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The effect of exposure to chlorine on pulmonary function tests and respiratory and allergic symptoms in Iranian lifeguards

MH Boskabady^{1,2}, M Esmaeilizadeh^{1,2} and M Boskabady^{1,2}

Abstract

Lifeguards are frequently exposed to various irritant chemicals including chlorine during work, which can induce respiratory and allergic disorders. In this study, pulmonary function tests (PFTs) and self-reported respiratory and allergic symptoms in lifeguards were compared with matched control subjects. The frequency of respiratory and allergic symptoms was evaluated in a sample of 38 Iranian male lifeguards and 38 control subjects with similar age, having other jobs from the general population, using a questionnaire including questions on work-related respiratory and allergic symptoms in the past year, smoking habits, and duration of working as a lifeguard. PFTs were also measured in lifeguard subjects before and 15 min after 200 µg inhaled salbutamol and baseline PFT in controls. A total of 22 (55%) participants reported work-related respiratory symptoms. Sputum (39.4%) and cough (18.4%) were the most common symptoms and only 7.9% and 15.8% of lifeguards reported wheezing and shortness of breath, respectively. Both sputum and breathlessness were significantly higher in lifeguards than control group ($p < 0.05$ and $p < 0.005$, respectively). Most allergic symptoms (sneezing and runny nose) in lifeguards were also significantly greater than control group ($p < 0.05$ for both cases). In addition, all respiratory (except sputum and wheezing) and allergic symptoms were significantly higher in lifeguards during work compared with rest period ($p < 0.05$ to $p < 0.005$). Most PFT values were also significantly lower in lifeguards than control subjects ($p < 0.05$ to $p < 0.001$). In addition, most (all) PFT values were significantly improved after 200 µg inhaled salbutamol ($p < 0.05$ to $p < 0.001$). These results showed that lifeguards have higher frequencies of work related respiratory symptoms and allergic symptoms particularly during the work period. PFT values were also significantly reduced among lifeguards.

Keywords

Respiratory symptoms, lifeguards, pulmonary function test, allergic symptoms, exposure to chlorine

Introduction

Swimming pools commonly are disinfected by chlorination of water with hypochlorite, chlorine gas, or chloroisocyanurates. These chlorine-based disinfectants, loosely referred to as chlorine, release in to water the hypochlorous acid, a nonselective biocide that oxidizes all forms of organic matter in pool water (Bernard, 2007; Erdinger et al., 1998). When chlorine reacts with nitrogenous compound, hypochlorous acid generates a complex mixture of harmful byproducts, among which the most irritant are the chloramines. Monochloramine and dichloramine (NH_2Cl and NHCl_2 , respectively) are water soluble. By contrast, the trichloramine also called nitrogen trichloride

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(NCl_3) is a water-insoluble gas, which gives indoor pools their distinctive 'chlorine' smell (Hery et al., 1995; Jessen, 1998). The respiratory disorders of swimmers were attributed to the irritating effects of trichloramine, the gas that gives indoor pools their typical smell and can cause asthma in lifeguards (Jacobs et al., 2007; Thickett et al., 2002).

Occupational diseases are a major concern and many studies have been conducted to determine high-risk occupations inducing respiratory diseases. Respiratory and allergic symptoms are more common among some athletes, especially those who are exposed to noxious agents (Langdeau and Boulet, 2001). For several years, it has been known that elite swimmers have a higher prevalence of respiratory symptoms, asthma, and airway inflammation than do other athletes. It was assumed that this poorer respiratory health of swimmers was the consequence of indoor swimming environment compared with other sports (Helenius and Haahtela, 2000).

Lifeguards which are exposed to chlorine have higher prevalence of respiratory and allergic disorders (Drobnic et al., 1996). The presence of a high prevalence of bronchial hyperresponsiveness and asthma-like symptoms in swimmers and swimming attendants such as lifeguards has been reported (Fjellbirkeland et al., 1995; Helenius et al., 1998). In addition, exercise-induced asthma and allergic symptoms are reported in lifeguards (Nemery et al., 2002; Zwick et al., 1990). The effects of exposure to chlorine in inducing respiratory disorders have been shown (Martinez and Long 1995). Exposure to chlorine can lead to acute lung edema, asthma, destruction of upper and lower airway mucosa, as well as airway hyperresponsiveness (Agabiti et al., 2001; Das and Blanc, 1993; Nemery, 1996; Pedersen et al., 2008; Zwick et al., 1990). Airway hyperresponsiveness, airway inflammation, and destruction of airway mucosa have also been reported in swimmers (Bougault et al., 2009a, 2009b; Helenius et al., 1998).

