RHINOLOGY

Nasal and lung function in competitive swimmers

Studio della funzionalità nasale e polmonare in un gruppo di nuotatori a livello agonistico

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SUMMARY

Nasal and sinusal complaints are considered common among swimmers. Aim of the present study was to evaluate the nasal and bronchial functions, before and after swimming, and the relationship between nasal resistances and FEV1 in competitive swimmers. A group of 30 competitive swimmers were examined: spirometry and nasal respiratory tests were carried out before and after swimming. Moreover, both the competitive swimmers and the 150 visitors of a swimming pool were asked to complete a specific questionnaire. In this questionnaire, 18% of the population reported nasal-sinusal symptoms after swimming. The differences between nasal volumes and resistances before and after swimming were not statistically significant. Nasal patency increased or remained unchanged in 21/30 athletes. The variations in FEV1 were not statistically significant. In conclusion, results showed that swimming is able to increase nasal patency or to leave it unchanged. Temporary worsening of the nasal patency was observed in only a few hyper-reactive patients. In the whole group, no variations, at bronchial level, were found.

KEY WORDS: Nose • Nasal physiology • Swimming pool • Chlorine

RIASSUNTO

La patologia naso-sinusale è considerata comune fra gli atleti che praticano sport acquatici. Scopo del presente studio è stato quello di valutare la funzionalità nasale e bronchiale prima e dopo l'attività natatoria e il rapporto tra le resistenze nasali e il FEV1 in nuotatori che praticano tale attività sportiva a livello agonistico. A tale scopo sono stati esaminati 30 nuotatori professionisti: su di essi sono stati eseguiti la spirometria e i test di funzionalità nasale prima e dopo l'attività sportiva. Inoltre agli sportivi e a 150 frequentatori della stessa piscina è stato chiesto di compilare uno specifico questionario. Dai questionari è risultato che il 18% della popolazione esaminata accusava sintomi naso-sinusali dopo il nuoto. Le variazioni di volumi e resistenze nasali prima e dopo il nuoto non sono risultate statisticamente significative. La pervietà nasale infatti è rimasta invariata o addirittura è risultata aumentata in 21/30 atleti. Anche le variazioni del FEV1 non sono risultate significative. Nel presente studio il nuoto si è dimostrato in grado di aumentare la pervietà nasale o di lasciarla invariata. Un temporaneo peggioramento della pervietà nasale è stata osservata solo in pochi soggetti affetti da iperreattività nasale. In nessuno degli esaminati sono state evidenziate variazioni dei parametri bronchiali

PAROLE CHIAVE: *Naso • Fisiologia nasale • Piscina • Cloro*

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Introduction

Rhino-sinusal disorders and, generally speaking, upper respiratory tract infections seem to be quite common among swimmers, as well as other more specific diseases related to swimming in pools, such as, external otitis, dermatitis, conjunctivitis, which are often a topic of discussion in Internet forums dedicated to competitive swimmers.

At the same time, in the everyday practice, the ENT specialist is aware of the correlation between nasal hyperreactivity and the practice of swimming, maybe due to the irritant effect of chlorine. In actual fact, it comes from "subjective impressions" and "probable correlations", since no scientific evidence confirmed or denied the noxious effects of chlorine, at proper doses, or of swimming practice itself. Few data are available on the problem and those existing are unsatisfactory as far as concerns methods and results.

It is well known that physical exercise increases breathing, due to the request for oxygen from muscular tissue. In athletes, this is expressed as an increased amplitude of breathing excursion and depth [1]; the efficiency of nasal respiratory function contributes to create the best conditions for breathing within the functional unit of the upper and lower airways [2].

The aim of the present study was to evaluate the nasal and bronchial functions, before and after swimming, and the relationship between nasal volumes/resistances and FEV_1 in subjects who practice competitive swimming. Furthermore, symptoms of rhino-sinusitis and/or pulmonary diseases have been investigated in non-competitive swimmers.

