

REGULAR ARTICLE

Overweight does not increase asthma risk but may decrease allergy risk at school age after infantile bronchiolitis

Virpi Sidoroff¹, Mari K Hyvärinen¹, Eija Piippo-Savolainen¹, Matti Korppi (matti.korppi@uta.fi)²

1. Department of Pediatrics, University of Eastern Finland and Kuopio University Hospital, Kuopio, Finland

2. Pediatric Research Centre, Tampere University and University Hospital, Tampere, Finland

Keywords

Allergy, Asthma, Bronchiolitis, Obesity, Overweight

Correspondence

Prof. Matti Korppi, Pediatric Research Center,
Tampere University and University Hospital, FM-3
building, 33014 Tampere University, Finland.
Tel: +358-3-35539407 |
Fax: +358-3-35518420 |
Email: matti.korppi@uta.fi

Received

24 May 2011; revised 22 July 2011;
accepted 3 August 2011.

DOI:10.1111/j.1651-2227.2011.02439.x

ABSTRACT

Aim: Increasing evidence suggests that overweight children are at increased risk of asthma. The association between weight gain and allergy is more complex. The aim was to evaluate the association between overweight or obesity and asthma, allergy, bronchial reactivity or atopic sensitization at school age in children with bronchiolitis in infancy.

Subjects and methods: Eighty-one children hospitalized for bronchiolitis at <24 months of age attended control visits at 7.2 and 12.3 years of ages. The visits consisted of medical examinations, weight and height measurements, body mass index (BMI) calculations, skin prick tests and exercise challenge tests. BMI >1.3 SD from age- and gender-specific references meant overweight and BMI >2.0 SD obesity.

Results: Current or previous overweight or obesity did not increase the risk of asthma, allergy, bronchial reactivity or atopic sensitization at 7.2 or 12.3 years of age. Previous and current obesity decreased the risk of atopic dermatitis, and current overweight and obesity decreased the risk of sensitization to outdoor allergens at 12.3 years of age.

Conclusion: Previous or current overweight does not increase asthma or allergy risk but current obesity may decrease allergy risk at school age after bronchiolitis in infancy.

INTRODUCTION

The prevalence of overweight and obesity among children, adolescents and young adults has reached epidemic proportions in Western countries, concomitantly with the asthma and allergy epidemics (1,2). Pediatric cross-sectional studies have reported a link between asthma and overweight (2,3), but the impact of overweight on asthma risk has been rather low (4). Some studies have documented an association between obesity and asthma symptoms (5–10), and some between obesity and parent-reported asthma (11,12). When airway reactivity has been studied objectively, the results have mainly been negative (2,5–7). A recent meta-analysis revealed an association between emerging overweight and subsequent onset of asthma in children (4). The few studies published on the association between weight gain and allergy have failed to confirm an association between overweight and allergic disease or atopic sensitization (5,7,13–16). Opposite to the expectations, underweight school

children have had more allergic rhinitis (AR) (10) and atopic sensitization (16).

In our long-term prospective follow-up study, children hospitalized for wheezing at <24 months of age have attended control visits on average at 4.0, 7.2 and 12.3 years of age (17–19). The weight and height of the children and the presence of asthma and allergic diseases were evaluated at all visits. In addition, atopic sensitization was studied by skin tests and bronchial reactivity by exercise challenge at school age.

The aim of this study was to evaluate the association between weight status and asthma or allergy at preschool and school age in former bronchiolitis patients, with a special focus on the influence of emerging overweight. In addition, we studied the association between weight status and atopic sensitization or bronchial reactivity.

Abbreviations

AD, Atopic dermatitis; AR, Allergic rhinitis; BHR, Bronchial hyper-reactivity; BMI, Body mass index; BMI-SDS, Body mass index standard deviation score (z-score); CI, Confidence interval; ECT, Exercise challenge test; OR, Odds ratio; RSV, Respiratory syncytial virus; SPT, Skin prick test.

