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Asthma in children exposed to nitrogen dioxide in ice arenas

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Asthma in children exposed to nitrogen dioxide in ice arenas. P. Thunqvist, G. Lilja, M. Wickman, G. Pershagen. ©ERS Journals Ltd 2002.

ABSTRACT: Very high concentrations of nitrogen dioxide (NO_2) have been measured in arenas using combustion engine-powered resurfacing machines. This study was performed to compare the occurrence of asthma in children playing ice hockey in arenas using propane-powered machines and in children attending arenas using electric machines.

Children regularly playing hockey in the arenas (nine propane, six electric) were sent a questionnaire, including questions on allergic disease and risk factors. Measurements of NO_2 were performed with passive diffusion samplers during 3 consecutive days.

The mean NO_2 concentration in the propane arenas was 276 $\mu g \cdot m^{-3}$ (range 28–1015 $\mu g \cdot m^{-3}$) and 11 $\mu g \cdot m^{-3}$ (2–30) in the electric arenas. Questionnaires were answered by 1,536 children (78%), with an overall prevalence of asthma of 16%. The odds ratio (OR) for asthma was 0.9 (95% confidence interval (CI) 0.7–1.2) comparing propane arenas to electric. However, children in propane arenas with higher than median concentration of NO_2 reported more wheezing (OR 1.4, 95% CI 1.0–1.9) and nasal symptoms (OR 1.7, 95% CI 1.3–2.3) than children in propane arenas with lower concentrations.

In conclusion, children playing ice hockey in indoor arenas have a high prevalence of asthma, but it appears unlikely that increased exposure to combustion products, including nitrogen dioxide, is a major contributor to this excess risk.
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Long-term exposure to ambient air pollution and its potential effect on the development of asthma and atopy has been a topic of interest in recent years. Some authors report an association between increased exposure to air pollution, with nitrogen dioxide (NO_2) as a major component, and respiratory tract illness as well as atopy in children, but the evidence is not consistent [1–5]. In these studies the contrast in exposure to NO_2 between study subjects was limited and together with potential confounding this makes the results difficult to interpret.

High concentrations of NO_2 may occur in ice arenas when propane- or gasoline-powered ice-resurfacing machines are used [6]. Outbreaks of respiratory illness have been reported after exposure to very high concentrations of NO_2 in ice arenas, *i.e.* in the order of several thousands of $\mu g \cdot m^{-3}$, probably due to malfunctioning of combustion engines and poor ventilation [7, 8]. In follow-up investigations after such accidents no long-term health effects have been demonstrated [7, 8]. However, there is a lack of studies on long-term effects of regular exposure to high NO_2 concentrations in ice arenas.

The aim of this study was to assess the risk of bronchial asthma for children playing ice hockey or figure skating in indoor ice arenas with propane-powered ice-resurfacing machines compared to a group of children primarily attending arenas with electric-powered machines.

Material and methods

Area and arenas

In the planning of this study a survey of all 286 Swedish indoor ice arenas was made in 1998. This showed that two thirds of the arenas used propane-powered ice-resurfacing machines. Based on this survey a region in the central part of Sweden with a large number of indoor ice arenas was selected. The region consists of small communities and rural areas except for the city of Gävle, which has ~67,000 inhabitants. Thus, 15 arenas at 14 different locations were included, nine using propane-powered and six using electric-powered machines. Two of the electric-powered arenas were located in the city of Gävle.

Study population

All children in hockey and figure-skating clubs in Sweden are registered from the age of 10 in a mandatory insurance file. From this file it was possible to identify 2,231 children, aged 10–16 yrs who were presently active in clubs using the selected arenas or had been active during any of the 3 yrs prior to the study. In the winter of 1999 a questionnaire was sent to the selected children and their parents. The response rate following two postal reminders was 77.8%, similar for children attending electric-powered and propane-powered arenas. One hundred and nine of the children who attended electric arenas reported that their main activity was on outdoor rinks and were excluded from analysis. Furthermore, children in electric arenas with mixed exposure to both types of resurfacing machines were also excluded, leaving a total of 1,535 children for the final analysis.