Material and methods

The study was designed at two levels: investigative and experimental. At investigative level, all the visitors of a swimming-pool were asked to fill-in a questionnaire (Fig. 1). The medical history, mainly concerning allergies, occupational history, proximal and remote pathological anamnesis was collected; moreover, symptoms of rhino-sinusitis and/or pulmonary diseases, related to the practice of swimming, were investigated.

The second level involved the swimming team of the same swimming pool and included answering the same questionnaire and a clinical-instrumental evaluation, that was carried out from January to February, 2004.

The team comprised 30 subjects (22 male, 8 female, age range 14-50 yrs (mean 32 yrs). The average swimming time was 17 years (minimum 3 yrs, maximum 40 yrs) with average weekly training of 5 hours.

The study design included:

– collection of medical history and objective examination, nasal respiratory tests and 3 spirometry tests (flow-volume curves) before training;
– evaluation of symptom score, according to the Borg Scale (i.e., a visual-analogue scale used to measure the perceived effort and exertion[3];
– spirometry and nasal respiratory tests immediately after training (within 5 min);
– a second spirometry, performed 10 minutes after training;
– a third spirometry and again nasal respiratory tests performed at rest (40 min after end of training) (Table I).

Age	**Sex:** M ☐ F ☐		**Profession**	
Smoke:	Yes ☐	No ☐	How long?	How much?
Do you suffer from a general disease?				
Are you affected with asthma, bronchitis, pulmonary disease?				
Do you take regularly drugs?				
Are you allergic to some substances or drugs?				
For how many years have you been swimming?				
How much do you swim in a day and in a week?				
Do you have any nose or ear disease, when you don't swim?				
Did you pass the medical examination for agonistic sport?				
Did you undergo any operation or treatment for nasal or ear disorders?				
Did you notice an increase in the frequency of sinusitis, otitis, rhinitis since you began swimming?				
Do you notice any nasal symptom like sneezing, rhinorrhoea or nasal obstruction in the hours following your swimming session?				
If yes, after how much time did they begin and how long did they last?				
Did any allergic symptom appear or, if already present, did it increase?				

Fig. 1. Questionnaire.

Table I. Study design.

150 swimmers	Questionnaire			
30 athletes	Questionnaire			
	Before training	Anamnesis Objective assay	AR	3 Spirometries
	Training			
	After 5 minutes		AR	Spirometry
	After 10 minutes			Spirometry
	After 40 minutes		AR	Spirometry

AR = Acoustic rhinometry.

The training lasted 90 minutes, an average distance of 2000 meters was covered (max 3000 m, min 1600 m), and the four styles (freestyle, breaststroke, butterfly stroke and backstroke), even though in variable percentage, were performed by each of the 30 competitive swimmers.
The athletes were all healthy and free from acute nasal-sinusal disorders. They were divided into groups of 5 subjects each in order to make the evaluation easier and to allow correct test timing.
The nasal function tests were performed by Eccovision Acoustic Rhinometry System (Hood Laboratories, Pem-Broke, Mass). This system provided the resistances and volumes (within 0 and 7 cm) of each nasal cavity, the Minimal Cross-sectional Area (MCA) and the percentage of the predicted Cross-Sectional Area (CSA) at the level of the nasal valve, the head of the inferior turbinate and the body of the inferior turbinate [4-6].
All the tests were performed in the same place and at the same time, i.e., between 7.30 p.m. and 9.30 p.m.; in particular, the nasal function tests were all performed in a seated position to avoid the physiological influence of the body position on the nasal parameters. Humidity and temperature were constant in every evaluation, in particular water and air temperatures were respectively 28° and 27°C.
The physicochemical analysis of the swimming-pool water was in the range of the recommended values; in particular. the water pH was constant at 7.6, free chlorine was 0.66 mg Cl_2/l, combined chlorine was 0.2 mg Cl_2/l and nitrates were 6.3 mg NO_3^-/l.
The swimming pool was equipped with an Unit Air Treatment.

Statistical analysis
Statistical analysis of the results obtained by the competitive swimmers was performed using Student's t test, $p < 0.001$ with a considered as statistically significant.