Key notes

- Overweight or obesity at any level does not increase the risk of asthma or bronchial hyper-reactivity at school age after bronchiolitis in infancy.
- Obesity (BMI >2.0 SD corresponding BMI >30 in young adults) may decrease the risk of allergy and atopic sensitization at school age after bronchiolitis in infancy.

PATIENTS AND METHODS

Study design

As described earlier in detail (20), 100 infants hospitalized for wheezing at <24 months of age were recruited into this prospective follow-up study in 1992–1993. The baseline data were collected by interviewing the parents during hospitalization using a structured questionnaire, including questions on the history of wheezing and allergy in the children.

Seven common respiratory viruses, including respiratory syncytial virus (RSV), were studied by antigen detection in nasopharyngeal aspirates obtained during hospitalization and by antibody assays in paired sera (20). Later, polymerase chain reaction for RSV and rhinoviruses was studied in frozen nasopharyngeal aspirates.

After hospitalization, 2–3 study visits depending on the age of the child on admission were arranged before the age of 24 months (20). Thereafter, three follow-up visits were organized at the median ages of 4.0, 7.2 and 12.3 years (17–19).

The presence of doctor-diagnosed asthma, parent-reported episodes of wheezing, night cough and prolonged cough after the previous control visit and the use of continuous anti-inflammatory medication for asthma were asked at all controls visits. At the 7.2- and 12.3-year control visits, asthma was considered to be present if the child was on continuous anti-inflammatory medication for asthma or if the child had both symptoms presumptive for asthma during the preceding 12 months and a pathological result in the exercise challenge test (ECT) (18,19). The exercise constituted of free running outdoors for 8 min at the heart rate >80% of the predicted maximum, monitored by telemetry (Polar Sport Tester; Polar Elektro Ltd, Kempele, Finland) at 1-min intervals. Flow-volume spirometry (FVS; Medikro spirometer, Kuopio, Finland) was measured before running, and 10 min (in the 7.2-year study) or 5, 10 and 15 min (in the 12.3-year study) after the exercise (18,19). Forced expiratory volume in 1 sec (FEV₁) changes were calculated using the equation: [(pre-exercise FEV₁–post-exercise FEV₁)/pre-exercise FEV₁] × 100%. Bronchial hyper-reactivity (BHR) was defined as >12% decrease in FEV₁.

The presence of doctor-diagnosed atopic dermatitis (AD) and AR during the preceding 12 months was asked and recorded, and skin prick tests (SPT) were performed at both control visits (18,19). The outdoor allergens birch, timothy grass and mugwort pollens, and the indoor allergens cat and dog epithelial dander and home dust mites *Dermatophagoides pteronyssinus* and *D. farinae* were tested at both visits, and in addition, common alder and meadow grass pollens, horse and cow epithelial dander and the spores of the moulds *Cladosporium herbarum* and *Alternaria alternata* were tested at 12.3 years of age (19). The reactions with a diameter of at least 3 mm were defined to be positive, and no reactions were allowed for negative controls. Atopic sensitization was defined as the presence of at least one positive result in SPTs to indoor or outdoor allergens.

Ninety-two children completed the first-year follow-up in infancy, 83 attended the control visits at 4.0 years, 82 at 7.2 years and 81 at 12.3 years of age (17–19).

Weight and height measurements

Weights and heights of all attending study subjects were measured at all control visits. Body mass index (BMI) was calculated using the equation: weight (kg)/height (m)². BMI standard deviation score (BMI-SDS) was assessed by an obesity calculator (available at: <http://www.phsim.man.ac.uk>) using British growth references. BMI-SDS >1.3 corresponds BMI >25 in 18-year-old young adults and means overweight, and BMI-SDS >2.0 corresponds BMI >30 in 18-year-old young adults and means obesity (21).

