Int Arch Occup Environ Health (2006) 80: 32–39
DOI 10.1007/s00420-006-0100-0

ORIGINAL ARTICLE

Benoit Lévesque · Jean-François Duchesne
Suzanne Gingras · Robert Lavoie · Denis Prud'Homme
Emmanuelle Bernard · Louis-Philippe Boulet
Pierre Ernst

The determinants of prevalence of health complaints among young competitive swimmers

Received: 28 July 2005 / Accepted: 20 February 2006 / Published online: 4 April 2006

Abstract Objectives: Chloramines, which are produced by the reaction of chlorine with the organic matter present in indoor pools, are potential airway irritants in swimmers. The objective of this study was to compare the prevalence of health complaints of young swimmers and young indoor soccer players and to evaluate the relationship between chloramine concentrations and the athletes' health complaints. Methods: Health complaints were first (Part 1) documented by questionnaire in 305 competitive swimmers and 499 indoor soccer players of the Québec City region (Canada). Then, (Part 2) health complaints were documented during five training sessions in 72 competitive swimmers in comparison to 73 soccer players. The chloramines in the swimming pool air and water were measured as well as the peak expiratory flow (PEF) before and after the training session. Results: In Part 1, the swimmers reported more lower (adjusted OR: 1.5; IC95% = 1.0–2.2) and upper respiratory symptoms (adjusted OR: 3.7; IC95% = 2.4–5.8). In Part 2, the swimmers experienced more frequent lower (adjusted OR: 3.5; IC95% = 2.0–6.0) and upper respiratory symptoms (adjusted OR: 3.1; IC95% = 1.8–5.4). Overall, swimmers exposed to the highest levels of chloramines in the air and water had more respiratory complaints. Conclusions: Swimmers exposed to chlorination by-products in both the water and air of indoor swimming pools experience frequent respiratory symptoms that could potentially be reduced by limiting exposure to these products.

Keywords Asthma · Wheezing · Respiratory diseases · Chlorine byproducts · Swimming pool

B. Lévesque (✉) · S. Gingras
Institut national de santé publique du Québec,
945 Ave Wolfe, G1V 5B3 Sainte-Foy, Québec, Canada
E-mail: benoit.levesque@inspq.qc.ca
Tel.: +1-418-6505115
Fax: +1-418-6543144

J.-F. Duchesne · B. Lévesque · S. Gingras
Unité de recherche en santé publique du CHUL-CHUQ,
945 Ave Wolfe, G1V 5B3 Sainte-Foy, Québec, Canada

R. Lavoie · L.-P. Boulet
Hôpital Laval, Université Laval, Sainte-Foy,
Québec, Canada

D. Prud'Homme · E. Bernard
School of Human Kinetics, Faculty of Health Sciences,
University of Ottawa and Behavioral and Metabolic Research
Unit, Montfort Hospital, Ottawa, Ontario, Canada

P. Ernst
Department of Medicine, McGill University,
Montréal, Québec, Canada

Introduction

Swimming is one of the most popular sports worldwide. It has been mentioned as an exercise that asthmatics might do to be less susceptible to exercise-induced asthma (Fitch and Morton 1971). It is also reported that swimming might improve physical conditioning and reduce the frequency of attacks and episodic wheezing, thus leading to a reduction in the need for medication, visits to emergency and school absenteeism (Potts 1996). However, the beneficial effects of swimming for asthmatics have been challenged (Anonymous 1979, Mustchin and Pickering 1979, Penny 1983), in part due to the potential adverse consequences of exposure to the irritant effects of chlorine and its derivatives.

Chlorine-based compounds are the basic disinfectants generally used in pool treatment. The reactions that occur between chlorine and organic matter result in the formation of by-products, including chloramines (monochloramines, dichloramines, nitrogen trichloride). Nitrogen trichloride is a volatile compound that has been shown to be a powerful upper respiratory irritant (Gagnaire et al. 1994).

The aim of the present study was to examine the effects of swimming in indoor pools on the health of competitive swimmers. The specific objectives were to compare the prevalence of health problems, particularly respiratory symptoms, in swimmers and indoor soccer players, to document the chloramine concentrations in the water and ambient air to which young competitive swimmers are exposed daily, and to evaluate the relationship between this exposure and health problems during the swimmers' training sessions.

Materials and methods

The study was approved by the Laval University Faculty of Medicine's Ethics Committee. It was conducted in accordance with national and institutional guidelines for the protection of human subjects.

