SWIMMING POOL ATTENDANCE, ASTHMA, ALLERGIES AND LUNG FUNCTION IN THE ALSPAC CHILD COHORT

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At a Glance commentary:

Scientific knowledge on the Subject: There is inconsistent evidence from cross-sectional studies for an association between swimming pool attendance and the risk of asthma in childhood.

What This Study Adds to the Field: This is the first prospective longitudinal study on the topic, following 5,738 British children from birth until age 10y. It suggests that swimming does not increase the risk of asthma. On the contrary it appears to be associated with higher lung function and less respiratory symptoms, particularly among asthmatic children.

This article has an online data supplement, which is accessible from this issue's table of content online at www.atsjournals.org.

ABSTRACT

RATIONALE: Cross-sectional studies have reported inconsistent findings for the association between recreational swimming pool attendance and asthma and allergic diseases in childhood.

OBJECTIVES: To examine whether swimming in infancy and childhood was associated with asthma and allergic symptoms at age 7 and 10 years in a UK longitudinal population-based birth cohort (ALSPAC).

METHODS: Data on swimming were collected by questionnaire at 6, 18, 38, 42, 57, 65 and 81 months. Data on rhinitis, wheezing, asthma, eczema, hay fever, asthma medication and potential confounders were collected through questionnaire at 7 and 10y. Spirometry and skin prick testing were performed at 7-8y. Data for analysis were available for 5,738 children.

MEASUREMENTS AND MAIN RESULTS: At age 7y, >50% of the children swam ≥once/week. Swimming frequency did not increase the risk of any evaluated symptom, either overall or in atopic children. Children with a high versus low cumulative swimming pool attendance from birth to 7y had an odds ratio (OR) of 0.88 (95% confidence interval 0.56-1.38) and 0.50 (0.28-0.87), respectively, for ever and current asthma at 7y, and a 0.20 (0.02-0.39) standard deviation increase in the mid forced expiratory flow. Asthmatic children with a high versus low cumulative swimming had an OR for current asthma at 10y of 0.34 (0.14-0.80).

CONCLUSIONS: This first prospective longitudinal study suggests that swimming did not increase the risk of asthma or allergic symptoms in British children. Swimming was associated with increased lung function and lower risk of asthma symptoms, especially among children with pre-existing respiratory conditions.

Key words: ALSPAC, pediatric, epidemiology, prospective, irritants

Word count Abstract: 261

INTRODUCTION

In recent years, several epidemiological studies have suggested that attending chlorinated swimming pools during childhood is a risk factor for developing asthma and other allergic diseases (1). The underlying hypothesis is that exposure to disinfectants and disinfection by-products in the swimming pool (probably trichloramine, a strong irritant (2)) may cause a detrimental effect in the airways of children with a consequent increased risk of developing asthma (3). It was previously shown that chronic exposure to the irritant environment of indoor swimming pools was associated with higher prevalence of respiratory symptoms among lifeguards (4). The prevalence of asthma among elite swimmers is also higher than among other elite athletes (1,5). However it has been argued that reverse causation may explain these findings since swimming is a well tolerated and recommended sport for asthmatics (1).

Epidemiological studies conducted in Belgium have found an increased risk of childhood asthma related to both indoor and outdoor swimming pool attendance (6-9). A recent study conducted in Ireland among 121 boys (10) found a significant association between asthma and the number of years attending pools, but not with the frequency of attendance. Studies conducted in Germany (11,12), Italy (13) and Spain (14) did not find an increased risk of asthma among children attending swimming pools. Despite the conflicting results, there is agreement on the complexity of the potential role of swimming in asthma etiology, and the important public health implications (1,15-17). Asthma is among the most common chronic diseases in children (18) and swimming is one of the most practiced sports in western countries (19), where sedentarism and obesity are rising, especially among children (20). In August 2007, a multidisciplinary group of experts evaluated the

evidence on childhood asthma and swimming pools to establish future research agenda (17). Several shortcomings in the current literature were identified in the area of exposure assessment and the characterization of asthma (17). Currently available studies used a cross-sectional design with a retrospective assessment of swimming pool attendance, which could have led to recall bias and exposure misclassification. The possibility of reverse causation has been identified as another limitation of previous studies, highlighting the need for longitudinal epidemiological studies (14-17), including the use of data in existing prospective birth cohorts (17).

The Avon Longitudinal Study of Parents and Children (ALSPAC) in the UK has followed from birth more than 5,700 children with prospectively collected data on swimming and respiratory symptoms and measurements. Therefore, this study represents a unique opportunity to assess the risk of childhood asthma associated with swimming pool attendance in childhood. The aim of our study is to examine whether swimming at different periods during early childhood is associated with the prevalence of asthma and allergic symptoms at 7 and 10 years of age.

