevalence and unadjusted ORs of wheeze associated with each exposure variables independently. The prevalence and ORs of asthma are shown in supplementary table 2. Overall, there were a greater number of significant associations with wheeze than with asthma. Boys had a significantly lower risk of current and ever wheeze than girls (OR=0.70, 95% CI 0.60 to 0.82; OR=0.81, 95% CI 0.72 to 0.91, respectively) but not statistically significantly for asthma. We observed a significant quadratic effect in the OR (p=0.036), with increased risk at very low and very high birth weights compared to normal birth weight. Being a single mother also significantly increased the risk of current and ever wheeze (OR=1.69, 95% CI 1.19 to 2.39 and OR=1.60, 95% CI 1.21 to 2.13, respectively). A maternal and paternal history of asthma and allergy/eczema was very strongly associated with adolescents' current and ever wheeze, and even stronger associations were observed for current and ever asthma. Exposure to smoking whether by parents at gestation or currently by the adolescent was associated with significantly increased risk of wheeze.

High maternal pre-pregnancy weight (in the top tertile) was significantly associated both with wheeze (table 1) and with asthma (supplementary table 2) in adolescents (OR=1.20, 95% CI 1.04 to 1.39 for ever wheeze; OR=1.35, 95% CI 1.11 to 1.64 for current wheeze; OR=1.28, 95% CI 1.06 to 1.54 for ever asthma; OR=1.30, 95% CI 1.01 to 1.67 for current asthma). When maternal weight was treated as a continuous variable, a highly significant association emerged with prevalence of ever wheeze (0.7% per kg/m^2, 95% CI 0.1 to 1.3) and of current wheeze (1.0% per kg/m^2, 95% CI 0.3 to 1.8). Likewise, maternal pre-pregnancy BMI was highly significantly associated with prevalence of wheeze and asthma in adolescents (2.7% per kg/m^2, 95% CI 0.9 to 4.4 for ever wheeze; 3.5%, 95% CI 1.3 to 5.8 for current wheeze; 3.0%, 95% CI 0.8 to 5.2 for ever asthma; 2.9%, 95% CI 0.0 to 5.8 for current asthma).

Associations between maternal pre-pregnancy weight and adolescents' wheeze and asthma were adjusted for potential

Table 1 Prevalence and unadjusted ORs for adolescents' wheeze (self-reported) at age 15 years in relation to demographic, adolescent, and parental factors