However, recent review articles reported that there is no definite relationship between swimming and asthma and more studies are required in this regard (Bougault et al., 2009a; Goodman and Hays, 2008). In addition, there is no information regarding respiratory disorders in lifeguards in Iran.

Therefore, the aims of this study were to assess lung function and self-reported prevalence of work related respiratory and allergic symptoms among lifeguards compared with control subjects in Mashhad city (north-east of Iran).

Table 1. Characteristic of normal subjects and lifeguards

	Normal subjects	Lifeguards
Number	38	38
Age (years)	31.83 ± 12.45	31 ± 7.51
Previous cardiovascular disease	None	None
Smoking	None	6
Daily work duration (h)	None	7.51 ± 1.2
Total work duration (years)	None	12.94 ± 10.96

Materials and methods

Population

A cross-sectional study was designed in the city of Mashhad, to assess respiratory and allergic symptoms and lung function tests in a cohort of lifeguards who has being exposed to pool chemicals including chlorine, and a control group of unexposed subjects. The study was performed on all lifeguards of two main pools of Mashhad city (Razavi and Saadabad). Therefore, the study included 38 lifeguards (male, age: mean $\pm$ SD = 31 ± 7.51 years) and 38 matched controls (male, age: mean $\pm$ SD = 31.83 ± 12.45 years). Two lifeguards and none of the control subjects were smokers (Table 1). Mean daily work in lifeguards was 7.51 ± 1.2 h (mean $\pm$ SD) and mean work history was 12.94 ± 10.96 years. The lifeguards worked in two different pools (Razavi and Saadabad) and the controls were selected from the same residential district with similar age range and job, all subjects were residents of Mashhad city. Participants were selected by nonprobable purposive method. All participants answered the designed questionnaire by a face-to-face interview. The study was approved by the ethical committee of Mashhad University of Medical Sciences, Mashhad, Iran, and all participants sign an informed consent.

Protocol

A questionnaire derived from preexisting studies (Bellia et al., 2003; Boskabady and Azdaki, 2005; Boskabady and Fasihfar, 2003; National Institutes of Health, 2007; Turcotte et al., 2003) was used to assess the respiratory and allergic symptoms. The questionnaire included questions on exposure pattern, respiratory symptoms, rhinoconjunctivitis, dermal reactions, past medical history of allergic reactions, and drug

history. Common risk factors like smoking habit, atopy and history of allergic reactions were also asked. Moreover, the participants answered questions regarding all employment period as a lifeguards (working hours per day and total working period). They also stated whether they quit working as a lifeguard for some reason for a period of more than a year. Respiratory and allergic symptoms of lifeguards were evaluated during work and rest period in the week end.

Pulmonary function tests (PFTs) in lifeguards and control subjects were measured using a spirometer with a pneumotachograph sensor (Model ST90, Fukuda, Sangyo Co. Ltd, Japan). Prior to pulmonary function testing, the PFT measurement technique was demonstrated by the operator, and the subjects were encouraged and supervised throughout the test performance. Pulmonary function testing was performed using the acceptability standards outlined by the American Thoracic Society (1995) with subjects in a standing position and wearing nose clips. All tests were carried out between 1000 and 1700 h, before starting lifeguard work. PFTs were performed three times in each subject. The highest level for forced vital capacity (FVC), forced expiratory volume in 1 s (FEV₁), peak expiratory flow (PEF), maximal mid expiratory flow (MMEF), and maximal expiratory flow at 75%, 50%, and 25% of the FVC (MEF₇₅, MEF₅₀, and MEF₂₅, respectively) were taken independently from the three measurements.

The chlorine concentration of the two pools as well as drinking water was measured using kit Palintest. Water samples of different parts of each pool and drinking water were collected and test tablets were added. The color of the water was then measured using standard solution and chlorine concentration and pH measurement had been performed.

Data analysis

The data of PFT values and age were expressed as mean $\pm$ SD and data of respiratory and allergic symptoms as percentage of each group having the corresponding symptom. Differences in the data of symptoms between lifeguards and control group were tested by chi-square analysis (2×2 contingency tables). Differences in the data of symptoms in lifeguards between work and rest period and also between the lifeguards of two pools were also tested by chi-square analysis (2×2 contingency tables). Differences in the data of symptoms between lifeguards and control group and also between rest and

working periods were tested by calculating odd ratio (OR) and the 95% confidence intervals (95% CI.). The data of PFT values between lifeguards and control groups as well as between lifeguards of two pools were tested using unpaired *t* tests. However, the comparison in PFT values before and after 200 μ g inhaled salbutamol was tested using unpaired *t* tests. A two-sided *p* value of 0.05 was the criterion for statistical significance. All analyses were performed with SPSS software (version 11.5, SPSS Inc. USA).