METHODS

Study design and population

The population-based Avon Longitudinal Study of Parents and Children (ALSPAC) study recruited 14,541 pregnant women resident in Avon, UK, with expected delivery dates between 1 April 1991 and 31 December 1992, resulting in a cohort of 14,062 live births (21). Ethical approval was obtained from the ALSPAC Law and Ethics Committee and the Local Research Ethics Committees. The study protocol has been

previously described (22) and further details are on the ALSPAC website (http://www.alspac.bris.ac.uk).

Measurements and data collection

Outcomes. Reported symptoms were ascertained through questions similar to those used by the International Study of Asthma and Allergies in Children (ISAAC). Current symptoms (in the last 12 months) included wheezing, asthma, eczema, hay fever, nasal, nasal and ocular (at 6.7 and 10y) and asthma medication (at 7.6y). Having ever had asthma at 7.6y and having ever had eczema and hay fever at 10y was also collected. Atopy was determined by a skin prick test at age 7–8y. Lung function and bronchial hyper-responsiveness (BHR) was measured at approximately 8y. Forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC) and forced mid expiratory flow ($FEF_{25–75}$) were measured by spirometry and converted to sex-, age- and height-adjusted standard deviation units (23). The rapid methacholine challenge test was performed to measure BHR (24).

Swimming. Ever swimming before age 4 years was estimated from questionnaires at 6, 18, 38 and 42 months. Swimming from age 4 to 7 years was summarized in a score based on the swimming frequency during school term periods at 57, 65 and 81 months (4.7, 5.4 and 6.7 years respectively). The answers “rarely or not at all”, “once a month”, “once a week” and “more than once a week” were assigned, respectively, 0, 1, 2 or 3 points. The scores for each period were summed into an overall score: low (0 to 2 points), medium (3 to 4 points) and high (5 to 9 points). A combined score (0 to 7 years) distinguished extreme categories: lowest exposed (never swimming <4y and 4-7y swimming score=0) and highest exposed (ever swimming <4y and 4-7y swimming score>4).

Confounders. Sex, birth weight, number of siblings, atopy, maternal education, maternal and paternal social class, maternal age at delivery, maternal asthma, allergy and hay fever, contact with pets, hours of TV watching and exposure to environmental tobacco smoke (ETS) in several periods, and body mass index (BMI, at 7 years) were considered. Atopy was also considered as a potential effect modifier.

See online supplement for details on variable definitions and clinical measurements.

Statistical analysis

Of the 14,062 live births, 13,988 were alive at one year. After excluding children in a triplet or quadruplet for confidentiality and missing observations on all swimming variables or outcomes at 7 years, 8,750 children remained. Since atopy was included in the final models, children with missing atopy were further excluded, leaving 5,738 for the final analysis. Missing values in outcomes and covariates (see methods and Table E1 in the online data supplement) led to varying sample sizes in the different models.

RESULTS

Twelve percent of mothers had ever had asthma, and 21.4% of children were positive to the skin prick test (Table 1). Twenty percent of the children had ever had asthma at 7 years of age (Table 2). The prevalence of hay fever and nasal symptoms increased from age 7 to age 10 years. Swimming before 4 years of age was reported in 14.2% of children (Figure 1). Between 4 and 7 years old, around 50% of children had attended pools at least once a week, while around 20% never or very rarely had done so. Forty-seven percent of the children had a high swimming

score between age 4 and 7, while only 10% had a high overall swimming score (Figure 1).

Higher social class and maternal education were associated with a higher frequency of swimming (Figure 2A). A decreased frequency of swimming was associated with having siblings, exposure to environmental tobacco smoke, high TV watching and low body mass index. A high maternal social class or education was associated with more atopy but with less asthma symptoms (Figure 2B). Girls had more eczema and lower prevalence rates of asthma, hay fever and atopy. Hours of TV watching as well as atopy, maternal asthma, maternal hay fever and maternal allergy were also predictors of symptoms.

As crude and adjusted models gave very similar results, only the latter are reported in the tables. After adjusting for confounders, swimming was not associated with ever asthma, but it was associated with a lower prevalence of current asthma and current asthma medication at 7 years of age (table 3). No significant association was observed between swimming and the prevalence of current wheezing, eczema, hay fever (table 3), nasal symptoms and nasal and ocular symptoms at 7 or at 10 years, atopy, having ever had eczema and hay fever at age 10 years (table E2 in the online supplement). In order to detect differences of the effect of swimming on asthma by previous respiratory conditions, we stratified the analysis by ever wheezing before 3.5 years (table 4). The protective effect of swimming on asthma medication and current asthma was only seen among children who wheezed before age of 3.5 years, while it disappeared among never wheezers before age 3.5 years. Swimming was protective for current asthma at 10 years among children ever having had asthma at 7 years of age. Swimming was associated with a higher FVC, FEV_1, FEV_1:FVC ratio and FEF_{25-75} at age 8 years (Table 5), indicating that children who

had swum more frequently tended to have a better lung function. No significant association was seen between swimming pool attendance and bronchial hyper responsiveness. To further control for socioeconomic status, we stratified the main results by maternal education and observed similar risk estimates indicating no effect modification by socioeconomic status (table E3 in online supplement).