Statistics

The data were analysed by logistic regression using SPSS 11.5 software (SPSS Inc., Chicago, IL, USA). As published earlier (17–19), the presence of AD in infancy increased the asthma risk at all follow-up visits at median ages of 4.0, 7.2 and 12.3 years. In addition, asthma risk was higher if bronchiolitis was caused by other viruses than RSV and if the child was admitted at >12 months of age. Therefore, the association between weight status and asthma or BHR was analysed as adjusted for AD in infancy and RSV aetiology of bronchiolitis. In many previous studies, the association between weight status and allergy and/or atopic sensitization has been dependent on gender (22–24). Therefore, the association between weight status and allergy or atopic sensitization was analysed as adjusted for gender and RSV aetiology of bronchiolitis. The presence of AD in infancy had so a strong interaction with later allergy and atopic sensitization that AD was not included in the analyses. The age on admission, although interacting with viral aetiology of bronchiolitis, was included in all analyses as a continuous variable.

Ethics

The study was approved by the joint Research Ethics Committee of Kuopio University and Kuopio University Hospital. Informed written consent was obtained from the parents of the children.

RESULTS

Overweight (BMI-SDS >1.3) was present in 23.2% of the children at age 7.3 years and in 33.3% at age 12.3 years. The proportion of obese children (BMI-SDS >2.0) was 8.6% at age 7.3 years and 19.8% at age 12.3 years.

Asthma was present in 33(40.2%) study subjects at 7.2 years of age, with no significant association with overweight and obesity (Table 1). Likewise, there were no significant associations between BHR, AD, AR or atopic sensitization and overweight or obesity (Table 1).

Asthma was present in 31(38.3%) study subjects at 12.3 years of age, with no significant association with overweight and obesity (Table 2). Again, there were no significant associations between BHR, AR or overall atopic sensitization and overweight or obesity (Table 2). However, obesity was associated with a decreased risk of AD (Table 2).

When sensitization to indoor and outdoor allergens at school age was analysed separately, an adjustment with the presence of sensitization at 7.2 years of age was added in

Table 1 Asthma and allergy in relation to overweight and obesity in 82 study children at 7.2 years of age

Asthma or allergy	Overweight*		OR (95% CI)	Obesity†		OR (95% CI)
	Yes (N = 19)	No (N = 63)		Yes (N = 7)	No (N = 75)	
Asthma (N = 33)	8	25	1.14 (0.35–3.65) [‡]	2	31	0.61 (0.10–3.81) [‡]
Bronchial hyper-reactivity [§] (N = 13)	4	9	1.41 (0.36–5.51) [‡]	2	11	2.33 (0.38–14.13) [‡]
Atopic dermatitis (N = 42)	9	33	0.86 (0.29–2.37) [¶]	3	39	0.68 (0.14–3.25) [¶]
Allergic rhinitis (N = 33)	6	27	0.46 [¶] (0.15–1.47)	2	31	0.547 [¶] (0.10–3.11)
Atopic sensitization** (N = 38)	11	27	1.32 (0.42–4.18) [¶]	4	34	1.70 (0.31–9.16) [¶]

OR, odds ratio; CI, confidence interval; RSV, respiratory syncytial virus; SPT, skin prick test.

*Overweight BMI-SDS >1.3.

†Obesity BMI-SDS >2 (body mass index standard deviation score = z-score).

[‡]Adjusted for age, atopic dermatitis in infancy and RSV aetiology of bronchiolitis.

[§]FEV1 decrease >12% in the exercise challenge.

[¶]Adjusted for age, gender and RSV aetiology of bronchiolitis.

**At least one positive reaction in SPTS: 37 to indoor and 28 to outdoor allergens.

Table 2 Asthma and allergy in relation to overweight and obesity in 81 children at 12.3 years of age

Asthma or allergy	Overweight*		OR (95% CI)	Obesity†		OR (95% CI)
	Yes (N = 27)	No (N = 54)		Yes (N = 16)	No (N = 65)	
Asthma (N = 31)	12	19	2.05 (0.70–5.60) [‡]	8	23	2.81 (0.82–9.64) [‡]
Bronchial hyper-reactivity [§] (N = 17)	7	10	1.76 (0.51–6.07) [‡]	2	15	0.59 (0.11–3.16) [‡]
Atopic dermatitis (N = 26)	8	18	0.87 (0.30–2.50) [¶]	1	25	0.09 (0.01–0.76) [¶]
Allergic rhinitis (N = 27)	10	17	1.18 (0.43–3.25) [¶]	4	23	0.63 (0.18–2.23) [¶]
Atopic sensitization** (N = 50)	14	36	0.53 (0.20–1.45) [¶]	9	41	0.74 (0.24–2.31) [¶]

OR, odds ratio; CI, confidence interval; RSV, respiratory syncytial virus.