Results

Comparison of respiratory and allergic symptoms between lifeguards and control group

A total of 22 (55%) participants reported work-related respiratory symptoms. Sputum (39.4%) and cough (18.4%) were the most common symptoms and only 7.9% and 15.8% of lifeguards reported wheezing and shortness of breath, respectively. Both sputum and breathlessness were significantly higher in the lifeguards compared with control group ($p < 0.01$ and $p < 0.005$, respectively, Table 2). In addition, most allergic symptoms (sneezing and runny nose) in the lifeguards were also significantly greater than control group ($p < 0.05$ for both cases, Table 2).

The effect of the exposure with chlorine on respiratory symptoms and PFT values

Most respiratory (except sputum and wheezing) and all allergic symptoms were significantly higher in lifeguards during work compared with rest period ($p < 0.05$ to $p < 0.005$, Table 3). In addition, most respiratory (except sputum) and allergic (except itchy eye) symptoms were significantly higher in lifeguards of Saadabad pool compared with Razavi pool ($p < 0.05$ to $p < 0.001$, Table 4). The concentration of chlorine in Saadabad pool, Razavi pool, and drinking water were 2.0–2.5, 1.5–2.0, and 0.2–0.8 ppm, respectively. The pH of Saadabad and Razavi pools water were also 7.8–8.0 and 8.0–8.2, respectively.

Comparison of PFT values between lifeguards and control group

Most PFT values except PEF and MEF₇₅ (maximal expiratory flow at 75% of the FVC) were significantly lower in lifeguards than control subjects ($p < 0.05$ to $p < 0.001$, Figure 1). In addition, most PFT values except MMEF, PEF, and MEF₇₅ were significantly

Table 2. Comparison of RS and AS between control subjects and lifeguards^a

Symptoms		Control group		Lifeguards		OR	95% CI	Statistical difference
		No	%	No	%			
RS	Cough	4	10.5	7	18.4	1.919	0.512–7.195	NS
	Sputum	2	5.2	15	39.4	11.73	2.453–26.168	$p < 0.001$
	Shortness of breath	1	2.6	6	15.8	7.161	0.818–32.728	$p < 0.01$
	Wheezing	1	2.6	3	7.9	3.171	0.315–31.946	NS
AS	Sneezing	3	7.9	9	23.7	5.621	0.896–14.628	$p < 0.05$
	Runny nose	4	10.5	12	31.6	4.923	1.134–13.576	$p < 0.05$
	Itchy eye	3	7.9	4	10.5	1.373	0.286–6.595	NS

RS: respiratory symptom; AS: allergic symptom; NS: nonsignificant differences; OR: odd ratio; CI: confidence interval.

^aValues are presented as the number and percentage of subjects of each group having the corresponding symptoms (for each group $n = 38$).

Table 3. Comparison of RS and AS in lifeguards between rest and work period^a

Symptoms		Rest period		Work period		OR	95% CI	Statistical difference
		No	%	No	%			
RS	Cough	2	5.2	7	18.4	5.065	0.786–14.021	$p < 0.05$
	Sputum	5	13.2	10	26.3	1.905	0.614–5.909	NS
	Shortness of breath	1	2.6	7	18.4	8.355	0.974–34.650	$p < 0.005$
	Wheezing	0	0	5	8.6	–	Infinity–Infinity	NS
AS	Sneezing	1	2.6	7	18.4	8.355	0.974–34.650	$p < 0.005$
	Runny nose	2	5.2	7	18.4	5.065	0.786–14.021	$p < 0.05$
	Itchy eye	1	2.6	6	15.8	6.93	0.793–40.714	$p < 0.01$

RS: respiratory symptom; AS: allergic symptom; NS: nonsignificant differences; OR: odd ratio; CI: confidence interval.

^aValues are presented as the number and percentage of subjects of each group having the corresponding symptoms ($n = 38$).