Before adjusting the models for atopic status, we performed stratified analyses and confirmed that atopy was not an effect modifier (see table E4 in online supplement). Swimming did not increase the risk of any respiratory symptom among atopic children, as defined by the skin prick test. Among atopic children, those in the highest overall swimming category also had less current asthma at age 7 years compared with those in the lowest swimming category (Odds Ratio (OR) = 0.41; 95% Confidence interval (CI): 0.17-0.99).

Finally, in order to detect possible reverse causation or health-related selection, we analyzed the association between wheezing before 3.5 years and swimming later on, as well as the association between symptoms at 7 years and the frequency of swimming at 8.6 years. There was no association with any swimming variable (table E5 in the online supplement), indicating that respiratory and allergic symptoms did not affect the probability of attending swimming pools later in life.

DISCUSSION

This large prospective birth cohort study indicated that reported swimming did not increase the risk of asthma, atopy or any respiratory and allergic symptom in British children. On the contrary, swimming was associated with increased lung function

and with a decreased prevalence of current asthma among children with previous respiratory conditions. In addition, no evidence of reverse causation was detected.

The results of this study are in accordance with the previous cross-sectional studies performed outside Belgium, where no significant positive association between pool attendance and ever having asthma (11,12,14) or hay fever (11,12) was reported. In Germany, swimming also did not increase the risk of eczema (11,12) although it did in Spain (14). Differences in the results on asthma risk between studies conducted in Belgium or in other countries may reflect true differences or may relate to methodological aspects. There are several possible explanations for real different effects among areas. First, different patterns of swimming pool attendance in children resulting in different cumulative exposures. Second, differences in the level of trichloramine or other irritants in the swimming pools. Third, uncontrolled confounding variables (e.g. physical activity) may be different. Finally, differences in the presence and extent of reverse causation, i.e. children with asthma attending or avoid swimming pools. In this study, the prevalence of swimming was very high and an extreme exposure category was created, and an undetected real effect is unlikely. Regarding methodological differences, the studies with negative results (11,12,14) are based on large and population-based samples, while the studies with positive results do not (6-9).

This is the first longitudinal study with prospectively collected data on the association between swimming pool attendance and childhood asthma. The use of questionnaires not originally designed to answer the specific research question under study led to potential exposure misclassification and absence of data on confounders such as physical activity. The data on swimming during the first years of life were obtained indirectly through open questions and therefore pool

attendance before 4 years of age has likely been underestimated. The effect on the results is difficult to foresee since we ignore if the exposure misclassification had been differential or non differential. However, a global interpretation of results shows a consistent pattern for different exposure periods, suggesting that findings for the earliest period are not spurious. The questionnaires referred to swimming instead of swimming pool attendance, but given the weather characteristics in the UK, it is reasonable to assume that answers refer mainly to indoor swimming pool attendance. Although there is no empirical data to confirm this, the majority of swimming pools in the area have probably been chlorinated during the study period, according to local authorities and the world health organization data showing that chlorine is the most common disinfectant used in swimming pools (2). The lack of quantitative data on irritants in the swimming pools is a drawback that prevents the evaluation of dose-responses and makes the comparison with other study settings difficult. Selection bias in the initial sample may affect the external validity of our findings. There was a considerable loss to follow up, that as in most cohort studies, was greater in children from less advantaged backgrounds, probably leading to an overestimation of the swimming prevalence (see table E6 in online supplement). However, since socioeconomic status was not an effect modifier, the validity of results in the analyzed dataset was not compromised. Data on other environmental exposures that could affect respiratory health, e.g. air pollution, was not available to check for effect modification or confounding. On the other hand, the available information on the health outcomes was very accurate, with clinical measurements and validated questions on asthma and allergic symptoms at 7 and at 10 years. The strengths of using data from a population based and longitudinal study are very relevant. The prospective nature of the data collection reduced the probability of

recall bias. It also allowed us to look for the first time at temporal relationships between swimming and allergic and respiratory symptoms at different points in time during childhood, showing that in this population there was no evidence of reverse causation. Along with the prospective design, the large sample size was an advantage that allowed us to analyze associations in subgroups of children with different previous respiratory conditions.

Similar to a previous study in Spain (14), an inverse association between swimming and asthma symptoms, but not with ever asthma, was found in the overall population of this British cohort. This appeared to be driven by the subgroup of asthmatics or early wheezing children. Since we could only use TV watching as a proxy for sedentarism, we can not disentangle whether this protective effect is caused by swimming per se or by other physical activities related to a more active and healthier life-style. Recent studies are providing evidence that asthmatics may benefit from swimming training as reflected in the clinical measures of disease severity (1,25,26). To our knowledge, this is the first longitudinal and population-based study showing that swimming is associated with less asthma symptoms among children with asthma, after discarding a “healthy-swimmer effect”. Although physical fitness in childhood may prevent asthma development in young adulthood (27), our data do not seem to indicate that swimming can prevent asthma development in children. If our results are further confirmed, swimming would not only be a safe sport for asthmatics (26), but also may help controlling asthma symptoms. These results are not extrapolable to swimming pool workers and elite swimmers, which are populations at risk of developing adverse respiratory outcomes deserving further research.