	Population distribution (%)	Ever wheeze		Current wheeze	
		%	OR (95% CI)	%	OR (95% CI)
Background and demographics					
Gender (n=9065)					
Girls (reference)	48.5	22.0		12.2	
Boys	51.5	18.7	0.81 (0.72 to 0.91)*	8.9	0.70 (0.60 to 0.82)*
Birth weight, g (n=9066)					
<2500	3.2	22.6	1.11 (0.80 to 1.55)	12.0	1.13 (0.74 to 1.73)
2500–2999	8.7	19.4	0.92 (0.73 to 1.15)	11.4	1.07 (0.81 to 1.42)
3000–3499	31.0	19.5	0.92 (0.79 to 1.06)	9.7	0.89 (0.73 to 1.07)
3500–3999 (reference)	37.2	20.8		10.8	
4000–4499	16.4	20.5	0.98 (0.83 to 1.17)	11.2	1.04 (0.83 to 1.31)
≥4500	3.5	24.3	1.22 (0.89 to 1.67)	11.5	1.08 (0.71 to 1.64)
Socioeconomic status at birth (n=8017)					
I. Professional/entrepreneur	17.8	20.8	1.03 (0.87 to 1.23)	10.2	0.96 (0.76 to 1.21)
II. Skilled non-manual	15.5	17.4	0.82 (0.68 to 1.00)*	7.9	0.72 (0.56 to 0.94)*
III. Skilled manual (reference)	40.9	20.4		10.5	
IV. Unskilled/apprentice	5.5	25.0	1.30 (0.98 to 1.73)	13.2	1.29 (0.90 to 1.85)
Farmer	9.0	19.3	0.94 (0.74 to 1.18)	10.7	1.02 (0.75 to 1.37)
Other: (student/at home/sick pension/unemployed)	11.3	22.4	1.13 (0.92 to 1.39)	12.8	1.25 (0.96 to 1.63)
Marital status at birth (n=9037)					
Married (reference)	80.5	19.9		10.3	
Cohabitation	14.3	21.5	1.10 (0.93 to 1.31)	11.1	1.08 (0.86 to 1.36)
Single	4.2	28.5	1.60 (1.21 to 2.13)*	16.3	1.69 (1.19 to 2.39)*
Divorced/widow	0.9	24.1	1.28 (0.68 to 2.39)	7.4	0.70 (0.25 to 1.93)
Maternal education at child's birth (n=7839)					
Primary school (reference)	26.6	20.9		10.2	
Vocational school	44.7	20.5	0.98 (0.83 to 1.14)	10.6	1.05 (0.85 to 1.29)
Matriculation	20.9	19.8	0.94 (0.78 to 1.13)	10.0	0.98 (0.76 to 1.25)
University	7.8	16.7	0.76 (0.58 to 0.99)*	8.4	0.81 (0.57 to 1.16)
Family history of atopy					
Maternal asthma (n=6225)					
No (reference)	92.6	18.9		9.8	
Yes	7.4	36.4	2.45 (1.99 to 3.03)*	18.3	2.06 (1.58 to 2.68)*
Paternal asthma (n=6181)					
No (reference)	93.6	19.4		9.9	
Yes	6.4	34.3	2.17 (1.73 to 2.73)*	19.7	2.23 (1.69 to 2.94)*
Maternal allergy/eczema (n=6264)					
No (reference)	69.7	17.8		9.3	
Yes	30.3	26.4	1.66 (1.45 to 1.90)*	13.2	1.49 (1.25 to 1.77)*
Paternal allergy/eczema (n=6155)					
No (reference)	80.0	19.1		10.0	
Yes	20.0	24.8	1.40 (1.20 to 1.63)*	12.4	1.27 (1.04 to 1.56)*
Exposure to smoking					
Parents smoking during gestation (n=8126)					
Neither parent (reference)	52.4	18.6		9.0	
One parent	31.0	21.5	1.20 (1.05 to 1.37)*	11.9	1.37 (1.14 to 1.64)*
Both parents	11.7	23.8	1.36 (1.13 to 1.65)*	13.0	1.51 (1.18 to 1.94)*
Adolescents current smoking, at age 15 years (n=4615)					
No (reference)	49.1	17.0		7.7	
Occasionally	21.0	24.1	1.55 (1.29 to 1.87)*	12.3	1.69 (1.32 to 2.16)*
Once/week or more	29.9	31.9	2.29 (1.95 to 2.68)*	21.1	3.21 (2.62 to 3.93)*
Maternal and adolescent weight					
Pre-pregnancy weight (n=8874)					
First tertile 35–54 (reference)†	32.3	19.1		9.1	
Second tertile 55–61	33.0	19.9	1.05 (0.91 to 1.22)	10.5	1.17 (0.96 to 1.43)
Third tertile 62–130	34.7	22.1	1.20 (1.04 to 1.39)*	12.0	1.35 (1.11 to 1.64)*
Continuous predictor (% per kg)		0.7% (0.1% to 1.3%) p=0.023*		1.0% (0.3% to 1.8%) p=0.009*	
Pre-pregnancy BMI (n=8838)					
<19 (underweight)	7.4	19.8	0.91 (0.72 to 1.16)	10.1	1.07 (0.79 to 1.45)
19–24.9 (normal) (reference)	75.3	18.4		10.7	
25–29.9 (overweight)	13.3	24.5	1.31 (1.10 to 1.55)*	12.0	1.22 (0.97 to 1.53)

Continued

Table 1 Continued

	Population distribution (%)	Ever wheeze		Current wheeze	
		%	OR (95% CI)	%	OR (95% CI)
≥30 (obese)	3.8	20.9	1.07 (0.78 to 1.48)	14.5	1.52 (1.04 to 2.21)*
Continuous predictor \(% per BMI unit)		2.7% (0.9% to 4.4%) p=0.002*		3.5% (1.3% to 5.8%) p=0.002*	
Adolescent BMI at age 15 yrs (n=6669)					
Continuous predictor (% per BMI unit)		4.8% (2.9% to 6.6%) p<0.0005*		4.8% (2.4% to 7.1%) p<0.0005*	

*95% CI for OR is significant.
†Tertile cut-offs, calculated from the whole-study population.

confounding factors, social class at birth, mother's marital status at birth, maternal education, maternal asthma, birth weight, parental smoking during gestation, and adolescents' BMI at age 15 years. Table 2 shows that a high maternal pre-pregnancy weight in top tertile was significantly associated with an increase in the risk of ever wheeze, current wheeze, and severity of current wheeze in adolescents after adjusting for confounders (OR=1.22, 95% CI 1.01 to 1.47; OR=1.52, 95% CI 1.19 to 1.95; OR=1.47, 95% CI 1.19 to 1.81, respectively). The OR for maternal pre-pregnancy BMI, used as a continuous variable, was also highly significant (2.8% per kg/m^2, 95% CI 1.5 to 5.1; 4.7%, 95% CI 1.9 to 7.7; 2.7% 95% CI 0.3 to 5.2, respectively).

