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Effects of swimming on spirometric parameters and bronchial hyperresponsiveness in children and adolescents with moderate persistent atopic asthma

Ivonne Bernardo Wicher,[1] Maria Ângela Gonçalves de Oliveira Ribeiro,[2] Denise Barbieri Marmo,[3] Camila Isabel da Silva Santos,[3] Adyleia Aparecida Dalbo Contrera Toro,[3] Roberto Teixeira Mendes,[4] Flávia Maria de Brito Lira Cielo,[5] José Dirceu Ribeiro[6]

Abstract

Objective: To investigate the medium-term benefits of a swimming program in schoolchildren and adolescents with moderate persistent atopic asthma (MPAA).

Methods: A randomized, prospective study of children and adolescents (age 7-18 years) with MPAA was carried out at the Hospital de Clínicas of Universidade Estadual de Campinas (UNICAMP), Campinas, Brazil. After a 1-month run-in period, 61 patients (34 female) were randomized into two groups, a swimming group (n = 30) and a control group (n = 31), and followed for 3 months. Both patient groups received inhaled fluticasone (dry powder, 250 mcg twice a day) and salbutamol as needed. The swim training program consisted of two weekly classes over a 3-month period for a total of 24 sessions. Both groups underwent spirometric assessment and methacholine challenge test – provocative concentration of methacholine causing a 20% fall in FEV_1 (PC_{20}) – before and after the study period. Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were measured only in the swimming group.

Results: Significant increases in PC_{20} (pre-training, 0.31±0.25; post-training, 0.63±0.78; p = 0.008), MIP (pre-training, 67.08±17.13 cm H_2O; post-training 79.46±18.66; p < 0.001), and MEP (pre-training, 71.69±20.01 cm H_2O; post-training, 78.92±21.45 cm H_2O; p < 0.001) were found in the swimming group.

Conclusion: Children and adolescents with MPAA subjected to a swim training program experienced a significant decrease in bronchial hyperresponsiveness, as determined by increased PC_{20} values, when compared with asthmatic controls who did not undergo swim training. Participants in the swimming group also showed improvement in elastic recoil of the chest wall.

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Introduction

Asthma is the most common chronic illness in childhood. In addition to pharmacological therapy, several alternative approaches have been studied and used as treatment aids, most with controversial or unproven results, including swimming.[1]

Swimming has been recommended as the optimal sporting activity for management of children and adolescents with asthma. Experimental and observational evidence from short-term studies suggests that swimming is less asthmogenic than other forms of physical activity.

1. Mestre, Saúde da Criança e do Adolescente, Universidade Estadual de Campinas (UNICAMP), Campinas, SP, Brazil.
2. Doutora, Saúde da Criança e do Adolescente. Coordenadora de Pesquisa, Laboratório de Fisiologia Pulmonar (LAFIP), Centro de Investigação em Pediatria (CIPED), UNICAMP, Campinas, SP, Brazil.
3. Doutora, Saúde da Criança e do Adolescente, UNICAMP, Campinas, SP, Brazil.
4. Doutor, Saúde da Criança e do Adolescente, UNICAMP, Campinas, SP, Brazil.
5. Mestre, Performance Humana, Universidade Metodista de Piracicaba (UNIMEP), Piracicaba, SP, Brazil.
6. Professor associado, Livre-docente. Coordenador, LAFIP, CIPED, UNICAMP, Campinas, SP, Brazil.

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Further evidence shows that water exercise and swimming increase aerobic capacity, improve cardiovascular fitness and quality of life, and produce less airway resistance than do other types of vigorous physical activity, such as running and cycling.[2] The benefits of swimming are also due to the horizontal position of the body, which provides a more adequate and constant breathing pattern compared with other forms of exercise, and to the high humidity present in pools.[2-7]

The few studies published thus far (Table 1) on the effects of swimming in asthmatic individuals cannot be compared among one another due to methodological differences, which include type and duration of swimming program used, choice of outcomes, absence of a control group, and sample size determination issues.

Thus far, no studies have included assessment of bronchial hyperresponsiveness (BHR) with the methacholine challenge test (methacholine PC_{20}) as a marker of asthma improvement before and after swim training in children.