In conclusion, this first large longitudinal study suggests that swimming was not associated with ever asthma or atopy in British children. Swimming was associated with increased lung function and with lower prevalence of asthma symptoms, especially among children with pre-existing respiratory conditions. Findings indicate no reverse causation, but confounding by concurrent physical activity or selection bias can not be ruled out. More large studies with improved exposure assessment especially during the first years of life conducted in different settings are required to confirm these results, since they entail important public health implications.

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Reference

1. Goodman M, Hays S. Asthma and swimming: a meta-analysis. *J Asthma* 2008;45:639-647.

2. World Health Organization. Guidelines for safe recreational water environments. Volume 2. Swimming pools and similar environments. World Health Organization, Geneva, 2006. Available at: http://www.who.int/water_sanitation_health/bathing/srwe2full.pdf

3. Bernard A. Chlorination products: emerging links with allergic diseases. *Curr Med Chem* 2007;14:1771-1782.

4. Massin N, Bohadana AB, Wild P, Hery M, Toamain JP, Hubert G. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. *Occup Environ Med* 1998;55:258-263.

5. Levesque B, Duchesne JF, Gingras S, Lavoie R, Prud'Homme D, Bernard E, Boulet LP, Ernst P. The determinants of prevalence of health complaints among young competitive swimmers. *Int Arch Occup Environ Health* 2006;80:32-39.

6. Bernard A, Carbonnelle S, de Burbure C, Michel O, Nickmilder M. Chlorinated pool attendance, atopy, and the risk of asthma during childhood. *Environ Health Perspect* 2006;114:1567-1573.

7. Bernard A, Carbonnelle S, Dumont X, Nickmilder M. Infant swimming practice, pulmonary epithelium integrity, and the risk of allergic and respiratory diseases later in childhood. *Pediatrics* 2007;119:1095-1103.

8. Bernard A, Nickmilder M, Voisin C. Outdoor swimming pools and the risks of asthma and allergies during adolescence. *Eur Respir J* 2008;32:979-988.

9. Bernard A, Nickmilder M, Voisin C, Sardella A. Impact of chlorinated swimming pool attendance on the respiratory health of adolescents. *Pediatrics* 2009;124:1110-1118.

10. Cotter A, Ryan CA. The pool chlorine hypothesis and asthma among boys. *Ir Med J* 2009;102:79-82.

11. Kohlhammer Y, Doring A, Schafer T, Wichmann HE, Heinrich J. Swimming pool attendance and hay fever rates later in life. *Allergy* 2006;61:1305-1309.

12. Schoefer Y, Zutavern A, Brockow I, Schafer T, Kramer U, Schaaf B, Herbarth O, von Berg A, Wichmann HE, Heinrich J. Health risks of early swimming pool attendance. *Int J Hyg Environ Health* 2008;211:367-373.

13. Carraro S, Pasquale MF, Da Fre M, Rusconi F, Bonetto G, Zanconato S, Baraldi E. Swimming pool attendance and exhaled nitric oxide in children. *J Allergy Clin Immunol* 2006;118:958-960.

14. Font-Ribera L, Kogevinas M, Zock JP, Nieuwenhuijsen MJ, Heederik D, Villanueva CM. Swimming pool attendance and risk of asthma and allergic symptoms in children. *Eur Respir J* 2009;34:1304-1310.

15. Angela Spivey. Widening the pool of factors. Studies needed to assess asthma-swimming link. *Environmental Health Perspective* 2009;117:A 162.

16. Uyan ZS, Carraro S, Piacentini G, Baraldi E. Swimming pool, respiratory health, and childhood asthma: should we change our beliefs? *Pediatr Pulmonol* 2009;44:31-37.

17. Weisel CP, Richardson SD, Nemery B, Aggazzotti G, Baraldi E, Blatchley ER, III, Blount BC, Carlsen KH, Eggleston PA, Frimmel FH, Goodman M, Gordon G, Grinshpun SA, Heederik D, Kogevinas M, LaKind JS, Nieuwenhuijsen MJ, Piper FC, Sattar SA. Childhood asthma and environmental exposures at swimming pools: state of the science and research recommendations. *Environ Health Perspect* 2009;117:500-507.

18. O'Connell EJ. The burden of atopy and asthma in children. *Allergy* 2004;59 Suppl 78:7-11.

19. Vaz dA, Graca P, Afonso C, D'Amicis A, Lappalainen R, Damkjaer S. Physical activity levels and body weight in a nationally representative sample in the European Union. *Public Health Nutr* 1999;2:105-113.