*Overweight BMI-SDS >1.3.

†Obesity BMI-SDS >2 (body mass index standard deviation score = z-score).

[‡]Adjusted for age, atopic dermatitis in infancy and RSV aetiology of bronchiolitis.

[§]FEV1 decrease >12% in the exercise challenge.

[¶]Adjusted for age, gender and RSV aetiology of bronchiolitis.

**At least one positive reaction: 40 to indoor and 42 to outdoor allergens.

the multivariate model. Current overweight and obesity at 12.3 years of age were associated with a decreased risk of sensitization to outdoor allergens (OR 0.10, 95%CI 0.02–0.52 for overweight; OR 0.03, 95%CI 0.00–0.27 for obesity).

Weight and height data were available in 74 children from both the 7.2- and 12.3-year visits. The great majority, 15/16 (93.8%), of the children who were overweight or obese at age 7.2 years were overweight or obese also at age 12.3 years, and overweight or obesity developed in 9/58 (15.5%) of those who were normal weight at age 7.2 years. There were no significant associations between overweight or obesity at 7.2 years of age and asthma, BHR, AD, AR or atopic sensitization at 12.3 years of age (Table 3). Overweight (6.0%) and obesity (3.6%) were so rare at age 4.0 years that the analyses on their relation to outcomes at 7.2 years of age were not reliable.

DISCUSSION

There are three main results in the present study. First, overweight and obesity increased constantly by age during the post-bronchiolitis follow-up until the median age of 12.3 years. Second, no association was found between previous

or current overweight or obesity and asthma or BHR at 7.2 or 12.3 years of age. However, overweight at 7.2 and 12.3 years of age was associated with decreased FEV₁/FVC (forced vital capacity), and overweight and obesity at 7.3 years of age were predictive for decreased FEV₁/FVC at 12.3 years of age in the same cohort, as published recently (25). And third, preliminary evidence was found that obesity (BMI >2.0 SD corresponding BMI >30 in young adults) may decrease the risk of allergy at late school age.

Three cross-sectional epidemiological studies have documented an association between excessive weight gain and asthma in children. Bibi et al. (6) analysed questionnaire data of 5984 Israeli children, supplemented by lung function tests. Obesity by BMI >95% was associated with wheezing symptoms, bronchodilator use and asthma diagnoses but not with BHR. Kusunoki et al. (10) analysed questionnaire data of 50 086 Japanese children. Obesity by BMI >95% was associated with an increased prevalence of asthma. Belamrich et al. (26) monitored 1322 asthmatic children aged 4–9 years from eight American cities by telephone interviews every 3 months for a 9-month period. Obesity by BMI >95% was associated with wheezing symptoms, use of medicines and need of emergency room visits, but not with decreased

Table 3 Asthma and allergy in 74 children at 12.3 years of age in relation to overweight and obesity at 7.2 years of age

Asthma, allergy and weight status at 12.3 years of age	Overweight at 7.2 years of age*			Obesity at 7.2 years of age†		
	Yes (N = 16)	No (N = 58)	OR (95% CI)	Yes (N = 6)	No (N = 68)	OR (95% CI)
Asthma (N = 28)	7	21	1.98 (0.56–7.07) [‡]	1	27	0.33 (0.03–3.53) [‡]
Bronchial hyper-reactivity [§] (N = 17)	3	14	0.73 (0.16–3.26) [‡]	0	17	
Atopic dermatitis (N = 24)	3	21	0.87 (0.301–2.503) [¶]	1	23	0.09 (0.01–0.76) [¶]
Allergic rhinitis (N = 24)	4	20	1.18 (0.43–3.25) [¶]	2	22	0.63 (0.18–2.23) [¶]
Atopic sensitization** (N = 45)	8	37	0.53 (0.20–1.45) [¶]	3	42	0.74 (0.24–2.31) [¶]

OR, odds ratio; CI, confidence interval; RSV, respiratory syncytial virus.