Results

As far as concerns the first part of the study, we collected 150 questionnaires, filled in by 95 males and 55 females, aged between 6 and 65 years (mean 35 yrs). For children, the questionnaires were filled up by the parents or caregivers. Regarding the clinical history, 21 subjects were smokers (14%), 35 were allergic and 7 had undergone septoplasty. Swimming had been practiced for an average of 15 years (range: 6-50 yrs), and the average weekly swimming time was 4 hours (range 1-20 hrs). Overall, 48 (32%) referred nasal-sinusal pathology (nasal obstruction, rhinitis, rhinorrhoea) which had arisen previously and independently of the swimming practice. Seventeen (18%) subjects reported that the frequency of rhino-sinusal disorders had been increasing because of swimming; only 3 subjects maintained that they had noticed an increase in allergic symptoms.
A total of 53 swimmers (35%) reported the appearance of nasal symptoms, such as nasal obstruction, rhinorrhoea and sneezing, following training. These symptoms had started a few minutes after swimming, in 18 subjects, after 1 or 2 hours, in 15 subjects, or after more than 2 hours, in 20 subjects, and had lasted a few minutes in 13 subjects and for hours (from 1 up to 48 hours) in the remaining 40 subjects.
In the second part of the study, we analysed the questionnaire filled in by the competitive swimmers.
Two competitive swimmers were smokers, 3 presented asthma (of these, one was treated with bronchodilators) and 3 were allergic; 8 complained of chronic rhinitis. A medium-severe septal deviation was seen in 9 of the subjects. In the case of the asthmatic subject who took bronchodilators, three basal spirometries were performed before the training and another three, 20 minutes after administration of bronchodilators. The basal value of FEV1 was 2,773 ml, 84% of the predicted value; after bronchodilators it rose to 2,950 ml, 89% of the predicted value. Like other swimmers, no decrease was observed in FEV1.
Five subjects (17%) mentioned an increase in the frequency of rhino-sinusal disorders since attending the swimming-pool; whereas 2 of them were affected by chronic rhinitis before starting their competitive practice.
Nine athletes (30%) complained of rhino-sinusal symptoms appearing after training (sneezing, nasal obstruction and rhinorrhoea), but 4 of them admitted that they had already been affected by chronic rhinitis before they began swimming regularly. The nasal troubles appeared immediately after swimming in 7 swimmers and 2 hours after in 2 swimmers: nasal obstruction and rhinorrhoea lasted for 1 to 24 hours. Only sneezing resolved after a few minutes. None of the subjects reported an increase in allergic symptoms (Table II).
The nasal respiratory tests, performed before training, showed that the total nasal resistances were within the normal range in all subjects (< 0.25 Pasec/cm^3) except one (0.33 Pasec/cm^3), who was affected by vasomotor rhinitis before starting swimming.
Basal nasal resistances of each nasal fossa were compared with the values recorded 5 minutes after the end of training and at rest (40 minutes after training) but differences were not statistically significant ($p > 0.5$) (Table III).
In 14 athletes (47%), the nasal resistances decreased bilaterally after 5 minutes, with a further increase in nasal patency 40 minutes after the end of training.
In 4 athletes, we detected an increase in the resistance of each nasal fossa, 5 minutes after the training, but values lower than those at baseline were recorded after 40 minutes; of these athletes, 2 had been previously diagnosed as suffering from vasomotor perennial rhinitis.
Three athletes presented no variations in nasal resistances and patency.

Table II. Results of agonistic swimming team evaluation.