Questionnaire and health outcome measurements

The questionnaire had 57 questions, including 10 on symptoms of atopic diseases identical to those in the International Study of Asthma and Allergies in Childhood (ISAAC-1) for children aged 13–14 yrs [9]. Furthermore, questions on "physician-diagnosed asthma" and asthma medication were added. To estimate the exposure to NO_2, questions on physical exercise in ice arenas, training intensity and use of more than one arena were included. Questions on living conditions, household pets (past and present), household smoking (past and present) and parental history of allergic disease were also included. The parents were given instructions to complete the questionnaire together with their child.

Nitrogen dioxide monitoring

At the time of distribution of the questionnaires ambient NO_2 was measured inside and outside all the selected arenas. In addition to the propane- or electric-powered resurfacing machines, all arenas used ice edgers powered by combustion engines. The resurfacing machines were used daily on average ~1 h and the edgers were usually used once or twice a week for ~15 min. The measurements were started on the day before the "special ice-care day", when the resurfacing machine was operated for a longer time and the edger was used. NO_2 concentrations were determined by passive diffusion samplers at three different locations in each arena during 3 consecutive days. Each sampler was in use for 1 day only. At each arena two samplers were located near the rink (goal and rink-side) and one outside.

The samplers were in position during open hours, usually 13 $h \cdot day^{-1}$. To control for passive diffusion of NO_2 into the sampler when not used, a control sampler not removed from its sealed tube was used during all 3 days in each arena. The sampler was developed by the Swedish Environment Research Institute and gives time integrated NO_2 concentrations [10]. The relative SD between duplicate samplers has been estimated as <4% and the concentrations are within ±15% of those obtained by volumetric techniques.

Statistical analysis

Comparisons between children exposed to propane-powered and electric-powered resurfacing machines were performed by estimating odds ratios (OR) and 95% confidence intervals (CI), using logistic regression analysis. Adjustment was made for sex and family history of allergic disease. Other potential confounders, such as keeping furred pets, a smoking mother or condensation on window panes during wintertime, did not influence the OR and were not included in the regression models. Individuals not responding to a particular question were excluded from analysis of that question. However, missing values were ≤1% in any single question.

Ethical considerations

The Ethics Committee of Karolinska Institute, Stockholm, Sweden, approved the study and all families gave informed consent before participation.

Results

Exposure and demographic data

Of the 1,535 children in the final analysis, 969 practised in propane arenas and 566 in electric arenas. The study group included 1,470 (95.8%) males and 65 (4.2%) females, with an average age of 13 yrs (range 9–16). Data on exposure to NO_2, demographic characteristics and potential risk factors for allergy among the participating children are presented in table 1. The age and sex distribution as well as training history were similar in the two groups of children. Most children had >3 yrs of activity in the ice arenas and 79% (propane arenas) and 76% (electric arenas)

Table 1. – Demographic data and potential risk factors for asthma in children attending ice arenas with either propane-powered or electric-powered ice-resurfacing machines

	Propane	Electric
Male	932 (96.2)	537 (95.0)
Age 9–11 yrs	227 (23.4)	144 (25.6)
Age 12–13 yrs	344 (35.5)	218 (38.5)
Age 14–16 yrs	398 (41.1)	203 (35.9)
Presently active in ice arenas	771 (79.6)	434 (76.7)
>3 Yrs of activity in ice arenas	835 (86.2)	461 (81.5)
Parental history of asthma or atopy	375 (38.7)	237 (41.9)
Reported atopy#	205 (21.2)	135 (23.8)
Smoking mother	210 (21.7)	113 (20.0)
Indoor smoking at any time¶	186 (19.2)	115 (20.3)
Present household pets+	338 (34.9)	201 (35.5)
Increased humidity at home§	252 (26.0)	147 (25.9)

Data are presented as n (%). #: reported allergy to pollens or furred pets (cat, dog); ¶: household member smoking indoors at present or at any time after the birth of the child; +: furred pets (cat, dog); §: reported condensation on window panes during wintertime.