The relationship between maternal pre-pregnancy weight and BMI, with adolescents' wheeze, stratified by parental history of atopy (an index of genetic predisposition), was investigated. Table 3 shows that high maternal weight (in top tertile) or high BMI (≥30, obese) significantly increased risk of current and ever wheeze among adolescents, with non-atopic parents, but there was no risk of current or ever wheeze among adolescents with atopic parents, adjusting for confounding factors. There was also a clear increasing trend in the ORs as maternal size increased among the non-atopic parents.

The population attributable risks for ever and current wheeze by the top two tertiles of maternal pre-pregnancy weight were 6.3% and 13.5%, and by overweight/obesity 3.4% and 3.9%, respectively.

DISCUSSION

In this population-based cohort of adolescents followed prospectively from the prenatal period, many early life factors were associated with later asthma and wheeze symptoms up to the age of 15–16 years. We found strong associations between high maternal pre-pregnancy weight and BMI, that is, overweight and obesity, and the risk of having wheeze or asthma. The association between maternal pre-pregnancy weight and BMI with adolescents' wheeze was observed only among those without parental history of atopy, but not among those with this history, suggesting that genetic predisposition is unlikely to explain these findings. This is in contrast to a previous smaller study of 8-year-olds.[23] Our novel results are important from a public health point of view, suggesting that maternal pre-pregnancy overweight and obesity may be a new target for prevention of adolescents' asthma and wheeze if the associations are causal.

The prevalence of women entering pregnancy who are overweight or obese and the prevalence of asthmatic symptoms in children have increased substantially in the past 2–3 decades. However, this study cannot conclude whether these trends are causally related as relatively small proportion of wheeze prevalence can be accounted for maternal obesity. Instead, the results of this large-scale and long-term prospective study show strong associations still present in adolescence. Thus, our study extends previous findings concerning infants[24] and children[23] and suggests that the associations are long lasting. Further because maternal and child weight are correlated[28] and previous studies have shown that obesity in children is associated with increased prevalence of current asthma symptoms,[29–31] it is possible that child weight may account for the association but here the adjustment for adolescents' current BMI did not remove the associations. Poor birth outcomes are also associated with high maternal pre-pregnancy weight and asthma in children, but adjustment for birth weight and parental asthma did not diminish the association.

We speculate that higher maternal weight may interfere with normal fetal development and give rise to asthma symptoms later in life. Altered metabolic, hormonal, or ovarian functions[32] among overweight and obese women are linked to reproductive

Table 2 Adjusted ORs for maternal pre-pregnancy obesity and adolescents' wheeze at age 15 years

	Adjusted* OR (95% CI), p Value		
Predictors	Ever wheeze	Current wheeze	Current wheeze severity†
Maternal pre-pregnancy weight‡ (n=8874)			
First tertile 35–54 kg	Reference	Reference	Reference
Second tertile 55–61 kg	1.08 (0.90 to 1.29), p=0.44	1.28 (0.99 to 1.64), p=0.06	1.41§ (1.15 to 1.73), p=0.001
Third tertile 62–130 kg	1.22§ (1.01 to 1.47), p=0.04	1.52§ (1.19 to 1.95), p=0.001	1.47§ (1.19 to 1.81), p<0.0005
Continuous predictor (% per kg)	0.6%§ (0.1% to 1.7%), p=0.03	1.5%§ (0.5% to 2.5%), p=0.004	0.9%§ (0.0% to 1.8%), p=0.04
Maternal pre-pregnancy BMI (n=8838)			
19–24.9 (normal)	Reference	Reference	Reference
<19 (underweight)	0.80 (0.58 to 1.09), p=0.15	0.87 (0.57 to 1.30), p=0.49	0.77 (0.54 to 1.08), p=0.13
25–29.9 (overweight)	1.18 (0.95 to 1.47), p=0.13	1.13 (0.85 to 1.50), p=0.41	1.10 (0.86 to 1.40), p=0.44
≥30 (obese)	0.99 (0.66 to 1.48), p=0.94	1.54§ (0.97 to 2.44), p=0.07	1.24 (0.82 to 1.90), p=0.31
Continuous predictor (% per BMI unit)	2.8%§ (0.5% to 5.1%), p=0.015	4.7%§ (1.9% to 7.7%), p=0.001	2.7%§ (0.3% to 5.2%), p=0.03

*Adjusted for social class at birth, marital status at birth, maternal education, maternal asthma, birth weight, parental smoking during gestation, and adolescent BMI at age 15 years.
†Severity of current wheeze, using ordinal regression, coding 0=never, 2=1–3 times, 8=4–12 times, 14=more than 12 times.
‡Tertile cut-offs, calculated from the whole-study population.
§95% CI for OR significant at least at p<0.05.