	Age (yrs)	Sex	Smoke	Anamnesis	Allergies	Nasal-sinusal disorder no swim	Nasal-sinusal disorder for swim	Nasal-sinusal symptoms after training	Total nasal resistances	FEV1
1	40	F	No	-	No	No	Rhinitis	No	Decr	Decr
2	41	M	No	-	No	No	No	No	Decr	Incr
3	40	M	No	-	No	No	No	Sneezes	Incr	Decr
4	33	M	No	-	No	No	No	No	Decr	Decr
5	40	M	No	-	No	No	No	No	Decr	Decr
6	16	M	No	-	No	No	No	No	Inv	Decr
7	19	M	No	-	No	No	No	No	Decr	Decr
8	33	M	15/day	-	No	No	No	No	Incr	Decr
9	44	F	No	Asthma	Yes	Allergic rhinitis	Otitis	No	Decr	Decr
10	24	M	No	-	No	No	No	No	Decr	Decr
11	16	M	No	-	No	No	Rhinitis	Nasal obstruction	Decr	Decr
12	29	M	No	-	No	Rhinitis	No	Sneezes	Incr	Decr
13	50	M	No	Septoplastic	No	No	No	No	Decr	Decr
14	44	M	No	-	No	No	No	No	Decr	Incr
15	47	M	No	-	No	No	No	No	Inv	Incr
16	33	F	4/day	-	No	No	Rhinitis-sinusitis	Sneezes-rhinorrhoea-obstruction	Decr	Incr
17	39	M	No	-	No	No	No	No	Incr	Incr
18	25	M	No	-	No	No	No	No	Decr	Decr
19	33	F	No	-	Yes	Rhinitis	Rhinitis	Rhinorrhoea-obstruction	Decr	Decr
20	25	M	No	-	No	No	No	Nasal obstruction	Incr	Incr
21	41	F	No	Asthma	No	Rhinitis	No	No	Incr	Decr
22	20	M	No	Asthma	Yes	No	No	Rhinorrhoea-obstruction	Inv	Decr
23	40	F	No	-	No	Rhinitis	No	Rhinorrhoea	Decr	Incr
24	40	M	No	-	No	No	No	No	Decr	Incr
25	15	M	No	-	No	No	No	No	Incr	Decr
26	27	M	No	-	No	Rhinitis	No	No	Decr	Incr
27	29	M	No	-	No	Rhinitis	No	Sneezes-rhinorrhoea	Decr	Decr
28	28	F	No	-	No	No	No	No	Decr	Decr
29	42	F	No	-	No	Rhinitis	Rhinitis	No	Incr	Decr
30	14	M	No	-	No	No	No	No	Incr	Decr

Table III. Statistical analysis of results.

	N	Mean	SD	t
RES BAS R1	30	0.13	0.07	
RES 5 Min R2	30	0.13	0.10	R1-R2 0.44
RES 40 Min R3	30	0.12	0.008	R1-R3 0.29
VOL BAS V1	30	13.37	4.821	
VOL 5 Min V2	30	15.39	5.947	V1-V2 0.08
VOL 40 Min V3	30	13.66	4.715	V1-V3 0.4
MCA BAS M1	30	0.627	0.162	
MCA 5 Min M2	30	0.692	0.225	M1-M2 0.1
MCA 40 Min M3	30	0.672	0.184	M1-M3 0.15
FEV1 BAS F1	30	4.209	0.810	
FEV1 5 Min F2	30	4.147	0.814	F1-F2 1.126
FEV1 10 Min F3	30	4.157	0.807	F1-F3 1.004
FEV1 40 Min F4	30	4.106	0.786	F1-F4 1.524

In 9 athletes (30%), we recorded an increase in nasal resistances together with a decrease in nasal patency, 3 of them were affected with previous chronic rhinitis and 3 reported the onset of nasal obstruction, lasting a few hours, at the end of their training.
The nasal volumes followed the trend of the nasal resistances: nasal volumes increased or remained unchanged in 21 athletes and decreased in 9 athletes.
With regard to the flow-volume curves, the mean baseline value of FEV1, given as percentage of the predicted value was within the normal range: 108% ± 13.9; the Tiffeneau index (FVC/FEV1) was also within the normal range: 79.7 ± 9.
For each athlete, we compared the mean value of basal FEV1 (F1) with the FEV1 after 5 minutes (F2), after 10 minutes (F3) and at rest (F4), calculating the difference between F1 and F2, F1 and F3, F1 and F4; however, the variations in FEV1 were not statistically significant ($p > 0.5$).
Overall, 70% of the subjects showed a decrease in FEV1, whereas the remaining 30% showed an increase.
The Borg scale followed the same FEV1 trend.
No correlation was found between variation of FEV1 and those of nasal resistances, nasal volumes, and MCA (Table IV).