*Overweight BMI-SDS >1.3.

†Obesity BMI-SDS >2 (body mass index standard deviation score = z-score).

‡Adjusted for age, atopic dermatitis in infancy and RSV aetiology of bronchiolitis.

§FEV1 decrease >12% in the exercise challenge.

¶Adjusted for age, gender and RSV aetiology of bronchiolitis.

**At least one positive reaction: 36 to indoor and 38 to outdoor allergens.

peak expiratory flow rates monitored at home. Thus, the association between asthma and obesity was based only on subjective observations in all these studies (6,10,26).

Three cross-sectional epidemiological studies reported mainly negative results, in line with the present prospective post-bronchiolitis follow-up. Schachter et al. (5) analysed pooled data of 5993 Australian children aged 7–12 years from seven epidemiological questionnaire studies in 1991–1993. In adjusted analyses, BMI >95% was an independent risk factor for cough and wheezing in girls but not in boys, and not for asthma or BHR by histamine challenge in either gender. Two cross-sectional studies on obesity and asthma were carried out in New Zealand in 11- to 12-year-old children, including 873 subjects in 1989 and 1321 subjects in 2000 (7). Although asthma presumptive symptoms, BHR by exercise challenge and asthma diagnoses increased from 1989 to 2000, no association was found with obesity.

Longitudinal studies are needed to answer to the question whether an excessive weight gain is a risk factor for future asthma. The present study failed to find such an association in former bronchiolitis patients followed prospectively for more than 10 years. In a meta-analysis (13), the combined results showed that preceding obesity increased the risk of subsequent asthma; though, the individual studies gave negative results. This association has been seen only in girls (27) or only in boys (12). In a birth cohort of 2911 children from Australia (8), asthma at 14 years of age had a significant association with BMI-SDS at 14 years but not with BMI-SDS at 5 years of age. In the most recent population-based, long-term follow-up study from Finland, the development of overweight was associated with an increased asthma risk, but not earlier than at 24–39 years of age (28).

The association between overweight and allergy is less studied, and the results have usually been negative (4). In a large multicentre cross-sectional study in 15 454 young adults from Australia, New Zealand and USA, obesity was not associated with AR nor with atopic sensitization (14). Some studies have demonstrated an association between overweight and non-atopic asthma but not between overweight and atopic asthma (13,29,30). In a recent study in

1576 non-selected Belgian children aged 3.4–14.8 years, overweight and obesity did not increase the risk of allergy, but atopic sensitization was more common in underweight girls (16). In a questionnaire study in 50 086 non-selected Japanese school children, AD and asthma were more common and AR was less common in obese children, the association being stronger in boys than in girls (10). In accordance, excessive weight gain at late school age decreased the occurrence of AD and sensitization to outdoor allergens in the present study.

The association between allergy and weight status may be dependent on gender (5,22–24). When clinical data on allergy and SPT results of 5999 children from seven epidemiological studies were combined, a significant association was found between allergy and overweight, but only in girls (5). In a birth cohort study from New Zealand, 1000 individuals were followed up until 9–26 years of age. An association was found between BMI and allergy in females but not in males (22). In a cross-sectional study in 1459 high school students from Taiwan, BMI was a significant predictor of AR, but only in females with BMI in the highest quartile (23). The numbers of children in the present study were too small for any relevant gender-specific analyses.

