The effect of scuba diving on airflow obstruction in divers with asthma

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Abstract

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Background: People with asthma are an under-represented group amongst scuba divers. Many may avoid or are advised against diving due to the potential risks, including bronchoconstriction, pulmonary barotrauma and arterial gas embolism. The aim of this study was to establish whether divers with asthma were more likely to experience reversible airways obstruction following typical scuba diving than divers without asthma.

Method: All divers with a history of asthma attending *Operation Wallacea* in Honduras were identified and peak expiratory flow rates (PEF) were measured pre and immediately post dive. All dives were boat dives in tropical sea water. Scuba dives were defined as those lasting between 40 and 55 minutes to a depth of between 10 and 18 metres. Of the 356 divers attending, 22 were identified as having asthma, of whom 19 were suitable for testing. They were classified by treatment regimen: five on no treatment, 11 on salbutamol only and three on regular preventative treatment. Twenty-four divers without a history of asthma acted as a control group.

Results: Open-water scuba diving caused a small decrease in PEF in all populations (median decrease 4.4%, $P < 0.001$). Percentage decrease in PEF was significantly more in divers with asthma on regular preventative medication than in the control group (mean 9.3%, median decrease 6% vs. mean 3.1%, median 4.3%; $P = 0.039$).

Conclusion: These findings support the view that asthmatics are more susceptible to airway changes following scuba diving. Differences to previous studies are likely due to environmental conditions, including dive depth.

Key words

Lung function; respiratory; diving research

Introduction

The prevalence of asthma amongst recreational scuba divers is around 6%, compared to a UK population prevalence of 8.4% and prevalence among UK 15 to 44-year-olds of 23%.[1–3] This lower prevalence suggests that many asthmatics avoid or are advised against scuba diving, while for some divers their asthma does not prevent them from diving.

Asthma was previously considered a contraindication to scuba diving owing to the danger of bronchoconstriction,[4,5] although this view has since progressed such that asthmatics with little airways hyper-reactivity are cleared for diving.[6,7] The British Thoracic Society's and other's guidelines now recommend that asthmatic individuals who are well controlled with normal pulmonary function tests (e.g., peak expiratory flow rate, PEF, within 10% of predicted) may dive if they have a negative exercise test.[7–9] Those with wheeze precipitated by exercise, cold or emotion are advised against diving.[10] The evidence to guide this view is largely based on case studies rather than bronchial provocation testing.[7]

There have been concerns over the potential for bronchoconstriction during diving to result in gas trapping and an increased risk of pulmonary barotrauma, as well as asthma being implicated as a risk factor for arterial gas embolism.[4,7] The various triggers to airways obstruction unique to diving include cold water, dry compressed air, salt water inhalation, exercise and anxiety.

PEF in healthy divers has been shown to decrease following scuba,[10] but whether scuba provokes increased airflow obstruction in an asthmatic population has not been established, as current evidence relies on swimming pool dives not open-water diving.[11,12] The aim of this study was to test the null hypothesis that people with asthma are no more likely to develop airway obstruction following scuba diving in typical recreational diving conditions than those without asthma.

Methods

SUBJECTS

All non-smoking recreational scuba divers joining *Operation Wallacea*[13] in Honduras, who had a history of asthma and had been passed fit to dive by their personal medical practitioner prior to arrival, were consented. Divers were identified from their submitted medical records and by interview on arrival at the diving site; smokers were excluded. Minimum requirements were that all participants had confirmed and had signed with their ordinary medical practitioner the Professional Association of Dive Instructors (PADI) Medical Statement, which requires normal spirometry pre- and post-exercise.[14] Informed research consent was obtained from each individual diver and ethical approval was granted by the supervising research organisation *Operation Wallacea*. Participants completed a short questionnaire regarding relevant health history, including current medications and personal demographic data. This was repeated with age- and

Table 1
Change in peak expiratory flow (PEF) after a scuba air dive between divers with or without asthma; A1 – no medication; A2 – short-acting beta agonists only; A3 – regular preventative medication

Groups	Divers (*n*)	Total dives (*n*)	Mean / median decrease PEF (%)	*P*-value
Non-asthmatic controls	23	51	3.1 / 4.3	0.004
Asthma				
A1	5	17	2.3 / 0.0	0.108
A2	11	44	3.6 / 5.1	< 0.001
A3	3	13	9.3 / 6.0	0.002
Total	42	125	3.8 / 4.4	< 0.001

sex-matched controls with no history of respiratory illness attending the same dives as the divers with asthma.

STUDY DIVE PROFILES

All dives were boat dives in tropical sea water, lasting for 40−55 min to a depth of 10−18 metres' sea water (msw). Water temperature was measured with each dive. Night dives and deep dives (over 18 msw) were excluded to avoid complicating environmental influences. In all cases, compressed, purified air was used. Dives took place during the morning (0900 h) and afternoon (1400 h).