Part 1

A questionnaire was sent to 600 competitive swimmers in the Québec City region (Canada) and 910 indoor soccer players listed in the register of their respective regional association in winter 2002. A reminder was sent two weeks after the first mailing.

The self-administered questionnaire was developed from questionnaires used by Potts (Potts 1994) and by the International Study of Asthma and Allergies in Childhood (ISAAC 1998). The swimmers and soccer players were mainly asked about respiratory or irritative symptoms that they generally felt when they practiced, such as cough, lung congestion, expectoration, sneezing, wheezing, breathing difficulties, throat and eye irritation, and headache. Some symptoms were grouped to represent lower or upper respiratory disease (Gold et al. 1989, Monto et al. 1971). The athlete's medical history (lifetime asthma diagnosed by a physician, allergies, skin problems, ear infections in the last year, other health problems) including the taking of medication as well as the family history of asthma and allergies were also documented. Finally, the questionnaire provided information on the athletes' sociodemographic characteristics (age, sex, socioeconomic status), number of years of training, number of training sessions per week and smoking habits.

The chi-square test (χ^2) or the Fisher test was used, whenever appropriate, to compare the proportions of different variables for the swimmers and soccer players. For the different symptoms, the crude and adjusted odds ratios (OR), for swimmers compared to soccer players, were calculated using logistical regression models. The adjustment variables were selected among those statistically associated with the type of sport (soccer or swimming; $p \leq 0.15$), and their potential modifying or confounding effects were verified (with interaction term, comparison of crude and adjusted OR and stratified analysis). The statistical significance level was established at 5%.

Part 2

The subjects participating in Part 2 were already included in Part 1. After signing a consent form approved by the Laval University Faculty of Medicine's Ethics Committee, a total of 72 competitive swimmers aged 8 to 22 years who trained a minimum of three times per week for 1.5 to 3 hours per session were divided into seven teams according to the swimming pool where they trained, with approximately ten swimmers per group. The comparison group consisted of 73 soccer players between 11 and 17 years of age also training intensively, divided into four teams (from four different gymnasiums). All subjects were seen during five different training sessions.

Peak expiratory flow (PEF) was measured three times in each of the five training sessions with a Mini-Wright™ peak flow meter (Ferraris, NY, USA). The PEF was measured before training (T0), and then five (T1) and ten (T2) minutes after the end of training. On each occasion, the participant had to perform three consecutive tests. The highest of the three measurements was used in the analyses.

Each subject evaluated his own intensity of effort during training sessions using an adaptation of the Borg scale, ranging from very light to very difficult (Borg 1970).

After each five training session, the participants had to complete a questionnaire on health complaints felt during training. This questionnaire dealt with respiratory symptoms (difficulty breathing, lung congestion, wheezing respiration with or without cold, cough, expectoration, sneezing, nose irritation, throat irritation, nasal congestion) as well as eye irritation and headache. Respiratory problems were grouped to represent lower and upper respiratory symptoms (Gold et al. 1989, Monto et al. 1971). Eye irritation and headache were the two other categories of symptoms.

For the swimming pools, air samples were collected to measure the chloramine concentration in the air. Sampling was done using the technique developed by Hery (Hery et al. 1995). The air samples were collected a few centimeters above the water surface using four pumps (Gilian HFS113-A) at a flow rate of 1 L/min for the entire training session. The pumps were placed in pairs along the edge of the swimming pools (at the center and at one end of the swimming pool). The mean of the results for the two pumps gave the sampling station's exposure value.

The swimming pool water was sampled twice (start and end of training session) in order to determine the concentrations of chlorine and chloramines, and the pH. The samples were collected in 1-liter polyethylene containers and analyzed 10 hours after sampling using a colorimetric DPD (*N*,*N*-diethyl-*p*-phenylenediamine) method (Sigma-Aldrich, Oakville, Canada). The readings were taken on a manual spectrophotometer (Stasar III, Gilford Instruments, Canada). The pH at 25°C was measured on an ABL 625 system from Radiometer

Medical (Copenhagen, Denmark). For each of the aqueous parameters, the mean of two measurements was reported for each swimming pool.

Health problems in swimming pools can be related to exposure to microbiological organisms. To detect microbiological organisms, a water sample was collected at the end of the training session using 250-ml sterile plastic bottles containing 5 ml of sodium thiosulfate (1%). The sample was stored at 4°C. The microbiological analyses were done within 12 hours to count the heterotrophic bacteria, *Pseudomonas aeruginosa* and total and fecal coliform using techniques recommended by the American Public Health Association (APHA 1998).