Table 3 Adjusted ORs for maternal pre-pregnancy obesity and adolescents' wheeze at age 15 years, stratified by parental history of atopy

	Adjusted* OR (95% CI), p Value			
	Ever wheeze		Current wheeze	
Factors	No parental atopy	Parental atopy	No parental atopy	Parental atopy
Maternal pre-pregnancy weight† (n=8874)				
First tertile 35–54 kg	Reference	Reference	Reference	Reference
Second tertile 55–61 kg	1.27 (0.95 to 1.68), p=0.10	0.95 (0.74 to 1.22), p=0.70	1.78‡ (1.20 to 2.64), p=0.004	0.97 (0.69 to 1.37), p=0.88
Third tertile 62–130 kg	1.51‡ (1.13 to 2.02), p=0.005	1.02 (0.80 to 1.31), p=0.87	2.00‡ (1.34 to 2.98), p=0.001	1.25 (0.90 to 1.74), p=0.19
Maternal pre-pregnancy BMI (n=8838)				
19–24.9 (normal)	Reference	Reference	Reference	Reference
<19 (underweight)	2.19‡ (1.19 to 4.02), p=0.012	1.08 (0.73 to 1.61), p=0.70	1.88 (0.86 to 4.12), p=0.11	0.99 (0.59 to 1.66), p=0.97
25–29.9 (overweight)	2.97‡ (1.52 to 5.82), p=0.001	1.13 (0.71 to 1.81), p=0.61	2.17 (0.91 to 5.18), p=0.08	1.12 (0.61 to 2.06), p=0.72
≥30 (obese)	3.51‡ (1.60 to 7.68), p=0.002	0.59 (0.28 to 1.27), p=0.18	4.03‡ (1.54 to 10.54), p=0.004	1.02 (0.41 to 2.49), p=0.97

*Adjusted for social class at birth, marital status at birth, maternal education, maternal asthma, birth weight, parental smoking during gestation, and adolescent BMI at age 15 years.
†Tertile cut-offs, calculated from the whole-study population.
‡95% CI for OR significant at least at p<0.05.

dysfunction that may affect the developing fetus. In both pregnant and non-pregnant women, increasing BMI is related to increasing levels of leptin.[33] Leptin receptors are present in the fetal lung and may contribute to lung development in utero.[34] Leptin is also involved in immune function, and it has been hypothesised that high pre-pregnancy BMI might contribute to the child's risk of developing atopy[35] through epigenetic mechanisms.

There is strong evidence that smoking during pregnancy adversely influences fetal development of the respiratory system and hence reduces the growth of lung function later in life and increases the risk of asthma in children.[36] A cohort study in Finland has shown that maternal smoking in pregnancy increases the risk of asthma during the first 7 years of life, and only a small fraction of the association was mediated through reduced fetal growth.[37] In line with these results, we found that adjusting for established confounders did not attenuate the strong association between pre-pregnancy overweight and obesity, and current wheeze in adolescents.

As in all epidemiological studies, information or selection bias cannot be ruled out. The response rates were very high in our study, and parental awareness of respiratory symptoms is unlikely to have changed in Finland, although treatment has improved in northern Finland, as reported in the 10-year asthma programme.[38] These facts imply that the effects of information or selection bias in this study are likely to be modest.

Our study has strong design features in that it is based on a large homogeneous population that was studied longitudinally using prospective data. Further the endpoint was assessed using standardised questions from ISAAC facilitating comparability of results over time and across studies. Even though prevalence of asthma is low compared to other European countries,[39] asthma symptoms in adolescents have increased substantially in Northern Finland, which provided an opportunity to study environmental factors.

Our research highlights the importance of the prenatal environment for programming the risk of asthma symptoms later in life. Our results show for the first time a link between maternal pre-pregnancy overweight and obesity, and risk of asthma symptoms in adolescent offspring, where the increase in risk was seen only among adolescents without parental predisposition. These lifestyle characteristics, for example, maternal pre-pregnancy weight, are amenable to change and if these associations are causal, prevention or amelioration would be achievable. Efforts to maintain maternal weight within a normal range could make a positive impact on children's asthma symptoms.

What is already known on this subject

- The increased and high prevalence of children's asthma symptoms, worldwide, is unexplained.
- Rapidly changing environmental factors that go beyond genetic predisposition are likely to explain the increase in asthma prevalence.

What this study adds

- Prenatal exposure to maternal overweight and obesity is an important risk of asthma symptoms later in life through to adolescence, after controlling for numerous relevant confounders.
- Our results suggest that maternal overweight and obesity prior to pregnancy may programme the risk of asthma symptoms in their adolescent offspring and be a new target for prevention of adolescents' asthma and wheeze if the associations are causal.

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