20. Hardy LR, Harrell JS, Bell RA. Overweight in children: definitions, measurements, confounding factors, and health consequences. *J Pediatr Nurs* 2004;19:376-384.

21. Maitra A, Sherriff A, Northstone K, Strachan D, Henderson AJ. Maternal age of menarche is not associated with asthma or atopy in prepubertal children. *Thorax* 2005;60:810-813.

22. Golding J, Pembrey M, Jones R. ALSPAC--the Avon Longitudinal Study of Parents and Children. I. Study methodology. *Paediatr Perinat Epidemiol* 2001;15:74-87.

23. Chinn S, Rona RJ. Height and age adjustment for cross sectional studies of lung function in children aged 6-11 years. *Thorax* 1992;47:707-714.

24. Yan K, Salome C, Woolcock AJ. Rapid method for measurement of bronchial responsiveness. *Thorax* 1983;38:760-765.

25. Wang JS, Hung WP. The effects of a swimming intervention for children with asthma. *Respirology* 2009;14:838-842.

26. Weisgerber M, Webber K, Meurer J, Danduran M, Berger S, Flores G. Moderate and vigorous exercise programs in children with asthma: safety, parental satisfaction, and asthma outcomes. *Pediatr Pulmonol* 2008;43:1175-1182.

27. Rasmussen F, Lambrechtsen J, Siersted HC, Hansen HS, Hansen NC. Low physical fitness in childhood is associated with the development of asthma in young adulthood: the Odense schoolchild study. *Eur Respir J* 2000;16:866-870.

Table 1. Characteristics of the study population. N=5,738.

	N		N total
Child characteristics			
Sex, male	2908	50.7%	5738
Birth weight (g). Median, percentiles 25, 75	3450	3120, 3770	5670
Body mass index at 7 years (Kg). Median, percentiles 25, 75	15.8	14.9, 17.0	5693
Environmental exposures			
Any older brothers at age 1.5 years	3197	55.7%	5738
Weekly contact with pets at age 2 or 4.5 years *	4585	82.5%	5555
Exposure to environmental tobacco smoke at 6 months †	1676	29.8%	5620
TV watching at 5.4 years, > 2h during weekdays	506	9.5%	5348
Maternal characteristics			
Age at delivery (years). Median, percentiles 25, 75	29	26, 32	5738
Higher education ‡	2498	44.3%	5638
Social class I, II	2110	42.9%	4923
Asthma	651	11.7%	5564
Allergy	2577	46.4%	5548
Hay fever	1750	31.8%	5498
Clinical evaluation at 7- 8 years			
Positive skin prick test	1226	21.4%	5738
Lung function *Standard deviation scores adjusted for height, age and gender*	Median	Percentiles 25, 75	N
Forced vital capacity (FVC)	-0.01	-0.62, 0.66	4708
Forced expiratory volume at 1 second (FEV1)	0.01	-0.65, 0.66	4636
FEV1:FVC ratio	0.89	0.85, 0.93	4636
Forced mid expiratory flow (FEF 25-75)	-0.04	-0.68, 0.64	4708
Bronchial hyper-responsiveness §	0.10	-1.33, 1.05	3117

* cat, dog or any furry pet

† During the weekend.

‡ Maternal higher education: A level or degree (studing at least until age 18)

§ Mean of least squares dose-response slope. Percentage decline in FEV1 per µmol methacoline

Table 2. Prevalence of reported respiratory symptoms at approximately 7 and 10 years of age. N=5,738.

	7 years			10 years		
	N	%	N total	N	%	N total
Current* asthma	632	11.4	5537	546	11.4	4770
Current wheezing	598	10.8	5545	487	10.2	4778
Current asthma medicine	762	13.8	5526			
Current eczema	956	17.3	5534	754	15.8	4774
Current hay fever	494	8.9	5520	741	15.5	4766
Current nasal problems	708	12.9	5495	868	18.6	4660
Current nasal-ocular problems	285	5.2	5493	516	11.1	4650
Ever asthma †	1109	20.2	5498			
Ever hay fever				990	21.3	4651
Ever eczema				1560	33.7	4626

* Current: in the last 12 months † Doctor diagnosed

Table 3. Association (odds ratio, OR) between swimming in different age periods and ever asthma, current symptoms (in the last 12 months) and atopic status at approximately 7 and 10 years of age. N=5,738.