We studied the relationships between the occurrence of the health complaints reported during the five training sessions in each sport (swimming vs indoor soccer) and in relation to the level of chloramines in the air and water for swimmers. Swimmers were considered as more exposed if they trained in the swimming pools with chloramine concentrations above the median, in the air (0.37 mg/m^3) or in the water (0.63 mg/l). For the different relationships studied, we calculated the crude and adjusted odds ratios as a function of the relevant variables using logistical regression analysis for repeated measures with a generalized estimating equations approach (Zeger and Liang 1986). Variables that were significantly different between groups and those associated with health complaints (among sex, age, asthma and allergies) in bivariate analysis were included initially in a multivariate model. The final multivariate model considered exposure (sport, level of chloramines in air and water for swimmers), the potential confounders and other variables associated with health complaints ($p \leq 0.05$). The modifying effects of sex and age were also systematically evaluated.

The magnitude of the change in PEF between the start and end of the training session was evaluated by calculating, for each of the participants, delta (Δ) PEF in relation to time T0 for the intervals T0 to T1 [(T1 - T0)/T0 × 100] and T0 to T2 [(T2 - T0)/T0 × 100]. The means of the Δ were compared for the two sports by repeated-measures analysis of variance, with adjustment, if necessary, for the number of training sessions per week. We also calculated the proportion of athletes who developed at least a 10% reduction in PEF during at least one of the training sessions. The proportions obtained were compared for the two sports using the chi-square (χ^2) test in relation to the time interval and the fact of having asthma. Finally, we measured the coefficient of variation (CV) of the three PEF values measured per training session for each individual (Aggarwal et al. 2000). The means of the individual CV for each of the groups (swimmers, soccer players, swimmers more or less exposed to the chloramines in the air and water) were compared by repeated-measures analysis of variance and adjustments for the pertinent variables as needed.

Results

Part 1

A total of 305 swimmers and 499 soccer players answered the questionnaire for response rates of approximately 50% and 55% respectively.

The proportion of girls was higher for the swimmers, who were also generally older than the soccer players (Table 1). The swimmers trained significantly more often and had been training for more years than the soccer players. The socioeconomic indicators, as documented by family income ($p=0.55$) and parents' education ($p=0.53$), and the individual susceptibility factors for respiratory diseases (Table 1) were comparable between the two groups.

Overall, the prevalence of symptoms was higher for the competitive swimmers than for the soccer players (Table 2). Except for wheezing and lung congestion during the training sessions, a diagnosis of lifetime asthma and the occurrence of otitis media in the last year, the prevalence of health complaints was significantly different in the two groups. The odds ratios adjusted for age, sex and the number of training sessions per week show that swimming is associated with an increase in the reporting of lower respiratory symptoms, cough, upper respiratory symptoms, sneezing, throat irritation, eye irritation, and otitis externa in the last year. Similar relationships were observed after stratifications by age and sex.

Part 2

The 72 competitive swimmers who participated in Part 2 were generally comparable to the 73 soccer players with regard to the subject's characteristics, except for the parents' level of education, the number of training sessions per week and the intensity of effort during training, which were higher for the swimmers (Table 3). Duration of training was longer for soccer players.

The pH values in the seven swimming pools varied between 7.13 and 7.56 (mean = 7.33). No coliform or *Pseudomonas aeruginosa* was detected in the water samples collected in the swimming pools. Furthermore, 61% of the samples were positive for heterotrophic bacteria but the counts did not exceed 32 colony forming units per ml (data not presented). The concentrations of chloramines in the water and air of the seven swimming pools varied respectively between 0.45 mg/l and 1.03 mg/l (mean = 0.54 mg/l) and between 0.26 mg/m^3 and 0.41 mg/m^3 (mean = 0.34 mg/m^3). The Pearson correlation coefficient for the correlation between the concentrations in air and water was 0.4 ($p= 0.02$).