Table IV. Correlation between variation of FEV1 and those of nasal resistances, nasal volumes, and MCA.

	Correlation*
Δ R1-R2/ΔF1-F2	-0.09
Δ R1-R3/ΔF1-F4	-0.24
Δ V1-V2/ΔF1-F2	0.29
Δ V1-V3/ΔF1-F4	0.38
Δ MCA1-MCA2/ΔF1-F2	0.10
Δ MCA1-MCA3/ΔF1-F4	0.29

* *Anaysis performed using Pearson test. R: Nasal resistance; F: FEV1; V: Nasal volumes.*

Discussion

People who attend swimming pools frequently complain about the irritating effect of chlorine water, especially on conjunctiva and the nasal mucosa. Few data in the literature support the occurrence of damage to nasal respiratory function [7], whereas many studies have focused attention on dermatitis, otitis, conjunctivitis and most of all concerning the relationship between swimming and asthma [8-11].
With regard to the present study, 18% of the subjects reported an increased frequency of rhinosinusitis since they started swimming and 35% of the subjects described the appearance of temporary symptoms after swimming.
Our data are in agreement with a study on 544 questionnaires according to which 25% of the subjects reported perennial rhinitis [12]. The report by Momas et al., based on the analysis of 246 questionnaires, found no significant differences between swimmers and non-swimmers as far as concerns the rhino-sinusal disorder, except for disturbances due to the changes in temperature between inside and outside the swimming-pool [13].
We choose spirometry, performed with portable instrument, and acoustic rhinometry, as easy tests to be performed at the edge of the pool, since they are not invasive and are suitable during a training.
No significant differences were recorded, comparing the flow-volumes curves (FEV1) between basal and post training conditions (neither in the three asthmatic patients) and no correlation between FEV1 and nasal resistances was evident.
From our 150 completed questionnaires, there was no evidence of an increased prevalence of bronco-pulmonary disorders after swimming.
It is well known that the suggested activity for asthmatic people is swimming, as it induces a minor bronco-constric-