Table 2. – Concentration of nitrogen dioxide (NO_2) ($\mu g \cdot m^{-3}$) during 3 consecutive days in and outside 15 ice arenas with either propane- or electric-powered resurfacing machines#

	Propane	Electric
Subjects n	9	6
Day 1		
Indoor	238 (171, 28–978)	11 (11, 3–17)
Outdoor	12 (11, 3–30)	9 (4, 2–24)
Day 2		
Indoor	297 (190, 43–819)	9 (4, 2–24)
Outdoor	10 (9, 3–29)	24 (24, 16–31)
Day 3		
Indoor	293 (187, 45–1016)	8 (8, 1–20)
Outdoor	11 (9, 0–28)	16 (11, 11–26)
Total		
Indoor	276 (190)	11 (9)
Outdoor	11 (10)	16 (14)

Data are presented as mean (median, range) unless otherwise stated. #: the samplers were in position during open hours, usually 13 $h \cdot day^{-1}$. For each day of measurement a new sampler was used in each position.

were still active in the winter of 1999 when the present study was performed. Of the 328 children who had stopped sport activities in ice arenas during the last 3 yrs, change of sports was reported as the main reason (78%). This was equally distributed between the two groups. However, 10 children reported breathing problems when attending ice arenas (four propane, six electric) as the major cause. There was no significant difference in potential risk factors for bronchial asthma between groups, such as housing conditions, indoor dampness, parental smoking (past or present) or keeping furred pets (past or present). However, children in the electric-arena group tended to have a higher prevalence of parental history of asthma and atopy (41.9%) than children in the propane-arena group (38.7%).

Nitrogen dioxide monitoring

The results from NO_2 measurements are presented in table 2. There was a wide range of NO_2 concentrations in the nine propane arenas (28–1,015 $\mu g \cdot m^{-3}$). The measurements were consistent within the arenas, *i.e.* the range of NO_2 was small in each arena. The same arena had the lowest concentrations on all 3 consecutive days and another arena had the highest levels during all 3 days. The mean and median values were higher on the second and third day in most arenas due to longer use of resurfacing and ice-edger machines on the second or third day. The mean indoor concentrations were >20-fold higher than the mean outdoors when propane-powered resurfacing machines had been used. The highest NO_2 concentrations in the electric arenas were similar to the lowest in the propane arenas. Outdoor NO_2 concentrations tended to be similar to those inside the electric arenas.

Respiratory symptoms and allergic disorders

Overall, "ever asthma" was reported by 16% of the children and physician-diagnosed asthma by 14%. Asthma medication in the past year was used by 16%. Male children tended to have a higher prevalence of "ever asthma" (M=16%, F=11%) and physician-diagnosed asthma (M=18%, F=9%). Signs of lower and upper respiratory allergic disease, "ever asthma", physician-diagnosed asthma and asthma medication in the past year were as prevalent in the group of children attending ice arenas with propane-powered machines as in the group of children attending ice arenas with electric machines (table 3). Most children with "ever asthma" had their onset of asthma before starting hockey training or figure skating in ice arenas (63% attending propane arenas, 58% attending electric arenas). When these children were excluded there was still no difference in symptom prevalence between the two exposure groups. Remission of asthma, expressed as "ever asthma" but without current symptoms of asthma and/or asthma medication during the past year, was also similar among children practising in electric arenas (16%) and in propane arenas (13%).