For the chloramines in both the air and water, the highest level of exposure was found in younger swimmers (aged 12 years and under, 13 to15 years, 16 years or more; air: $p=0.007$; water: $p< 0.001$) and those who

Table 1 Description of the participants in the questionnaire survey (Part 1)

	Swimmers (n = 305) %	Soccer players (n = 499) %	*P*
Sex			
Boys	33.2	59.5	< 0.001
Girls	66.8	40.5	
Age			
12 and under	42.9	67.6	< 0.001
13 to 15 years of age	36.3	27.1	
16 years of age or more	20.8	5.4	
Training sessions per week			
1 to 3 times	33.0	85.4	< 0.001
4 times or more	67.0	14.6	
Years of training			
3 years or less	45.1	65.9	< 0.001
4 years or more	54.9	34.2	
Active smokers			
13 to 15 years of age	0	0.8	1.000[a]
16 years of age or more	1.6	4.0	0.495[a]
Individual susceptibility factors for respiratory diseases			
Lifetime asthma	15.4	13.2	0.417
Medication for asthma	3.9	3.9	0.985
Wheezing in the last 12 months	19.2	15.7	0.203
Family asthma diathesis	20.7	21.5	0.802
Hay fever	7.5	7.6	0.968
Other allergies	43.6	37.8	0.121
Family allergic diathesis	67.8	66.3	0.655

[a]Fisher test

Table 2 Prevalence of health complaints reported by competitive swimmers and indoor soccer players (Part 1)

Symptoms	Swimmers (n = 305) n (%)[b]	Soccer players (n = 499) n (%)[b]	Crude OR (IC 95%)	Adjusted OR[a] (IC 95%)
During training				
Lower respiratory symptoms	118 (39.5)	106 (21.7)	2.4 (1.7–3.2)	1.5 (1.0–2.2)
Cough	77 (25.6)	68 (13.7)	2.2 (1.5–3.2)	1.7 (1.1–2.7)
Lung congestion	26 (8.6)	30 (6.1)	1.4 (0.8–2.5)	0.9 (0.4–1.7)
Wheezing	28 (9.3)	30 (6.1)	1.6 (0.9–2.7)	0.7 (0.4–1.4)
Breathing difficulties	71 (23.5)	46 (9.3)	3.0 (2.0–4.5)	1.5 (0.9–2.6)
Upper respiratory symptoms	117 (38.9)	64 (13.2)	4.2 (2.9–5.9)	3.7 (2.4–5.8)
Sneezing	90 (29.8)	21 (4.3)	9.4 (5.7–15.6)	7.2 (4.0–13.1)
Throat irritation	56 (18.7)	51 (10.3)	2.0 (1.3–3.0)	2.1 (1.3–3.5)
Eye irritation	112 (37.1)	20 (4.1)	13.9 (8.4–23.0)	11.9 (6.7–21.0)
Headache	87 (29.2)	95 (19.4)	1.7 (1.2–2.4)	1.1 (0.7–1.7)
Other problems				
Skin problems	61 (21.3)	48 (10.0)	2.4 (1.6–3.6)	1.5 (0.9–2.6)
Otitis externa in the last year	76 (25.9)	27 (5.6)	6.0 (3.7–9.5)	4.4 (2.5–7.7)
Otitis media in the last year	39 (13.3)	43 (8.9)	1.6 (1.0–2.5)	1.5 (0.9–2.7)
Lifetime asthma	43 (15.4)	63 (13.2)	1.2 (0.8–1.8)	1.0 (0.6–1.8)

[a]Adjusted for age, sex and the number of training sessions per week
[b]For some variables, the percentages were not calculated for the total participants due to missing data

trained less often per week (1 to 3 times, 4 times and more; air: $p = 0.003$; water: $p < 0.001$). There was also a significant difference between the two groups regarding the number of years of training (3 years or less, 4 years or more; $p < 0.001$) in relation to exposure by water. Swimmers with the highest exposure had fewer years of training. The mean duration of training sessions in minutes ($p = 0.006$) and the intensity of effort (very light, light, average, difficult, very difficult; $p < 0.001$) were higher for the highest level of exposure to chloramines in the air.

The prevalence of health complaints during the five training sessions was higher for the swimmers than the soccer players for lower respiratory symptoms, upper respiratory symptoms and eye irritation (Table 4). The swimmers most exposed to the chloramines in the air had significantly more upper respiratory symptoms and more eye irritation (Table 4). Lower respiratory symptoms were significantly more frequent in the swimmers most exposed to the chloramines in the water. Similar relationships were observed after stratifications by age and sex.