In August 2009, a group of physicians, epidemiologists, environmental scientists, and pool maintenance experts gathered to discuss the influence of pool swimming on childhood asthma and develop recommendations for future research on the matter. The results of this workshop showed that the current evidence of association between swimming and childhood asthma is suggestive but not conclusive, and that additional studies are required if current doubts are to be addressed.[2]

On the other hand, increased asthma risk has been associated with asthmatic children swimming in pools, but the evidence is inconsistent and inconclusive. In an attemt to address the issue, Font-Ribera et al.[14] studied the effects of swimming and of the hazards associated with pool irritants on Spanish children, and found no increase in asthma risk.

The recent literature shows that physical activity in childhood[16] or adulthood[17] may reduce hay fever severity,[16] decrease BHR[17] and prevent the development of asthma.[16] Rasmussen et al.[16] showed that poor fitness in childhood correlates with development of asthma during adolescence, and that moderate and intense physical activity appears to be associated with reduced risk of new-onset asthma in adolescence.

The present study sought to assess and compare spirometric parameters and BHR (as measured by methacholine PC_{20}) in two groups of children and adolescents with moderate persistent atopic asthma (MPAA), one subjected and the other not subjected to swim training.

Methods

A prospective, randomized study was conducted between November 2004 and August 2009 at the Pulmonary Physiology Laboratory (Laboratório de Fisiologia Pulmonar, LAFIP) of the Hospital de Clínicas da Universidade Estadual de Campinas (UNICAMP) Division of Pediatric Pulmonology.

Inclusion criteria were a clinical history of reversible, recurrent symptoms of airway obstruction, serum immunoglobulin E values within or above the 97.5th percentile for age in at least one blood sample, positive skin tests for at least one tested antigen, and a family history of allergy. All participants had MPAA, as diagnosed according to Global Initiative for Asthma (GINA) criteria.[18] None received systemic steroids, theophylline, leukotriene antagonists, or oral beta2-adrenergic agonists for at least one month prior to inclusion in the study.

To calculate the required sample size, we analyzed the variables used in a few other published studies.[3,4,13] We chose forced expiratory volume in 1 second (FEV_1) and methacholine-challenge PC_{20} as variables, and obtained an ideal figure of 30 and 31 patients for the swimming group (SG) and the control group (CG), respectively. Under these conditions, type I and type II error rates were 0.05 (α = 5%) and 0.20 (β = 20%) respectively, giving approximately 80% power.

After a one-month run-in period, 71 children and adolescents (age 6-18 years) of both genders de were selected. All underwent spirometry, allergy skin testing, and serum IgE measurement, and were then randomized into groups SG and CG for spirometry and methacholine challenge test (for PC_{20} assessment of bronchial hyperresponsiveness). Both groups received the exact same pharmacological treatment throughout the 3-month study period: fluticasone (dry powder inhaler, 250 mcg twice a day) and formoterol (dry powder inhaler, 12 mcg twice a day).

Spirometry and BHR assessment were carried out in accordance with American Thoracic Society standards.[19]

No participants reported any history of respiratory infection in the 15 days prior to inclusion in the study. Pulmonary function tests [forced vital capacity (FVC), FEV_1, and forced expiratory flow between 25 and 75% of vital capacity (FEF 25-75%)] were conducted with a MedGraphics CPFS/D BREEZE PF Version 3.8 B model spirometer (Medical Graphics Corp., St. Paul, MN, USA) and expressed and analyzed according to the reference values published by Polgar & Promadhat.[20] Bronchial challenge testing was performed with methacholine (A2251, Sigma-Aldrich Co., St. Louis, MI, USA) provocation, to establish the concentration of methacholine causing a 20% fall in FEV_1 from baseline.[19]