In order to further assess the effect of NO_2 exposure, children who had attended propane arenas were divided into two exposure groups based on the results of the NO_2 measurements (table 4). Four of the propane arenas had NO_2 concentrations above the median of NO_2 (mean 510 $\mu g \cdot m^{-3}$, median 396 $\mu g \cdot m^{-3}$). The remaining nine arenas had a mean

Table 3. – Odds ratios (OR) and percentages for symptoms of asthma and rhinitis among children attending ice arenas using propane-powered resurfacing machines in relation to children from arenas using electric-powered machines

	Propane	Electric	OR# (95% confidence interval)
Asthma			
Wheezing ever	183 (18.9)	121 (21.4)	0.9 (0.7–1.1)
Wheezing 12 months	127 (13.1)	83 (14.6)	0.9 (0.7–1.2)
Exercise wheeze	103 (10.6)	76 (13.4)	0.8 (0.6–1.1)
Asthma ever	144 (14.9)	96 (17.0)	0.9 (0.7–1.2)
Asthma diagnosed by physician	133 (13.7)	84 (14.8)	1.0 (0.7–1.3)
Asthma medication 12 months	148 (15.3)	95 (16.8)	0.8 (0.5–1.3)
Rhinitis¶			
Nose symptoms ever	251 (26.0)	158 (27.8)	0.9 (0.7–1.1)
Nose symptoms 12 months	214 (22.1)	142 (25.1)	0.9 (0.7–1.1)

Data are presented as n (%) unless otherwise stated. #: OR adjusted for parental history of asthma or atopy and sex; ¶: nose symptoms without upper respiratory infection.

Table 4. – Odds ratios (OR) and percentages for symptoms of asthma and rhinitis among children attending arenas using propane-powered resurfacing machines with high (mean 510 $\mu g \cdot m^{-3}$) concentrations of nitrogen dioxide (NO_2) in relation to children from such arenas with low (mean 89 $\mu g \cdot m^{-3}$) concentrations

	High NO_2	Low NO_2	OR# (95% confidence interval)
Asthma			
Wheezing ever	90 (21.4)	87 (16.2)	1.4 (1.0–1.9)
Wheezing 12 months	61 (14.5)	63 (11.7)	1.2 (0.8–1.8)
Exercise wheeze	49 (11.7)	51 (9.5)	1.2 (0.8–1.9)
Asthma ever	71 (16.9)	69 (12.9)	1.4 (0.9–2.0)
Asthma diagnosed by physician	66 (15.7)	63 (11.7)	1.4 (0.9–2.0)
Asthma medication 12 months	68 (16.2)	76 (14.2)	1.2 (0.8–1.7)
Rhinitis¶			
Nose symptoms ever	130 (30.9)	114 (21.3)	1.7 (1.3–2.3)
Nose symptoms 12 months	114 (27.2)	97 (18.1)	1.7 (1.2–2.4)

Data are presented as n (%) unless otherwise stated. #: odds ratios adjusted for parental history of allergic disease and sex; ¶: nose symptoms without upper respiratory infection.

concentration of 89 $\mu g \cdot m^{-3}$ and a median concentration of 65 $\mu g \cdot m^{-3}$. Thirteen subjects attended propane arenas without known concentrations of NO_2 and are excluded from this subanalysis. Nasal symptoms, without upper respiratory infection and "ever wheeze" were more prevalent among children with high exposure levels of NO_2. There was also a tendency to increased prevalence of "ever asthma", physician-diagnosed asthma and symptoms of asthma in the high exposure group. The onset of asthma before beginning to attend ice arenas regularly was similar in the two exposure groups (low 63%, high 62%). There was no significant difference in years of indoor hockey activities, training intensity and/or potential risk factors for development of atopic disease among children in the high and low NO_2-exposure groups.

The study area mainly consisted of small communities and rural areas except for the city of Gävle. To minimise potential effects of other sources of air pollution, further analysis was made after exclusion of the 102 children exercising in the two electric arenas in Gävle. However, the results remained unchanged. The present study was conducted during February and March, *i.e.* before the pollen season. Exclusion of children reporting symptoms related to furred pets and/or pollen also did not change the results.