			Age 7 years			Age 10 years		
	Swimming		OR *	95% CI	N	OR *	95% CI	N
Ever asthma	Age < 4 y	Never	1		4440			
		Ever	1.01	0.81-1.26				
	Age 4 – 7 y	Low	1		4425			
		Medium	1.09	0.88-1.35				
		High	1.07	0.87-1.32				
	Age 0 – 7 y	Lowest	1		4193			
		Highest	0.88	0.56-1.38				
Current asthma	Age < 4 y	Never	1		4751	1		3876
		Ever	**0.73**	0.55-0.98		0.90	0.67-1.21	
	Age 4 – 7 y	Low	1		4481	1		4147
		Medium	1.00	0.76-1.31		0.78	0.59-1.05	
		High	0.97	0.75-1.25		0.91	0.69-1.19	
	Age 0 – 7 y	Lowest	1		4243	1		3497
		Highest	**0.50**	0.28-0.87		0.61	0.32-1.15	
Current wheezing	Age < 4 y	Never	1		4757	1		3885
		Ever	0.83	0.63-1.11		0.95	0.70-1.29	
	Age 4 – 7 y	Low	1		4488	1		3670
		Medium	0.93	0.70-1.24		0.90	0.64-1.26	
		High	1.12	0.86-1.46		1.06	0.77-1.45	
	Age 0 – 7 y	Lowest	1		4249	1		3504
		Highest	0.58	0.33-1.02		0.60	0.31-1.14	
Current asthma medication	Age < 4 y	Never	1		4511			
		Ever	**0.70**	0.53-0.93				
	Age 4 – 7 y	Low	1		4437			
		Medium	0.87	0.68-1.12				
		High	0.97	0.76-1.23				
	Age 0 – 7 y	Lowest	1		4204			
		Highest	**0.58**	0.35-0.98				
Current eczema	Age < 4 y	Never	1		4784	1		4430
		Ever	0.93	0.75-1.16		1.07	0.85-1.34	
	Age 4 – 7 y	Low	1		4448	1		4181
		Medium	0.95	0.76-1.20		0.88	0.69-1.12	
		High	1.12	0.91-1.38		0.99	0.79-1.23	
	Age 0 – 7 y	Lowest	1		4267	1		3977
		Highest	0.66	0.42-1.02		0.86	0.53-1.39	
Current hay fever	Age < 4 y	Never	1		4726	1		3828
		Ever	1.16	0.85-1.56		1.05	0.81-1.36	
	Age 4 – 7 y	Low	1		4451	1		3617
		Medium	1.17	0.84-1.63		0.78	0.58-1.05	
		High	1.17	0.86-1.60		1.00	0.76-1.31	
	Age 0 – 7 y	Lowest	1		4210	1		3454
		Highest	1.70	0.82-3.52		0.85	0.46-1.56	

* Adjusting variables per model: Ever asthma) maternal education, maternal asthma, birth weight, maternal age, TV watching, atopy; Current asthma) maternal asthma, education, atopy; Wheezing) maternal asthma, social class, atopy; Asthma medication) maternal asthma, atopy, education, TV watching; Eczema) maternal allergy, atopy and sex. Hay fever) maternal hay fever, social class, atopy;

Table 4. Association (odds ratio, OR) between asthma and highest vs. lowest swimming score between age 0 – 7 years in the overall population and by previous respiratory conditions. N=5,738.

			Wheezing before 3.5 years		
		All children	*Yes (44.3%)*	*No (55.7%)*	interaction p-value
Ever asthma at 7 years					
	OR †	0.88	0.59	1.63	0.061
	95% CI	0.56-1.38	0.33-1.04	0.62-4.26	
	n	4193	1806	2416	
Current asthma medication at 7 y					
	OR *	**0.55**	**0.35**	1.88	0.036
	95% CI	0.33-0.92	0.18-0.67	0.51-6.85	
	n	4233	1816	2457	
Current asthma at 7 y					
	OR *	**0.50**	**0.35**	1.27	0.157
	95% CI	0.28-0.87	0.18-0.69	0.33-4.91	
	n	4243	1815	2468	
Current asthma at 10y					
	OR *	**0.50**	**0.39**	0.57	0.802
	95% CI	0.28-0.87	0.19-0.81	0.21-1.58	
	n	3980	1701	2267	
			Ever asthma at 7 years		
Current asthma at 10y		*All children*	*Yes (20.2%)*	*No (79.8%)*	
	OR *	0.61	**0.34**	0.94	0.213
	95% CI	0.32-1.15	0.14-0.80	0.32-2.73	
	n	3497	750	3160	

Adjusting variables per stratifyed models:

† atopy, maternal asthma, education and age

* atopy, maternal asthma and education

Table 5. Association (adjusted linear regression coeficient) between swimming at different age periods and lung function and airway responsiveness at 8 years, expressed as standard deviation scores adjusted for height, age and gender. N=5,738.