Allergy skin testing

Immediate-type hypersensitivity skin testing was carried out in the morning, between 8 and 12 a.m., after making sure that patients were not taking any antihistamines. The chosen method was Pepys's[21] skin prick test as modified by Osterballe & Weeke.[22] The following allergens were used, all provided by International Pharmaceutical Immunology (IPI)/ASAC Brasil (ASAC Pharma), São Paulo, Brazil, and standardized in protein nitrogen units (PNU/mL): American house dust mite (5,000 PNU/mL); *Dermatophagoides pteronyssinus* (1,500 PNU/mL); *Dermatophagoides farinae* (1,500 PNU/mL); fungi I – *Alternaria tenuis, Botrytis cinerea, Cladosporium herbarum, Curvularia spp., Fusarium spp.*, and *Helminthosporium* (5,000 PNU/mL); fungi II – *Aspergillus spp., Mucor spp., Penicillium spp., Aureobasidium pullulans, Rhizopus nigricans*, and *Serpula lacrymans* (5,000 PNU/mL); and *Blomia tropicalis* (5,000 PNU/mL). Histamine 10 mg/mL and saline solution with 50% glycerin were used as positive and negative controls respectively. Results were read after 20 minutes. Positive skin response was defined as a ≥ 3 mm wheal with attendant erythema (European Academy of Allergy and Clinical Immunology criteria).[23]

Table 1 - Summary of main studies on the clinical and physiological effects of swimming in children and adolescents with asthma

Reference	Swimming program	Control group	n	Effects of swimming
Fitch et al.[4]	3 to 5 times a week for 5 months	Present	46 swimmers 10 controls	Benecifical physical and emotional effects
Svenonius et al.[8]	60 minutes twice a week for 3 to 4 months; program included concurrent non-water exercises	Absent	50	Decrease in EIA
Szentagothal[9]	Swimming + aerobic exercises + running	Absent	121	Decreased morbidity and school absenteeism
Huang et al.[10]	60 minutes 3 times a week for 2 months	Randomized	45	Decreased morbidity and school absenteeism
Courteix et al.[11]	12 hours a week of intensive swimming (swimming group), 2 hours a week of various physical activities (control group)	Present	5 swimmers, 11 controls (all female)	Intensive swimming training in prepubertal girls leads to increased lung volumes and improved maximal expiratory flow-volume relationship, promoting isotropic growth of the alveolar space
Mastsumoto et al.[3]	15 minutes twice a day for 6 months	Random	8 swimmers 8 controls	Increased aerobic capacity
Wardell & Isbister[12]	Once a week for 2 years	Absent	73 swimmers	Decreased morbidity and school absenteeism
Weisgerber et al.[13]	45 minutes twice a week for 5 or 6 weeks	Present	5 swimmers 3 controls	No significant change in PFTs or symptoms
Font-Ribera et al.[14]	NA (assessment of trichloramine levels in indoor and outdoor pools)	Absent	3,223 respondents	Effects of swimming may improve lower respiratory symptoms and worsen eczema, but do not increase risk of asthma in children
Bemanian et al.[15]	3 times a week for 8 weeks	Absent	76 girls	Significant improvement in peak flow rates among asthmatic children Despite harmful effects of chlorination, swimming in indoor pools is useful
Wicher et al. (present study)	Twice a week for 3 months	Present	30 swimmers 31 controls	Improvement in bronchial hyperresponsiveness and elastic force of the chest

EIA = exercise-induced asthma, PFT = pulmonary function tests.

Participants were included one week after clinical and laboratory examination. Spirometry and methacholine challenge test for assessment of BHR were performed in both groups before the trial and after conclusion of the 3-month study period. Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were measured only in the swimming group.

Pharmacological treatment of asthma was kept constant in both groups throughout the study, with inhaled fluticasone (250 mcg twice a day) and rescue medication (200 mcg salbutamol every 6 hours) as needed. All children were monitored by a physician throughout the program.

Swimming techniques

Each swimming session lasted 60 minutes. Before exercise, children underwent peak expiratory flow (PEF) measurement to detect any possible bronchial obstruction at the time of swimming. This was followed by light stretching exercises, lower and upper limb warm-up with global postural exercises, and awareness of diaphragmatic breathing, with participants lying on mats, for 15 minutes. Children were then led to the pool, where training was divided by skill level, namely: Level I – adaptation to the water environment, total immersion breathing, floating/treading water, moving underwater, and elementary diving; and Level II, in which children who had acquired the aforementioned skills and mastered body control in the water began learning the front crawl and backstroke. Twenty-six children (who had never attended swimming lessons before) completed Level I, and four completed Level II, mastering the front crawl and backstroke. The program lasted three months and consisted of two weekly lessons for a total of 24 lessons per participant. Minimum attendance of 80% was considered a requirement for study participation; when children failed to attend a lesson, their parents or guardians were contacted in order to ascertain the reason for absence. Children who did not attend 80% of classes were excluded from the study.