Table 3 Variables significantly different between swimmers and soccer players in Part 2

	Swimmers (n = 72) %	Soccer players (n = 73) %	*p*
Training sessions per week			
1 to 3 times	18.6	40.9	0.009
4 times or more	81.4	59.1	
Parents' education			
Secondary	6.1	29.6	0.003
College	30.3	18.2	
University	63.6	52.3	
Intensity of effort[a]			
Very light	11.8	11.2	< 0.001
Light	25.1	28.6	
Average	21.1	38.4	
Difficult	27.6	18.3	
Very difficult	14.6	3.6	
Duration of training (mean, sd in minutes)[b]	87.9 (18.0)	93.3 (14.5)	< 0.001

[a]Proportions were based on all five training sessions and p value were obtained with repeated measures analysis
[b]Means and standard deviation were based on all five training sessions and p value were obtained with repeated measures analysis

Table 4 Prevalence of health complaints in relation to the level of exposure to chloramines (Part 2)

Symptoms				
Prevalence in relation to sport	Soccer players (%)[b]	Swimmers (%)[b]	Crude OR[a] (CI 95%)	Adjusted OR[a] (CI 95%)
Lower respiratory symptoms[c]	18.2	46.4	3.6 (2.1–6.1)	3.5 (2.0–6.0)
Upper respiratory symptoms[d]	28.0	51.4	2.9 (1.7–4.8)	3.1 (1.8–5.4)
Eye irritation[e]	4.0	14.6	4.0 (1.5–11.0)	5.7 (1.1–28.3)
Headache[f]	8.0	8.1	1.0 (0.4–2.3)	0.7 (0.3–1.7)
	Less exposed (%)[b]	More exposed (%)[b]		
Prevalence in relation to the chloramines in the air for the swimmers[g]				
Lower respiratory symptoms[c]	40.4	51.4	1.6 (0.8–3.3)	1.3 (0.6–2.6)
Upper respiratory symptoms[d]	39.0	61.6	2.6 (1.3–4.9)	2.2 (1.0–4.8)
Eye irritation[e]	3.4	23.7	9.4 (3.6–25.0)	4.9 (1.9–12.5)
Headache[h]	8.2	7.9	0.9 (0.3–2.7)	0.4 (0.1–1.1)
Prevalence in relation to the chloramines in the water for the swimmers[i]				
Lower respiratory symptoms[d]	38.9	52.5	1.7 (0.8–3.5)	2.3 (1.0–5.2)
Upper respiratory symptoms[d]	54.2	49.2	0.8 (0.4–1.6)	0.8 (0.3–1.7)
Eye irritation[e]	19.4	10.6	0.5 (0.2–1.1)	0.5 (0.3–1.2)
Headache[h]	9.0	7.3	0.7 (0.2–2.3)	0.5 (0.2–1.5)

[a]Calculated with repeated-measures analyses
[b]Percentage calculated by dividing the number of training sessions for all individuals with a health problem by the total number of training sessions carried out by all the swimmers
[c]Odds ratios adjusted for self-report effort and duration of training
[d]Odds ratios adjusted for age, self-report effort and duration of training
[e]Odds ratios adjusted for allergies and duration of training
[f]Odds ratios adjusted for self-report effort
[g]Swimmers exposed to an average concentration of less than 0.37 mg/m^3 versus 0.37 mg/m^3 or more
[h]Odds ratios adjusted for sex and self-report effort
[i]Swimmers exposed to an average concentration of less than 0.63 mg/l versus 0.63 mg/m^3 or more

The mean Δ PEF were low ($|\Delta| \leq 2.01\%$) for the intervals T0 to T1 and T0 to T2 in the two groups of athletes. The mean Δ was negative for the soccer players for the interval T0 to T2 (-0.32%) and was significantly different from that obtained for the swimmers (2.01%) ($p = 0.038$). The mean of the coefficient of variation of the PEF values for the swimmers (5.86%) tended to be higher than that for the soccer players (5.11%) ($p = 0.054$).

Overall, the proportion of swimmers and soccer players who, at least once during the five training sessions, had a 10% or more drop in PEF with respect to time T0 was not significantly different ($p > 0.300$). According to the time interval evaluated and the analysis with or without asthmatics, these proportions varied between 14.1% and 22.2% for swimmers and between 20.3% and 24.7% for soccer players.

In the swimmers, there was no significant difference ($p > 0.120$) between the means of the Δ PEF for the intervals T0 to T1 (range 0.82% to 1.17%) and T0 to T2 (1.38% to 2.82%) based on the level of exposure to the chloramines in the air and water. However, the means of the PEF coefficients of variation in the swimmers most exposed to the chloramines in the air and water were significantly higher (5.85% and 5.08% respectively) than those measured in the swimmers least exposed to these contaminants (4.44%, $p = 0.006$, and 3.81%, $p = 0.001$ respectively).