	Swimming		Mean differenc	95% CI		N
Forced Vital Capacity (FVC)	Age < 4 y	Never	0 (reference)			4395
		Ever	-0.05	-0.13	0.03	
	Age 4 – 7 y	Low	0 (reference)			4060
		Medium	-0.01	-0.09	0.08	
		High	**0.08**	0.00	0.16	
	Age 0 – 7 y	Lowest	0 (reference)			3831
		Highest	0.05	-0.13	0.23	
Forced expiratory volume in 1 second (FEV_1)	Age < 4 y	Never	0 (reference)			4318
		Ever	-0.03	-0.11	0.05	
	Age 4 – 7 y	Low	0 (reference)			3997
		Medium	0.05	-0.04	0.13	
		High	**0.10**	0.02	0.18	
	Age 0 – 7 y	Lowest	0 (reference)			3771
		Highest	0.14	-0.05	0.32	
FEV1:FVC	Age < 4 y	Never	0 (reference)			4383
		Ever	0.00	-0.00	0.01	
	Age 4 – 7 y	Low	0 (reference)			4050
		Medium	**0.01**	0.00	0.01	
		High	0.00	-0.00	0.01	
	Age 0 – 7 y	Lowest	0 (reference)			3821
		Highest	0.01	-0.00	0.02	
Forced mid expiratory flow (FEF_{25-75})	Age < 4 y	Never	0 (reference)			4419
		Ever	0.04	-0.04	0.12	
	Age 4 – 7 y	Low	0 (reference)			4081
		Medium	**0.10**	0.02	0.19	
		High	**0.09**	0.01	0.17	
	Age 0 – 7 y	Lowest	0 (reference)			3851
		Highest	**0.20**	0.02	0.39	
Bronchial hyper-responsiveness †	Age < 4 y	Never	0 (reference)			2848
		Ever	0.08	-0.08	0.25	
	Age 4 – 7 y	Low	0 (reference)			2677
		Medium	-0.04	-0.22	0.14	
		High	0.05	-0.12	0.21	
	Age 0 – 7 y	Lowest	0 (reference)			2584
		Highest	0.03	-0.33	0.40	

Adjusting variable per model: FVC) body mass index, birth weight; FEV1) body mass index, birth weight, environmental tobacco smoke, atopy; Ratio FEV1:FVC) body mass index, sex, atopy; FEF 25-75) Older siblings, birth weight, atopy; Bronchial hyper- responsiveness) sex, maternal asthma, maternal hay fever, atopy

† Mean of least squares dose-response slope (% decline in FEV1 per µmol methacoline)

LEGGENDS OF FIGURES

Figure 1. Percentage of reported swimming at different ages. N=5,738.

Figure 2. Association between confounders and swimming at age 4 to 7 years (A) and between confounders and symptoms at 7 or 8 years (B). Odds Ratio (OR) with 95% confidence intervals. N=5,738.

Leggend

* Adjusted by maternal education, except social class.

† ETS: Environmental tobacco smoke

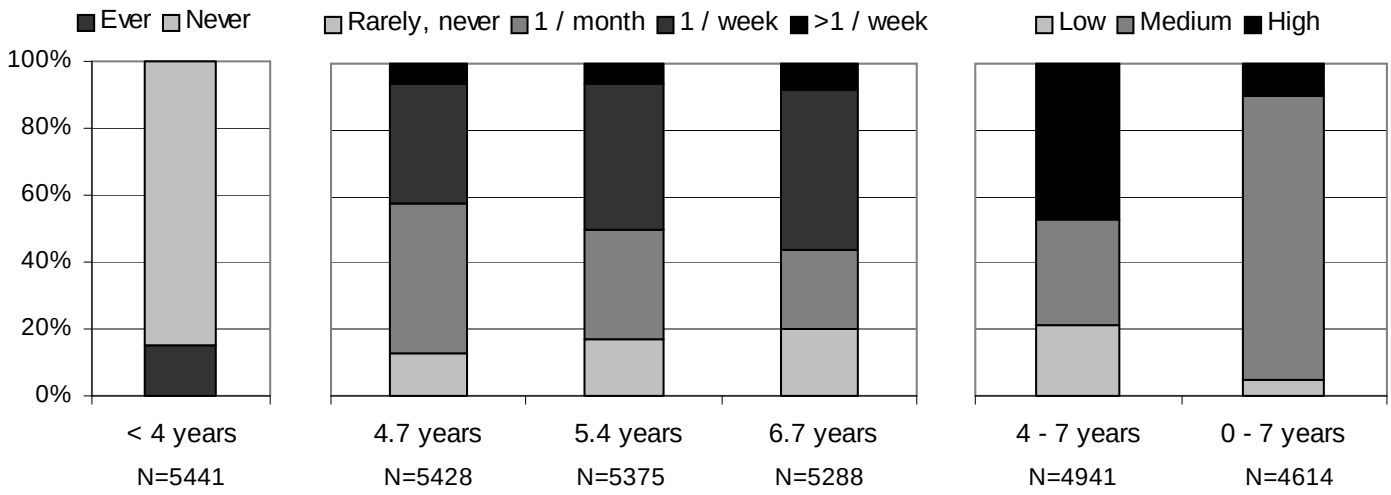
Ever
Never
Rarely, never
1 / month
1 / week
>1 / week
Low
Medium
High
100%
80%
60%
40%
20%
0%
< 4 years
N=5441
4.7 years
N=5428
5.4 years
N=5375
6.7 years
N=5288
4 - 7 years
N=4941
0 - 7 years
N=4614

Figure 1.