There are three main strengths in the present study. First, the study was prospective and longitudinal; the asthma and allergy diagnoses were based on doctoral examination, and the follow-up time was long, more than 10 years. Second, the weights and heights of the children were measured at all control visits by standard methods, thus allowing reliable longitudinal BMI monitoring. And third, prospectively collected data on confounding factors were available from early childhood and carefully evaluated in previous studies from the same cohort, allowing a proper use of adjusted analyses. The main shortcoming of the study was the small number of the patients. Although more than 80% of the 100 children originally recruited completed the follow-up until the median age of 12.3 years, the study was evidently underpowered to prove all negative results. In addition, the material of the study was selected, consisting of children hospitalized for wheezing in early life. On the other hand,

this group is important in health care, as their asthma and allergy risks are high, and therefore, the understanding of potential risk factors like obesity is particularly important.

In conclusion, no evidence was found for an association between previous or current overweight and asthma in former bronchiolitis patients at school age, although overweight in the same cohort was associated with reduced lung function (25). Obesity may even decrease the risk of allergy and atopic sensitization at late school age.

ACKNOWLEDGEMENTS

Kuopio University Hospital, Finland and National Foundation for Pediatric Research in Finland are acknowledged for financial support.

CONFLICT OF INTEREST AND FUNDING

The authors do not have any conflict of interests or any financial relationship with a commercial entity that has an interest in the subjects of this manuscript.