Table 4. Comparison of RS and AS between the lifeguards of two pools (Razavi, $n = 24$ and Saadabad, $n = 14$)^a

Symptoms		Razavi		Saadabad		OR	95% CI	Statistical difference
		No	%	No	%			
RS	Cough	1	4.2	6	42.9	17.25	1.792–66.088	$p < 0.001$
	Sputum	7	29.2	8	57.1	7.238	0.817–22.828	$p < 0.01$
	Shortness of breath	3	12.5	3	21.4	1.909	0.329–11.082	NS
	Wheezing	1	4.2	2	14.3	4.833	0.315–26.693	$p < 0.05$
AS	Sneezing	4	16.7	5	35.7	4.778	0.600–18.856	$p < 0.05$
	Runny nose	5	20.8	7	50.0	4.8	0.902–16.008	$p < 0.05$
	Itchy eye	2	8.3	2	14.3	1.833	0.229–14.709	NS

RS: respiratory symptom; AS: allergic symptom; NS: nonsignificant differences; OR: odd ratio; CI: confidence interval

^aValues are presented as the number and percentage of subjects of each group having the corresponding symptoms.

increased due to 200 μg inhaled salbutamol in lifeguards ($p < 0.05$ to $p < 0.001$, Figure 2). Most PFT values except MMEF, MEF_{50} , and MEF_{25} were also significantly lower in lifeguards of Saadabad pool compared with Razavi pool ($p < 0.05$ to $p < 0.01$, Figure 3).

Discussion

The results of the present study showed significantly greater respiratory symptoms and lower PFT values in lifeguards compared with control subjects, which indicate the effect of the exposures to chlorine on respiratory status of these workers. The results also

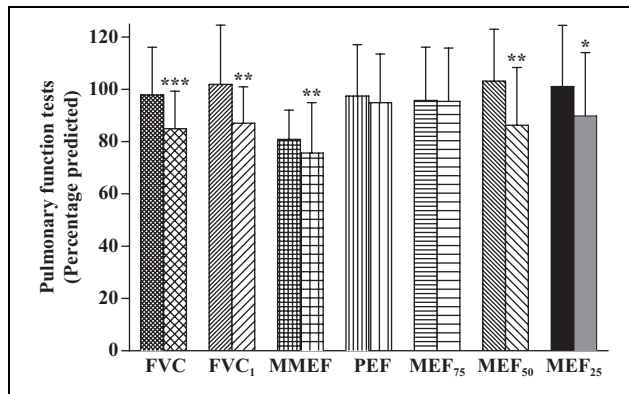


Figure 1. Comparison of PFTs between control subjects (fine-filled bars) and lifeguards (medium-filled bars, for each group $n = 38$). Values were presents as mean $\pm$ SD. Statistical significance between two groups: * $p < 0.05$; ** $p < 0.005$; *** $p < 0.001$. FVC: forced vital capacity; FEV₁: forced expiratory volume in 1s; MMEF: maximal mid expiratory flow; PEF: peak expiratory flow; MEF₇₅, MEF₅₀, and MEF₂₅: maximal expiratory flow at 75%, 50%, and 25% of the FVC, respectively; PFT: pulmonary functional test.

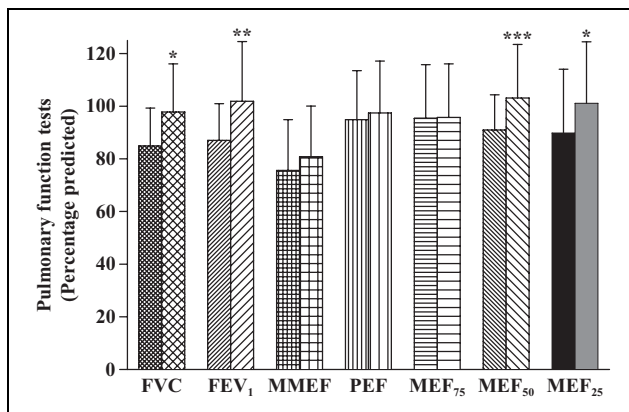


Figure 2. Comparison of PFTs before (fine-filled bars) and after 200 μ g inhaled salbutamol (medium-filled bars) in lifeguards ($n = 38$). Values were presented as mean $\pm$ SD. Statistical significance in PFT values between before and after inhaled salbutamol; * $p < 0.02$; ** $p < 0.005$; *** $p < 0.001$. FVC: forced vital capacity; FEV₁: forced expiratory volume in 1s; MMEF: maximal mid expiratory flow; PEF: peak expiratory flow; MEF₇₅, MEF₅₀, and MEF₂₅: maximal expiratory flow at 75%, 50%, and 25% of the FVC, respectively; PFT: pulmonary functional test.

demonstrated a significantly greater incidence of most allergic symptoms among lifeguards indicating that irritant chemicals related to chlorine can induce allergy in people working as lifeguards. In addition, the respiratory and allergic symptoms were significantly higher while lifeguards were at work when compared with while they were not. This finding