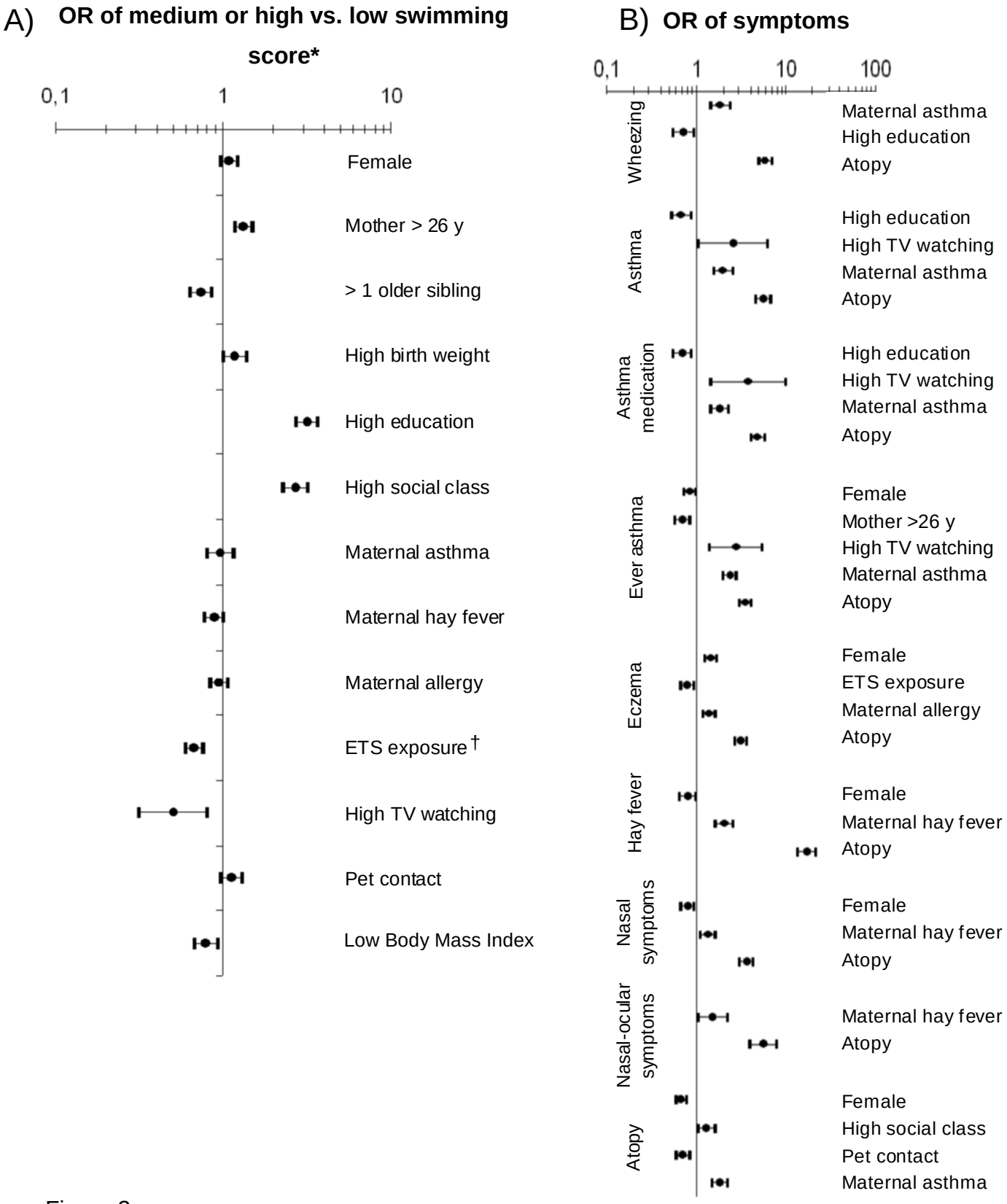
A) OR of medium or high vs. low swimming score*
0,1
1
10
Female
Mother > 26 y
> 1 older sibling
High birth weight
High education
High social class
Maternal asthma
Maternal hay fever
Maternal allergy
ETS exposure †
High TV watching
Pet contact
Low Body Mass Index
B) OR of symptoms
0,1
1
10
100
Wheezing
Maternal asthma
High education
Atopy
Asthma
High education
High TV watching
Maternal asthma
Atopy
Asthma medication
High education
High TV watching
Maternal asthma
Atopy
Ever asthma
Female
Mother >26 y
High TV watching
Maternal asthma
Atopy
Eczema
Female
ETS exposure
Maternal allergy
Atopy
Hay fever
Female
Maternal hay fever
Atopy
Nasal symptoms
Female
Maternal hay fever
Atopy
Nasal-ocular symptoms
Maternal hay fever
Atopy
Atopy
Female
High social class
Pet contact
Maternal asthma

Figure 2.