Statistical methods

Data were entered into the Microsoft Excel 2000 application, and statistical analyses were performed in the SAS System for Windows 8.02 software package (SAS Institute Inc., Cary, NC, USA). The chi-square, Wilcoxon, Mann-Whitney, and Spearman's rank correlation tests were performed.

The sample profile in terms of study variables was presented in frequency tables (with absolute and percentage frequencies) for categorical variables, and expressed in descriptive statistics (mean, standard deviation, and minimum, maximum, and median values) for continuous variables.

Progression of variables in both groups (pre- and post-treatment) was analyzed with the Wilcoxon signed-rank test. The Mann-Whitney U test was used for comparison of participant ages, anthropometric parameters, FEV_1, and PC_{20} between the swimming and control groups. Spearman's rank correlation coefficient was used for analysis of the relationship between numeric variables. P-values <0.05 were considered significant.

Ethical considerations

The present study was approved by the Hospital Universitário of UNICAMP Research Ethics Committee (ruling 529/2002), and all participants and their legal guardians signed free and informed consent forms before the study.

Results

Of the 71 patients selected, 61 completed the study: 30 in the swimming group (18 female, 12 male) and 31 controls (16 female, 15 male). Ten patients did not complete the study: four lived in other cities and had difficulty making the trip, one had worsening rhinitis, two completed pulmonary function tests but did not return for swimming classes, and three attended less than 80% of program sessions.

No patients in either group received leukotriene antagonists or any other type of control medication. Salbutamol was the only permitted rescue therapy in case of acute asthma attacks. In both groups, the number of exacerbations was the same before and during the study. Compliance with fluticasone/salbutamol treatment was also equal in both groups. No patients were hospitalized due to asthma attacks, whether in the run-in period or during training.

In the swimming group, 17 patients were schoolchildren aged > 6 < 10; 8 were teenagers aged ≥ 10 < 15; and 5 were 15 years old or older. Table 2 shows a comparison of pre-study anthropometric parameters, FEV_1, and PC_{20} for the 61 asthmatic participants of both groups. Age of asthmatic patients in the swimming group ranged from 6 to 18 years (mean ± standard deviation, 10.35±3.13).

Table 3 shows the distribution of each study variable in the SG and CG, before and after the study. Maximum voluntary ventilation (MVV), MIP, and MEP values for the swimming group are shown in Table 4.

Discussion

An extensive review of the literature revealed that the present study was the first to use two markers for assessment of asthma improvement – BHR measurement and spirometric parameters – in a group of MPAA patients subjected to swim training compared with a control group of asthmatic non-swimmers.

Several authors have shown that aerobic exercise and training improve physical fitness.[3,8-12,24-27] On the other

Table 2 - Comparison of pre-study anthropometric parameters, FEV_1, and PC_{20} in the swimming and control groups

	Swimming group (n = 30)	Control group (n = 31)	p
Age (years)*	10.35±3.13	10.90±2.63	0.285
Gender (male/female)†	12/18	15/16	> 0.005
Weight (kg)*	40.09±19.25	39.02±11.34	0.708
Height (cm)*	142.17±17.25	145.79±15.07	0.257
FEV_1 (L)*	1.88±0.62	1.80±0.59	0.740
FEV_1 (% predicted)*	87.19±13.24	74.73±15.58	0.001
PC_{20} (mg/mL)*	0.31±0.25	0.30±0.23	0.707
n	30	31	–

FEV_1 = forced expiratory volume in 1 second; PC_{20} = provocative concentration of methacholine causing a 20% fall in FEV_1.
* Mann-Whitney U test.
† Chi-square test = 0.23, degree of freedom = 1.