Discussion

The participation rates in Part 1 were similar for the swimmers and indoor soccer players, being slightly more than 50% in both cases. It was impossible to obtain data to compare the participants to the nonparticipants. The two groups of athletes in Part 1 differed in the girl/boy ratio, which was higher in the swimmers, as well as in training intensity and duration, with the swimmers being more trained in both cases. However, the two groups were comparable as to socioeconomic indicators and individual susceptibility factors for respiratory diseases, namely smoking and a family asthma and allergic diathesis as well as a prevalence of hay fever, other allergies and asthma. In this regard, the 15.4% and 13.2% of asthmatic subjects among swimmers and soccer players respectively, are comparable to what was reported in a survey conducted by questionnaire that found prevalences varying between 14.1 and 15.2% for representative samples of young Quebecers 9, 13 and 16 years of age (ISQ 2002). From these data and the relatively similar participation rate for the two groups, the low participation rate does not seem to be associated with a selection biais, and if so, it would be non differential.

Symptoms during training were reported more frequently by swimmers than indoor soccer players. However, wheezing during training and the reporting of lifetime asthma were comparable for the two groups.

In British Columbia, Potts (Potts 1994) found, using a questionnaire, a 13.4% prevalence of asthma diagnosed by a physician in 738 competitive swimmers and 20.6% for those doing high level swimming. Also, 27% and 23% of the swimmers, respectively, said that they had fits of coughing and wheezing during their swimming sessions. In this study, 26% of the swimmers said they coughed during their training, a proportion similar to that documented by Potts, but only 9.3% said they suffered from wheezing.

Despite some methodological differences that affect comparisons, several studies have shown higher prevalences of asthma (Helenius et al. 1998a, Langdeau et al. 2000, Potts 1994, Weiler et al. 1998, Weiler and Ryan 2000) and airway hyperresponsiveness (AHR) (Helenius et al. 1998a, Helenius et al. 1998b, Langdeau et al. 2000, Potts 1994, Zwick et al. 1990) in athletes than in the general population. Among athletes, even if there are some conflicting results (Langdeau et al. 2000), swimmers seem more at risk of having asthma (Helenius et al. 1998a, Helenius et al. 1998b, Weiler et al. 1998). However, it is clear that they more frequently present AHR (Helenius et al. 1998a, Helenius et al. 1998b, Langdeau et al. 2000). Helenius et al. (Helenius et al. 2002) followed 42 swimmers for 5 years, and 26 (62%) stopped swimming before the follow-up examination. The prevalence of asthma based on asthma symptoms and AHR increased from 31% (5/16) to 44% (7/16) during the five years for the active swimmers but decreased from 23% (6/26) to 4% (1/16) for the old swimmers ($p = 0.025$). The authors concluded that asthma in swimmers seems partially reversible and that it can develop during and disappear after a sports career.

The water sampled in the seven swimming pools visited in the Part 2 study was of good microbiological quality and met the criteria suggested by the World Health Organization (World Health Organization 2000). The mean concentrations of chloramines in the air varied from 0.26 to 0.41 mg/m^3, which is the same order of magnitude as those documented using the same technique in France (Hery et al. 1995, Massin et al. 1998). There was a weak correlation between the concentrations in air and water ($r = 0.4$, $p = 0.02$). Theoretically, these variables should be strongly related but the correlation depends on the ventilation in the different buildings.

In Part 2, as in Part 1, swimmers experienced more frequent symptoms of irritation of the eyes and respiratory tract than soccer players. These symptoms were associated with exposure to chloramines, particularly in the air. Hery et al. (Hery et al. 1995), after having correlated health complaints of swimmers with exposure to chloramines in the air of 13 swimming pools, suggested a reference limit of 0.5 mg/m^3. In the context of the actual study, the swimmers were divided on the basis of an exposure above 0.37 mg/m^3 and the results show more frequent symptoms with the most exposed individuals. Consequently, if a reference limit were to be suggested, it would be below this value. Massin et al. (Massin et al. 1998) used the same measurement technique to verify the concentrations of chloramines in the air of 63 indoor pools and their relationship to chronic and irritative respiratory symptoms in 334 lifeguards. The authors demonstrated a link between exposure and symptoms of ocular or respiratory tract irritation but not with chronic respiratory symptoms. There also was no relationship between exposure and AHR.