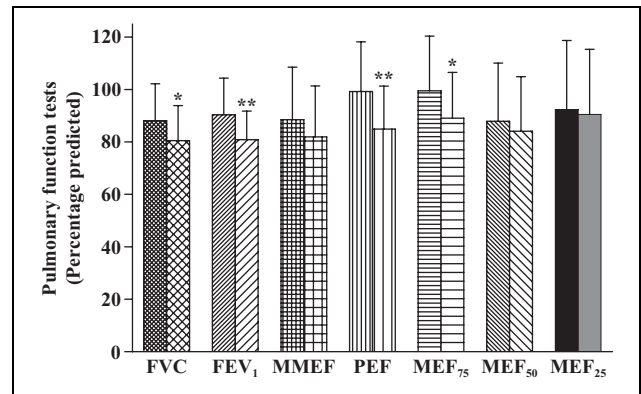


Figure 3. Comparison of PFTs between lifeguards of Razavi (fine-filled bars) and Saadabad (medium-filled bars) pools (for Razavi and Saadabad pools, $n = 24$ and 14, respectively). Values were presents as mean $\pm$ SD. Statistical significance between lifeguards of Razavi and Saadabad pools; * $p < 0.05$; ** $p < 0.01$. FVC: forced vital capacity; FEV₁: forced expiratory volume in 1s; MMEF: maximal mid expiratory flow; PEF: peak expiratory flow; MEF₇₅, MEF₅₀, and MEF₂₅: maximal expiratory flow at 75%, 50%, and 25% of the FVC, respectively; PFT: pulmonary functional test.

confirms that exposure to chlorine in work environment induces respiratory and allergic symptoms.

The results of the present study supported by several previous studies showed increased respiratory and allergic symptoms among lifeguards after exposure to chlorine (Cantor, 1994; Drobic et al., 1996; Martinez and Long 1995; Nieuwenhuijsen et al., 2000) which support increasing respiratory symptoms of the present study. In addition, the exposure to chlorine can induce bronchial hyperresponsiveness and asthma-like and allergic symptoms (Fjellbirkeland et al., 1995; Helenius et al., 1998; Nemery et al., 2002; Zwick et al., 1990), which also support the finding of the present study.

However, the findings of our study more clearly indicate the effect of exposure to chlorine on respiratory and allergic symptoms as well as PFT values. The results showed increased respiratory and allergic symptoms in lifeguards while they are at work when compared with their rest period. More importantly, the results showed greater respiratory and allergic symptoms and lower PFT values among lifeguards were worked in the Saadabad pool with higher chlorine concentration compared with those working in the Razavi pool. In addition, the chlorine concentration of both pools was much higher than that of drinking water. These observations confirm that exposure to chlorine in lifeguards is mainly responsible for the development of allergic and respiratory symptoms.

However, reduction in PFT values and existence of respiratory symptoms in rest period in lifeguards indicate a permanent respiratory change in these workers.

The results of our study showed a considerable reduction in PFT values in lifeguards when compared with control subject. In fact, the effect of acute inhalation of gas on pulmonary function changes has already been shown (Ploysongsang et al., 1982), which supports the finding of the present study. Rotman et al. (1983) also indicate that an 8-h exposure of humans to chlorine concentration less than that of the present study (1 ppm) resulted in a sensory irritation and changes in pulmonary functions. The reason for less obvious reduction in PEF and MEF₇₅ values in lifeguards in the present study may indicate the higher effect of exposure to chlorine on smaller airways (Cots and Leathart, 1993). The other important finding of the present study was increased PFT values due to inhaled salbutamol. These results indicated reversible airway constriction in these workers, which is more compatible with the induction of asthma due to exposure to chlorine.

Although, recent review articles reported that there is no definite relationship between swimming and asthma (Bougault et al., 2009a; Goodman and Hays, 2008), the results of the present study showed a clear increased respiratory and allergic symptoms as well as reduction in PFT values in lifeguards. Lifeguards may differ with swimmers in the duration of exposing to chlorine. In addition, the chlorine concentration in different pools may vary which will differ in the effect on respiratory and allergic status as was seen for Saadabad and Razavi pools in the present study.

In conclusion, the results of this study showed that lifeguards were associated with a higher frequency of work related allergic and respiratory symptoms. The symptoms particularly aggravated after exposure to chlorine at working time. PFT values were also significantly reduced among lifeguards when compared with normal control subjects indicating a permanent change in respiratory system in this occupational group. The results indicate a clear relationship of exposure to chlorine on respiratory and allergic status.

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