References

1. Ford ES. The epidemiology of obesity and asthma. *J Allergy Clin Immunol* 2005; 115: 897–909.
2. Peroni DG, Pietrobello A, Boner AL. Asthma and obesity in childhood: on the road ahead. *Int J Obes* 2010; 34: 599–605.
3. Matricardi PM, Gruber C, Wahn U, Lau S. The asthma-obesity link in childhood: open questions, complex evidence, a few answers only. *Clin Exp Allergy* 2007; 37: 476–84.
4. Flaherman V, Rutherford GW. A meta-analysis of the effect of high weight on asthma. *Arch Dis Child* 2006; 91: 334–9.
5. Schachter LM, Peat JK, Salome CM. Asthma and atopy in overweight children. *Thorax* 2003; 58: 1031–5.
6. Bibi H, Shoseyov D, Feigenbaum D, Genis M, Friger M, Peled R, et al. The relationship between asthma and obesity in children: is it real or a case of over diagnosis? *J Asthma* 2004; 41: 403–10.
7. Wickens K, Barry D, Friezema A, Rhodius R, Bone N, Purdie G, et al. Obesity and asthma in 11–12 year old New Zealand children in 1989 and 2000. *Thorax* 2005; 60: 7–12.
8. Mamun AA, Lawlor DA, Alati R, O'Callaghan MJ, Williams GM, Najman JM. Increasing body mass index from age 5 to 14 years predicts asthma among adolescents: evidence from a birth cohort study. *Int J Obes* 2007; 31: 578–83.
9. Joseph CLM, Havstad SL, Ownby DR, Zoratti E, Peterson EL, Stringer S, et al. Gender differences in the association of overweight and asthma morbidity among urban adolescents with asthma. *Pediatr Allergy Immunol* 2009; 20: 362–9.
10. Kusunoki T, Morimoto T, Nishikomori R, Heike T, Ito M, Hosoi S, et al. Obesity and the prevalence of allergic diseases in schoolchildren. *Pediatr Allergy Immunol* 2008; 19: 527–34.
11. Gilliland FD, Berhane K, Islam T, McConnell R, Gauderman WJ, Gilliland SS, et al. Obesity and the risk of newly diagnosed asthma in school-age children. *Am J Epidemiol* 2003; 158: 406–15.
12. Mannino DM, Mott J, Ferdinands JM, Camargo CA, Friedman M, Greves HM, et al. Boys with high body masses have an increased risk of developing asthma: findings from the National Longitudinal Survey of Youth (NLSY). *Int J Obes (Lond)* 2006; 30: 6–13.
13. Garcia-Marcos L, Arnedo Pena A, Busquets-Monge R, Morales Suárez-Varela M, García de Andoin N, Batlles-Garrido J, et al. How the presence of rhinoconjunctivitis and the severity of asthma modify the relationship between obesity and asthma in children 6–7 years old. *Clin Exp Allergy* 2008; 38: 1174–8.
14. Jarvis D, Chinn S, Potts J, Burney P. Association of body mass index with respiratory symptoms and atopy: results from the European Community Respiratory Health Survey. *Clin Exp Allergy* 2002; 32: 831–7.
15. Ross K, Hart M, Storfer-Isser A, Kibler A, Johnson N, Rosen C, et al. Obesity and obesity related co-morbidities in a referral population of children with asthma. *Pediatr Pulmonol* 2009; 44: 877–84.
16. Van Gysel D, Govaere E, Verhamme K, Doli E, De Baets F. Body mass index in Belgian schoolchildren and its relationship with sensitization and allergic symptoms. *Pediatr Allergy Immunol* 2009; 20: 246–53.
17. Reijonen TM, Kotaniemi-Syrjänen A, Korhonen K, Korppi M. Predictors of asthma three years after hospital admission for wheezing in infancy. *Pediatrics* 2000; 106: 1406–12.
18. Kotaniemi-Syrjänen A, Reijonen TM, Korhonen K, Korppi M. Wheezing requiring hospitalization in early childhood: predictive factors for asthma in a six-year follow-up. *Pediatr Allergy Immunol* 2002; 13: 418–25.
19. Hyvärinen MK, Kotaniemi-Syrjänen A, Reijonen TM, Korhonen K, Korppi MO. Teenage asthma after severe early childhood wheezing: an 11-year prospective follow-up. *Pediatr Pulmonol* 2005; 40: 316–23.
20. Reijonen TM, Korppi M. One-year follow-up of young children hospitalized for wheezing: the influence of early anti-inflammatory therapy and risk factors for subsequent wheezing and asthma. *Pediatr Pulmonol* 1998; 26: 113–9.
21. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *Br Med J* 2000; 320: 1240–6.
22. Hancox RJ, Milne BJ, Poulton R, Taylor DR, Greene JM, McLachlan CR, et al. Sex differences in the relation between body mass index and asthma and atopy in a birth cohort. *Am J Respir Crit Care Med* 2005; 171: 440–5.
23. Huang S-L, Shiao G-M, Chou P. Association between body mass index and allergy in teenage girls in Taiwan. *Clin Exp Allergy* 1999; 29: 323–9.
24. Nagel G, Koenig W, Rapp K, Wabitsch M, Zoellner I, Weiland S. Association of adipokines with asthma, rhinoconjunctivitis, and eczema in German schoolchildren. *Pediatr Allergy Immunol* 2009; 20: 81–8.
25. Sidoroff V, Hyvärinen M, Piippo-Savolainen E, Korppi M. Lung function and overweight in school-aged children after early childhood wheezing. *Pediatr Pulmonol* 2011; 46: 435–41.
26. Belamarich FP, Luder E, Kattan M, Mitchell H, Islam S, Lynn H, et al. Do obese inner-city children with asthma have more symptoms than nonobese children with asthma? *Pediatrics* 2000; 106: 1436–41.
27. Castro-Rodriguez JA, Holberg CJ, Morgan WJ, Wright A, Martinez F. Increased incidence of asthma-like symptoms in girls who become overweight or obese during the school years. *Am J Respir Crit Care Med* 2001; 163: 1344–9.
28. Jartti T, Saarikoski L, Jartti L, Lisinen I, Jula A, Huupponen R, et al. Obesity, adipokines and asthma. *Allergy* 2009; 64: 770–7.
29. von Mutius E, Schwartz J, Neas LM, Dockery D, Weiss ST. Relation of body mass index to asthma and atopy in children: the National Health and Nutrition Examination Study III. *Thorax* 2001; 56: 835–8.
30. Gold DR, Damokosh AI, Dockery DW, Berkey CS. Body-mass index as a predictor of incident asthma in a prospective cohort of children. *Pediatr Pulmonol* 2003; 36: 514–21.