In the current study, there was no drop in PEF in swimmers during training and there was no difference between the swimmers and soccer players in relation to the proportion of subjects who had a 10% reduction after training. However, a significantly increased variability in PEF in swimmers in relation to chloramine exposure both in the air and water was noted. Some authors consider that an increased variation in diurnal PEF can be an indicator of AHR (Quackenboss et al. 1991, Zureik et al. 1995).

Thickett et al. documented occupational asthma in two lifeguards and one swimming instructor and attributed this to chloramine (nitrogen trichloride) exposure (Thickett et al. 2002). Furthermore, Bernard et al. showed an increase in serum pneumoproteins (SP-A, SP-B, SP-B/CC16 ratio) during a visit to an indoor swimming pool, a relationship between these pneumoproteins and the cumulative use of swimming pools by children, and a possible link between asthma and swimming indoors (Bernard et al. 2003).

Swimming is a complete sport with enormous advantages. In Part 1 of this study, none of the 110 swimmers from 13 to 15 years of age was an active smoker, and only 1 (1.6%) of the 63 young people 16 years of age or older smoked showing that young swimmers do not expose themselves to this important risk factor for respiratory diseases. In the social and health survey of Québec children and adolescents, the proportions were 5% for young people 13 years of age, and 23% for adolescents 16 years of age (ISQ 2002). Furthermore, of the participants in Part 2 for which there were anthropometric measurements, only 4 swimmers out of 72 (5.5%) were overweight and none was obese. On the other hand, the proportion of young Quebecers 9, 13 and 16 years of age who were overweight varied from 10.9% to 12.6%, and the proportions of individuals truly obese, from 3.2% to 4.2% (ISQ 2002). These statistics alone reveal the importance of continuing to promote physical activity, including swimming, among the different sports promoted in the population.

The current study has demonstrated that swimmers have more irritative symptoms than soccer players in the context of practicing their sport. The study has also shown a link between the occurrence of these symptoms and chloramine concentrations, particularly in the ambient air where a significant increase in respiratory complaints was noted at levels in the air of 0.37 mg/m^3 or greater. However, it did not show a relationship between wheezing and swimming for a highly exposed population. Nevertheless, the long-term effects of such exposure remain to be established. The overall results and the review of the literature have shown the importance of limiting exposure to chlorination by-products in both the water and air of indoor swimming pools.

Even though treatment processes already exist for reducing and even eliminating chlorination (ozone, ultraviolet, Cu/Ag), it seems that for various reasons (economic, effectiveness...), the replacement of existing chlorination systems would be unrealistic over the short term. Also, research should be undertaken to improve the systems in order to eliminate the by-products likely to be harmful to users and workers. In the meantime, regulatory agencies should take into consideration potential air quality problems in indoor pools by including ventilation criteria and precise chlorination parameters suitable for countering the microbiological hazards. This could be achieved by attempting to limit the generation of harmful by-products such as chloramines. For technical reasons, chloramines unfortunately cannot be measured routinely in the air; however, they can be carefully monitored in the water of swimming pools. The best guarantees against respiratory system adverse effects with indoor pools are a strengthening of hygiene measures for swimmers (shower, swimming cap, etc.) and around the swimming pool to limit the entry of organic matter, tight control of the chlorination done by competent operators with the help of automated technology, regular monitoring of the chlorination parameters, and adequate ventilation at all times.

Acknowledgements This study was conducted thanks to the financial support of the Fonds de Recherche en Santé du Québec (FRSQ) through a grant from Hydro-Québec. We thank these organizations for their support. We also want to thank all the swimmers, soccer players, trainers and swimming pool managers who took part in the project, as well as Marc Amyot, Jean-Pierre Haubert, Karl Dupuis, Sylvain Allaire, Jean Tardif, Philippe Cantin, Lise Côté, and finally, Luc Pelletier from Medigas for supplying the peak flow meters.