PEAK EXPIRATORY FLOW

All participants received training in the correct use of a peak flow meter prior to providing measurements. Readings were all taken sitting in the upright position while in a wetsuit or swimming attire, not while wearing scuba equipment. PEF measurements were taken following the European Respiratory Society protocol[15] using a MediHealth Adult Peak Flow Meter with standard EU scale at 0–5 minutes pre dive and 0–5 min post dive, with the best-of-three PEF being chosen for analysis. The mean number of readings per person in the divers with asthma was 3.9 (median 5) and in the control group 2.2 (median 2).

The percentage change in PEF after each dive compared to the pre-dive value was then calculated. This process was repeated over multiple separate dives up to a maximum of five sets of measurements in any one individual. Results were grouped according to asthma severity as determined by treatment level as follows:

- Control group (C): divers with no history of asthma;
- Asthma group 1 (A1): no treatment, history of asthma;
- Asthma group 2 (A2): short-acting beta agonist only; history of asthma;
- Asthma group 3 (A3): regular preventative treatment, inhaled corticosteroid and long-acting beta agonists.

DATA ANALYSIS

Data were entered into SPSS® version 17 for analysis using descriptive statistics. Data significantly deviated from normal distribution (Kolmogorov-Smirnov and the Shapiro-Wilk tests). Consequently we compared the control group with each of the three asthma groups using a non-parametric one-way ANOVA (Kruskal Wallis). Change in PEF in each group was compared against no change using the Wilcoxon signed ranks test.

Results

DEMOGRAPHICS AND EXCLUSIONS

Of the 356 divers attending, 22 were identified as having asthma. Two of these 22 divers were considered unfit to dive due to co-morbidity and recent asthma exacerbation and another declined to take part in the study, leaving 19 divers (six female and 13 male) with a total number of changes in PEF readings (TR) of 73; five (TR 16) in group A1, 11 (TR 43) in group A2 and three (TR 14) in group A3. No divers were using pre-dive salbutamol. One of the 24 control group divers was excluded owing to a co-morbidity, leaving 23 (six female and 17 male; TR 51). Diving experience varied from five to over 400 dives in the control group and five to 100 dives in the asthmatic group.

The age range of the sample group was from 16 to 27 years (median 20 years). Complications due to rough seas and seasickness affected divers' ability to perform post-dive PEF in certain circumstances and this limited total data collection. Water temperature was 28−30^{O}C for all dives. No diver reported symptomatic airflow obstruction during or post dive.

PEAK EXPIRATORY FLOW

Pre-dive PEF was significantly lower in groups A1 (P = 0.003) and A3 (P = 0.022) compared with group C (Figure 1). The percentage decrease in PEF (and median values for each group) for all recorded dives (total 125) are plotted in Figure 2. Comparison between Group C and the combined asthma groups showed no significant difference. There was a significant difference in the decrease in PEF in group C compared to the A3 group (4.3% vs. 6%; P = 0.039; Figure 2) but not to groups A1 and A2 (P = 0.398 and P = 0.82, respectively). The mean and median decreases in PEF from pre dive in the four groups are shown in Table 1; except for Group A1 these decreases were statistically significant.

Figure 1
Pre-dive peak expiratory flow (PEF) measurements in all groups with medians; C – control group; A1 – no medication; A2 – short-acting beta agonists only; A3 – regular preventative medication

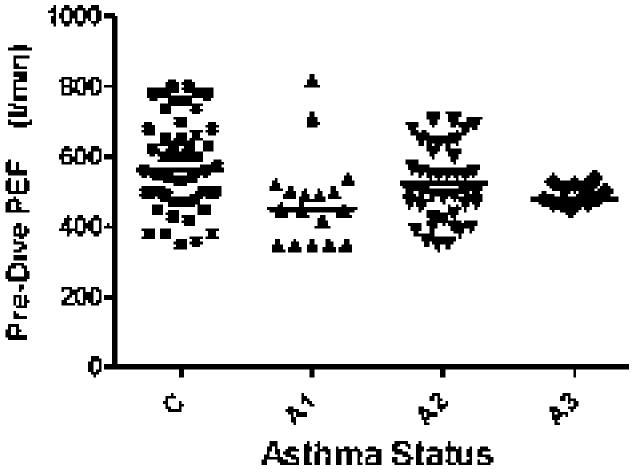
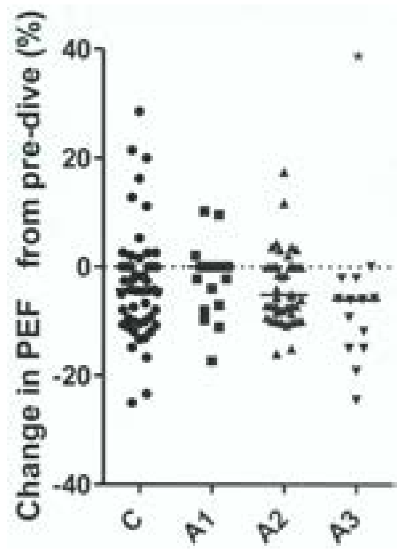