Table 3 - Distribution of spirometric parameter values (mean ± standard deviation) in the study sample

	Swimming group			Control group		
	Pre	Post	p*	Pre	Post	p*
PC_{20} (mg/mL)	0.31±0.25	0.63±0.78	0.008	0.30±0.23	0.42±0.48	0.185
FVC (L)	2.37±0.83	2.77±0.90	0.001	2.33±0.74	2.53±0.80	0.012
FEV_1 (L)	1.88±0.62	2.04±0.69	0.013	1.80±0.59	1.95±0.59	0.024
FEV_1/FVC ratio	79.04±9.01	78.57±8.72	0.489	76.36±11.85	78.01±10.22	0.301
FVC (% predicted)	96.42±11.40	97.77±12.34	0.524	80.60±14.86	82.73±13.40	0.169
FEV_1 (% predicted)	87.19±13.24	81.90±13.09	0.862	74.73±15.58	90.56±12.07	0.557
FEV_1/FVC ratio (% predicted)	88.77±9.77	87.06±9.32	0.138	91.35±8.53	90.56±12.07	0.449
FEF 25-75% (% predicted)	72.71±24.78	71.65±23.91	0.734	59.57±21.70	58.20±16.39	0.974

FEF 25-75% = forced expiratory flow between 25 and 75% of vital capacity; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; PC_{20} = provocative concentration of methacholine causing a 20% fall in FEV_1.
* Wilcoxon signed-rank test, comparison of pre- and post-training values.

hand, although swimming is the best choice of physical activity for people with asthma, few randomized controlled trials with medium- to long-term follow-up have been conducted to assess its effects in the various degrees of asthma severity.

After the treatment period, both groups showed improvement in spirometric parameters, although the difference did not reach statistical significance. There was also significant improvement in BHR, with higher values in the swimming group.

The mechanisms underlying this significant improvement in BHR and improvement in lung function upon comparison of the swimming and control groups probably involve changes in airway inflammation, mechanical, neurogenic, and humoral factors, and smooth muscle changes,[28] but this remains to be proved. Recent studies have shown encouraging results on the effects of physical exercise in decreasing BHR.[17,28] Shaaban et al.[17] reported a strong negative correlation between physical activity and BHR in adults. If this relationship is indeed a causal one, these

Table 4 - Other spirometric parameters measured in the swimming group (n = 30)

	Swimming group		
	Pre	Post	p*
MVV (L/min)	56.83±18.25	66.81±23.02	0.001
MIP (cm H_2O)	67.08±17.13	79.46±18.66	0.001
MEP (cm H_2O)	71.69±20.01	78.92±21.45	0.001

MEP = maximal expiratory pressure; MIP = maximal inspiratory pressure; MVV = maximum voluntary ventilation.
* Wilcoxon signed-rank test, comparison of pre- and post-training values.

results suggest that a small amount of physical activity is able to effect a significant reduction in BHR; this could then be added to the growing list of already-known benefits of exercise. Using an experimental model of asthma, an intriguing study by Silva et al.[28] showed that physical training can reverse airway inflammation and remodeling and improve respiratory mechanics, consequently reducing BHR.[28] If confirmed, these encouraging results could contribute to the development of programs for the primary prevention of lung disease.

In our review of the Brazilian literature, we were unable to find any studies that assessed bronchial hyperresponsiveness with methacholine challenge test after swimming. This fact was addressed at length in a Thorax editorial[25] commenting on a study by Matsumoto et al.[3], which assessed BHR to histamine in 16 patients with severe asthma (8 swimmers and 8 non-swimmer) before intervention and at 6-week follow-up. There was no difference in BHR between the two groups before or after swim training. It bears stressing that the Matsumoto study included only a small number of severely asthmatic patients who did not follow the same medication regimen, whereas our study included a greater number of participants, all of whom received adequate and standardized treatment.

The increase in PC_{20}, which was significantly greater in the swimming group, suggests a need for further, long-term studies of swim training that include assessment of markers of inflammation, cardiorespiratory function, and clinical improvement of asthma, as well as quality of life questionnaires.