Discussion

In this study there was no difference in the prevalence of asthma among children playing hockey or figure skating in ice arenas with propane-powered ice-resurfacing machines compared to children in ice arenas with electric machines, despite high exposure to NO_2 during several years in the former group. However, there appeared to be a difference within the group of children attending ice arenas using propane-powered resurfacing machines. Among children exposed to very high concentrations of NO_2, upper respiratory symptoms and "ever wheeze" were more common compared to children exposed to lower concentrations, suggesting an exposure-response relationship.

Inhalation of extremely high concentrations of NO_2 can induce toxic pneumonitis and pulmonary oedema. Controlled exposure studies show an increased bronchial hyperresponsiveness in normal subjects at concentrations >2,000 $\mu g \cdot m^{-3}$ and >200 $\mu g \cdot m^{-3}$ in asthmatics [6, 11]. However, little is known about the impact of frequent, short-term exposure to high concentrations of NO_2. In the present study of ice arenas, NO_2 concentrations ranged from 29–1,015 $\mu g \cdot m^{-3}$ (mean 276 $\mu g \cdot m^{-3}$), and concentrations of the same magnitude of NO_2 have been reported by others [6, 7]. The wide range of concentrations could probably be explained by differences in ventilation systems, type and function of catalytic converter, size of the arena and activity on the ice.

The prevalence of "ever asthma" was 16% compared to 10.8% in a Swedish part of the ISAAC study investigating 13–14-yr-olds [12]. Conversely, symptoms of asthma and rhinitis were not more frequent than in the ISAAC study. Exercise is an important provoking factor for asthma in individuals with bronchial hyperreactivity. Physically active children may have an increased perception or awareness of respiratory symptoms, which may explain the high prevalence of asthma in the present study. Sports are often recommended in asthmatic children as one of the cornerstones in asthma treatment. This may contribute to the high prevalence of asthma among athletic children also shown by other investigators [13]. However, the increase of the asthma prevalence in the present study could also be due to a true increase of the asthma occurrence among children attending ice arenas. Recently, several studies have indicated a relationship between athletics and asthma. Thirty one per cent of Swedish elite cross-country skiers have exercise-induced asthma [14]. In a Swiss study, it was demonstrated that ice hockey players had higher prevalence of asthma and bronchial hyperresponsiveness than floor ball players [15]. An American investigation involving 121 elite ice skaters showed exercise-induced bronchoconstriction in 35% of the skaters [16]. However, neither of the two latter studies presented objective measurements on air quality. It was suggested that exercising on ice at temperatures ~5–10°C, compared to training at higher temperatures, could induce bronchial hyperresponsiveness.

Questionnaire-based information on prevalence is widely used in asthma epidemiology in combination with cross-sectional methodology. This design has disadvantages related to control of certain types of bias, such as recall bias. Conversely, the question on "physician diagnosed asthma" is shown to have very high specificity, near 100%, and a sensitivity of about 70% in a study with similar design and age group [17]. However, a poor sensitivity has less effect on the estimation of OR than poor specificity of the health outcome assessment [18].

Selection bias could contribute to the lack of difference in symptom prevalence between propane arenas and electric arenas. The insurance file that was used to identify study subjects only registered children from the age of 10 when they become licensed players in Sweden. Consequently, children who stopped hockey or figure skating before that age were not included and some children may have experienced more discomfort in the propane arenas and quit or changed sports before the age of ten. The fact that children in electric arenas showed a tendency to report more atopy and parental atopy supports this hypothesis. Furthermore, it is possible that some children in the electric-arena group had regular activities in propane arenas during tournaments and matches, contributing to a smaller exposure contrast and difficulties in detecting exposure-related differences in health outcomes.

In conclusion, children with >3 yrs of frequent exposure to very high concentrations of nitrogen dioxide in ice arenas using propane-powered ice-resurfacing machines did not have a higher prevalence of asthma or rhinitis than children in ice arenas using electric resurfacing machines. However, children exposed to the highest concentrations of nitrogen dioxide had more respiratory symptoms, particularly nasal symptoms, than children exposed to lower concentrations. Furthermore, the overall prevalence of asthma appears high among children playing ice hockey.

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