Figure 2
Percentage change in peak expiratory flow (PEF) following a scuba dive on each recorded occasion, sorted by asthma type, with medians; C – control group; A1 – no medication; A2 – short-acting beta agonists only; A3 – regular preventative medication; * $P < 0.05$, non-asthmatic controls vs. Group A3 asthmatics, horizontal lines represent medians



Discussion

In a swimming pool study to a depth of five metres looking at the effect of scuba on divers with and without asthma, no significant changes in PEF were seen pre and post dive.[11] In contrast, our study shows that tropical, open-water scuba diving is associated with a post-dive increase in airflow limitation as measured by PEF in divers both with and without asthma. This is likely to represent increased airflow obstruction, as recorded in previous studies.[16] Based on current medication usage, those divers at greater risk of increased post-dive airflow obstruction were those taking regular preventative medication (inhaled corticosteroids +/- long-acting beta agonists). This is particularly relevant because we investigated typical recreational scuba dives to a depth of 18 msw, to which a PADI Open Water certified diver, the most commonly attained registered recreational scuba diving level, may reach.[17]

This decrease may be a consequence of increased depth and the increased hydrostatic pressure leading to an increase in thoracic blood flow during diving[18] and to decreased lung elasticity. A depth-dependent response would be in keeping with findings from a study of healthy divers, comparing dives of 10- and 50-metre depths, in which a significantly reduced forced expiratory volume in one sec (FEV_1) was found post 50-metre dives but not post 10-metre dives.[7]

In asthma, this is relevant due to the increased bronchial mucosal blood flow present in this condition.[19] This, in combination with the effect of increased hydrostatic pressure, may compound the decreased pulmonary elasticity and increase the stress on the peribronchial alveolar tissue,[20] thus increasing the risk of alveolar damage and potentially provoking bronchoconstriction.

We had the advantage of being able to collect data in tropical diving conditions where temperature and diving technique were stable. However, this does not allow us to comment on the cause of the identified airflow obstruction. We suspect that certain features specific to diving such as breathing of dry compressed air, salt water, dive depth and duration and exposure to other toxins such as boat fumes may be causally linked to bronchial hyper-responsiveness.

Diving, compared to other more vigorous exercise, is thought to be low risk for exercise-induced asthma;[21] however, the cool, dry air used in scuba is in keeping with the identified triggers for bronchospasm in asthma.[22] A fall in FEV_1 was seen in subjects with exercise-induced bronchoconstriction after breathing compressed air via a regulator, which supports the notion that the cool, dry air was the key trigger for this. However, these tests took place after a treadmill test, which the authors acknowledged represented a higher exercise intensity than that of a typical scuba dive.[23]

There are several limitations to our study, especially the small number of divers with a history of asthma joining *Operation Wallacea*.[1] Also, the highest risk group for airflow obstruction was limited to only three out of the 19 divers studied; actively recruiting more divers to this group for further studies may present an ethical dilemma. Use of a peak flow meter has the advantage of cost and portability over a spirometer; however, its use can be unreliable in people with poor technique.[24] Nevertheless, our subjects were instructed in correct technique. In addition, we did not control for the diurnal variation in PEF which may confound results as dives took place in both the morning and afternoon.[25] Height data were not collected, so we were unable to calculate exact predicted PEF values.

We hope that these data will provide practitioners assessing and risk stratifying people with asthma prior to diving with a modest evidence basis on which to advise them of their relative risk of airflow obstruction compared to the normal population. We aim to repeat this study with portable spirometry to allow more detailed interpretation. The effect of depth on airway obstruction needs further investigation. Additionally, previous studies have demonstrated a decrease in forced vital capacity (FVC) following diving,[7,16] but PEF is probably independent of FVC in this population, and these changes in PEF, although small, do represent a separate effect on airways.

Conclusions

Open-water scuba diving causes a small decrease in PEF in divers with and without asthma. This appears to be greater in divers with asthma who are taking regular preventative medication. However, our asthma sub-groups were small. Differences to previous studies are likely due to environmental conditions, including dive depth. These findings support the view that people with asthma are more susceptible to airway changes following scuba diving.

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Conflict of interest: nil

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