While some studies have shown beneficial effects of swimming on pulmonary function test parameters,[11,15] others have failed to show any such effect.[3,10,13,29] However, none of these studies used BHR assessment as a follow-up tool. BHR must be assessed, especially in studies that evaluate response to asthma treatment over time.[30]

Three issues stand out in most articles on the matter indexed in major databases: small, uncalculated sample size; absence of a control group; and very short duration of swim training. The present study, which was designed with a group of MPAA patients in mind, had a predefined and properly calculated sample size, had a control group, and used standardized pharmacological treatment of asthma and swimming exercises across all participants. Fitch et al.[24] reported great improvement in asthma symptoms after one year of swim training, even though no improvement in BHR or pulmonary function tests was observed.

In the present study, we found significant improvement in FVC and FEV_1 in both groups, and confirmed the efficacy of inhaled corticosteroids as a standard treatment for childhood asthma. The difference in BHR reduction between groups, as measured by increased PC_{20} values, shows the efficacy of swimming. Improvement in MIP and MEP values shows that swimming also proved useful for improving the respiratory mechanics of children and adolescents with asthma. Other controlled trial may corroborate these findings.

Regarding spirometric parameters, one possible limiting factor in our study was the fact that children were still in the early stages of the swimming program. This may have limited improvement in cardiorespiratory fitness and had an even greater influence on results. Only four of the children in our sample had previously engaged in swimming.

Welsh et al.[29] suggest that regular physical activity, when in conjunction with adherence to proper pharmacological treatment, should be encouraged by physicians and other health professionals to all children and adolescents with asthma. Immediate benefits can be derived from engaging in physical activity, particularly increased expiratory reserve capacity, which may provide protection against asthma attacks.[29]

In spite of recent evidence suggesting that chlorine exposure during swimming may be associated with an increase in the frequency of asthma attacks,[31,32] there is considerable evidence[1] that swimming in a heated indoor pool environment, which provides warm, moist air for inhalation, is still far less asthmogenic than other types of exercise, such as running or cycling.[2] The harmful effects of chlorine appear to be dependent on concentration and length of exposure, and still require further study.[2,14]

A 2009 study by Bemanian et al.[15] showed significant improvement in peak expiratory flow rates in asthmatics after swimming, and suggested that indoor swimming is useful for patients with asthma, regardless of the potentially toxic effects of chlorine.

Research has shown airway irritation and BHR changes in competitive swimmers, who regularly attend heated indoor pools with high water and air levels of chlorinated compounds (particularly NCl_3). [29] This was demonstrated in a study by Thickett et al.[33] and warranted an editorial on the matter.[34] The pool facility in which our patients trained did not have completely enclosed walls near the roof; we are unsure as to whether this may have decreased the concentration of chloramines in the air. This factor set our study apart from those conducted in Europe, where indoor swimming facilities are completely enclosed due to the harsh winter. The findings of these studies have prompted encouragement of unchlorinated pools or increased ventilation in pool facilities. Future studies to measure the concentration of chloramines in the air of swimming facilities are thus required.

Swimming has been recommended in asthmatics because it is associated with less exercise-induced bronchospasm (EIB) than are other types of exercise. This has been proven by several authors. The mechanisms behind this protective effect have yet to be fully elucidated. They probably inclide epithelial, cellular, or sensorineural factors in a moist environment, as EIB does not appear to be an issue in asthmatic swimmers. None of the participants in our sample experienced asthma attacks during swimming or in the first few hours after swimming.

Our results show that three months of swim training (at adequately ventilated pools) leads to significant reduction in bronchial hyperresponsiveness and improves elastic recoil of the chest wall in children and adolescents with moderate asthma and atopy. Swimming should therefore be one of the sporting activities encouraged in children with MPAA.

Other well-designed studies that address the important issue of physical training programs as a tool for improved asthma control and must be encouraged.

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Correspondence:
José Dirceu Ribeiro
Centro de Investigação em Pediatria, UNICAMP
Rua Tessália Vieira de Camargo, 126 -
Cidade Universitaria Zeferino Vaz
CEP 13083-887, Caixa Postal 6111 - Campinas, SP - Brazil
Tel.: +55 (19) 3521.8983, +55 (19) 3289.3874,
+55 (19) 3521.8884
E-mail: dirceu@fcm.unicamp.br, ribeirojd@terra.com.br, alwicher@uol.com.br