tion in comparison with other sports, thanks to the high humidity of the air, that reduces the loss of heat and decreases the mucus osmolarity of the lower airways. Moreover, the horizontal position and the immersion in water exert a beneficial role [11]. On the other hand, however, chlorine exerts an irritating effect on the lower airways, that could give rise to the risk of developing asthma and allergies [14].
No statistically significant difference had been recorded between basal and five minutes resistances of each nasal fossa nor between basal and "at rest" resistances.
As the total nasal resistances were found to be within the normal range in subjects exposed to the effects of swimming, over an average period of 17 years, no chronic negative effects on the nasal patency, nor on the frequency of rhinitis and sinusitis, had emerged in our sample, in accordance with other studies [15].
In 21 athletes (70%), nasal patency resulted increased or unchanged.
This is due, primarily, to the decongestion of the inferior turbinate head caused by several factors such as the warm water (28°) and air (27°) temperature [16], the physical training effect [17], and the beneficial effect of the water lavage in the nasal cavities.
From physiological studies, it is known that warm water or air, on the nasal mucosa, triggers a neurovegetative reflex, which affects vascular constriction leading to a decrease in nasal resistances. These latter decrease quickly returning to normal values within 15-30 minutes, as a result of the physical activity. In fact, to meet the change in oxidative demands, produced by the physical stress, blood flows from the nasal, tracheal-bronchial and intestinal mucosa to the muscles, heart, brain and skin, thus leading to a reduction in nasal resistances, related to the work load (the more the load, the more speed to achieve the reduction). This effect is obtained by hormonal mediation (increase in catecholamine) and also thanks to neurogenic factors, such as the increase in the sympathetic tone in the cavernous nasal tissue. Moreover, changes in the nasal flow activate the alar muscle of the nose, the contraction of which increases nasal compliance, avoiding the inspiratory collapse of the nasal valve.
The effects of the nasal cycle were minimized by the short time elapsing between the basal and the following tests, in our study. Furthermore, the nasal cycle is temporarily abolished by the physical activity.
In nine athletes (30%), we found a decrease in nasal patency. Of these, three reported sneezing and nasal obstruction, at the end of the training, that could be due to the so-called "allergy to chlorine" [2]. Three subjects showed a basal nasal hyperactivity, that could have become more severe due to the temperature changes and the irritating effect of chlorine.
Chlorine is a yellow-green gas, responsible for inflammation and oedema of the respiratory system. It is considered dangerous, when used at high concentrations in the industrial field [2 16-18]. The irritating effect of chlorine, dissolved in the swimming pool water, is due to trichlorate nitrogen (NCl_3) [19] and, to a lesser extent, to monochloramines and chloroform. The latter are produced when chlorine, in solution as hypochlorose acid, reacts together with organic contaminants, such as urine and sweat.
The main cytotoxic effect of chlorine results from the oxidative reaction. The acid produced may be responsible for a secondary irritation. Among the consequences, the mucosal oedema can lead to degeneration and desquamation of the respiratory epithelium with, subsequently, an inflammatory reaction, nasal and bronchial congestion and hyperreactivity. The resulting clinical pattern is defined as "allergy to chlorine" and is characterized by several degrees of nasal obstruction, rhinorrhoea and sneezing, which can become chronic rhinitis and rhinosinusitis [2].
Some Authors suggest that the pathological conditions related to chlorine are more common in the case of indoor swimming-pools [19] and when swimming is practiced for more than 30 hours/week [12].
The water that enters the nose can affect ciliary function [8] and could be responsible for dryness of the mucosa, often complained by the swimmers.
Small & Murray measured the mucociliary clearance time, by means of the saccharine clearance test, in 10 swimmers [17], who were asked to stop swimming two weeks before the trial. Mucociliary clearance resulted increased in six subjects, decreased in two and prolonged beyond 20 minutes in the remaining two. In spite of the poor statistical significance, the results suggest some degree of ciliary stasis secondary to exposure to the chlorinated water [17], whereas chronic effects are excluded both from clinical examination and instrumental evaluation (posterior rhinomanometry, lung function tests and mucociliary clearance) and, according to the Authors, this depends on the water composition and percentage of chlorine [17].
On the contrary, Deitmer & Scheffler [22] found an effective mucociliary transport in the nose of swimmers: the saccharine test did not reveal any difference between the group of swimmers and the group of controls [21].
The nasal obstruction, that rises after swimming, can be attributed to the changes in temperature and humidity between in and out of the swimming pool [17].
From a review of the Literature, swimming was proved to be associated to rhinosinusitis when the water temperature was lower than the skin temperature, causing mucosa cooling and subsequently oedema, hyperemia, peripheral vasoconstriction and bronchoconstriction [21,22].
On the basis of the maxillary sinus sonography, Deitmer & Scheffler [21 22] found a higher percentage of sinusitis in swimmers than in controls: the Authors named it "swimmer's sinusitis" and maintained that it was caused by the water entering the sinuses and by the effect of the cold water on the skin.
On the other hand, Desterbeck et al. carried out a retro-

spective study on effect of swimming in 154 children, showing an improvement in middle ear ventilation [23].
In our study, we did not find any allergic symptoms related to swimming: therefore, our data did not confirm an earlier report by Zwick et al. who pointed out an increase in bronchial hyperactivity and allergic reactions, maybe due to the damage caused by chlorine and chloroform to the bronchial defenses and cellular immune system [24].
Other Authors proposed that the complaint of nasal symptoms could reflect the trend of these patients to hide their inability with physical activity or to confuse chronic rhinorrhoea with allergy [17].

Conclusions

According to our study, swimming did not affect bronchial functions, either at short or long term, nor did it increase allergic symptoms. As far as concerns the rhino-sinusal district, swimming proved to be able to increase the nasal patency at short term, maybe because of the benefit both of the physical activity and the nasal lavage, if the prescribed values of water chloration and air/water temperature were observed. In the hyperreactive patients, and in other subjects, who might be more sensitive to the irritant effects of chlorine, swimming had a negative effect upon the nasal patency, in a temporary fashion, without further evidence of chronic lesions.

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