References

Aggarwal AN, Gupta D, Chaganti S, Jindal SK (2000) Diurnal variation in peak expiratory flow in healthy young adults. Indian J Chest Dis Allied Sci 42:15–19

Anonymous (1979) Wheezing at the swimming pool Lancet 2:1342–1343

APHA (1998) Standard method for the examination of water and wastewater. American Public Health Association, Washington, DC

Bernard A, Carbonnelle S, Michel O, Higuet S, De Burbure C, Buchet JP, Hermans C, Dumont X, Doyle I (2003) Lung hyperpermeability and asthma prevalence in schoolchildren: unexpected associations with the attendance at indoor chlorinated swimming pools. Occup Environ Med 60:385–394

Borg G (1970) Perceived exertion as an indicator of somatic stress. Scand J Rehabil Med 2:92–98

Fitch KD, Morton AR (1971) Specificity of exercise in exercise-induced asthma. Br Med J 4:577–581

Gagnaire F, Azim S, Bonnet P, Hecht G, Hery M (1994) Comparison of the sensory irritation response in mice to chlorine and nitrogen trichloride. J Appl Toxicol 14:405–409

Gold DR, Weiss ST, Tager IB, Segal MR, Speizer FE (1989) Comparison of questionnaire and diary methods in acute childhood respiratory illness surveillance. Am Rev Respir Dis 139:847–849

Helenius IJ, Rytila P, Metso T, Haahtela T, Venge P, Tikkanen HO (1998a) Respiratory symptoms, bronchial responsiveness, and cellular characteristics of induced sputum in elite swimmers. Allergy 53:346–352

Helenius IJ, Tikkanen HO, Sarna S, Haahtela T (1998b) Asthma and increased bronchial responsiveness in elite athletes: atopy and sport event as risk factors. J Allergy Clin Immunol 101:646–652

Helenius I, Rytila P, Sarna S, Lumme A, Helenius M, Remes V, Haahtela T (2002) Effect of continuing or finishing high-level sports on airway inflammation, bronchial hyperresponsiveness, and asthma: a 5-year prospective follow-up study of 42 highly trained swimmers. J Allergy Clin Immunol 109:962–968

Hery M, Hecht G, Gerber JM, Gendre JC, Hubert G, Rebuffaud J (1995) Exposure to chloramines in the atmosphere of indoor swimming pools. Ann Occup Hyg 39:427–439

ISAAC (1998) Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Lancet 351:1225–1232

ISQ (2002) Enquête sociale et de santé auprès des enfants et adolescents québécois, 1999. Direction Santé Québec, Institut de la statistique du Québec

Langdeau JB, Turcotte H, Bowie DM, Jobin J, Desgagne P, Boulet LP (2000) Airway hyperresponsiveness in elite athletes. Am J Respir Crit Care Med 161:1479–1484

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

Monto AS, Napier JA, Metzner HL (1971) The Tecumseh study of respiratory illness. I. Plan of study and observations on syndromes of acute respiratory disease. Am J Epidemiol 94:269–279

Mustchin CP, Pickering CA (1979) "Coughing water": bronchial hyperreactivity induced by swimming in a chlorinated pool. Thorax 34:682–683

Penny PT (1983) Swimming pool wheezing. Br Med J 287:461–462

Potts J (1994) Adverse respiratory health effects of competitive swimming: The prevalence of symptoms, illness, and bronchial responsiveness to metacholine and exercise. Faculty of Graduate Studies University of British Columbia, Vancouver

Potts J (1996) Factors associated with respiratory problems in swimmers. Sports Med 21:256–261

Quackenboss JJ, Lebowitz MD, Krzyzanowski M (1991) The normal range of diurnal changes in peak expiratory flow rates. Relationship to symptoms and respiratory disease. Am Rev Respir Dis 143:323–330

Thickett KM, McCoach JS, Gerber JM, Sadhra S, Burge PS (2002) Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J 19:827–832

Weiler JM, Layton T, Hunt M (1998) Asthma in United States Olympic athletes who participated in the 1996 Summer Games. J Allergy Clin Immunol 102:722–726

Weiler JM, Ryan EJ (2000) Asthma in United States olympic athletes who participated in the 1998 olympic winter games. J Allergy Clin Immunol 106:267–271

World Health Organization (2000) Draft guidelines for safe recreational-water environment: swimming pools, spas and similar recreational-water environments. Geneva

Zeger SL, Liang KY (1986) Longitudinal data analysis for discrete and continuous outcomes. Biometrics 42:121–130

Zureik M, Liard R, Segala C, Henry C, Korobaeff M, Neukirch F (1995) Peak expiratory flow rate variability in population surveys. Does the number of assessments matter? Chest 107:418–423

Zwick H, Popp W, Budik G, Wanke T, Rauscher H (1990) Increased sensitization to aeroallergens in competitive swimmers. Lung 168:111–115