# PREVALENCE OF BRONCHIAL HYPERRESPONSIVENESS IN A GROUP OF EXPERIENCED SCUBA DIVERS

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## Summary

50 unselected experienced scuba divers with total diving experience of over 70,000 dives were investigated to see how many would now be allowed to train as scuba divers under various suggested medical standards in current use in Australia. Subjects had both hypertonic saline and histamine bronchial provocation tests as well as routine spirometry. Using published criteria anything between 10% and 46% of these divers would not now be allowed to train. However there were few reported diving incidents and these were not more prevalent in those with abnormal results. Five (10%) of the subjects had current clinical asthma and bronchial provocation tests failed to identify 3 (60%) of these.

Some current recommendations for medical standards seem excessively severe and should be modified. We suggest that prospective study of novice divers with positive results on bronchial provocation testing would be helpful to quantify any increased risks these subjects may have when scuba diving.


## Introduction

Active bronchial asthma is universally regarded as a contraindication to scuba diving. There are good theoretical reasons for this. Obviously an attack of asthma while in the water, either diving or at the surface, could have extremely serious consequences by reducing exercise capacity. In addition airway narrowing falling short of an acute attack of asthma could result in air trapping either globally or regionally within the lung. Such air trapping presents an obvious risk of pulmonary barotrauma on ascent. The scuba diver is in an environment where there are several potential triggers for asthma. These include exercise, inhalation of cold, dry air and possible inhalation of non-physiologically isotonic water, hypotonic fresh water or hypertonic sea water. However, hard evidence that asthmatics are at greater risk of pulmonary barotrauma or death during diving is scarce. Analysis of American diving accident statistics over a long period does not show an over representation of asthmatics.[1] Australian and New Zealand data has been interpreted differently by different authorities. For example Gorman[2] states that "asthmatics are over represented in diving fatalities" and the standard Australian text book on diving medicine states that "only 1% of divers are asthmatic...at least of 9% of deaths were in asthmatics".[3] On the other hand Walker,[4] after analysing the coronial reports on 201 Australian and 120 New Zealand scuba diving related fatalities, could find only four cases in which asthma could have been the probable cause of death.

This divergence of opinion is reflected in the guidelines issued by authorities in different countries regarding fitness to dive. ln the United States there do not seem to be any agreed medical standards, though active asthma is regarded as a contraindication and bronchial provocation testing is felt to be an useful tool.[1] In the United Kingdom asthma is regarded as a contentious issue[5] and British Sub-aqua Club guidelines do not preclude asthmatics from diving unless they have proven exercise induced asthma or have had a very recent attack.[6] In Australia an extremely conservative approach has been adopted in recent years. This is laid down in the Australian Standard AS 4005.1 (1992).[7] This states that current asthma or obstructive airways disease is an automatic disqualification, but that potential divers with abnormal spirometry or possible bronchial hyperreactivity need a specialist opinion and bronchial provocation testing. In its advice to the examining physician the standard suggests for further reading the textbook by Edmonds, Lowry and Pennefather.[3] This textbook takes a more rigid line and suggests disqualification if there is a history of asthma or of use of bronchodilators over the previous five years, wheezing on hyperventilation or after exercise, and forced expiratory volume in one second ($FEV_{1)}$ or vital capacity of less than 80% of predicted, mid-expiratory flow rates of less than 70% of predicted or greater than 10% fall in expiratory flow rates after bronchial provocation testing with histamine and with hypertonic saline. The Thoracic Society of Australia and New Zealand has a slightly more liberal approach, but also emphasizes the role of bronchial provocation tests.[8] In practice this testing is usually applied to potential divers who give a history suspicious of previous bronchospasm or who have mildly abnormal spirometry.

Despite the sometimes very specific recommendations outlined above and a widespread use of bronchial provocation tests to disqualify potential student scuba divers there is no information as to whether having an abnormal provocation test in fact puts the diver at increased risk nor of the prevalence of varying degrees of bronchial hyperresponsiveness in the diving population. The present study attempts to address this last point.

## Subjects and methods

Volunteers were sought through local dive clubs and organizations. It was emphasized that this was a prevalence study in a normal diving population and no effort was made specifically to recruit known asthmatics. All subjects were experienced scuba divers who had qualified either overseas or before current standards were introduced. Subjects filled in a questionnaire with particular emphasis on the respiratory system and all

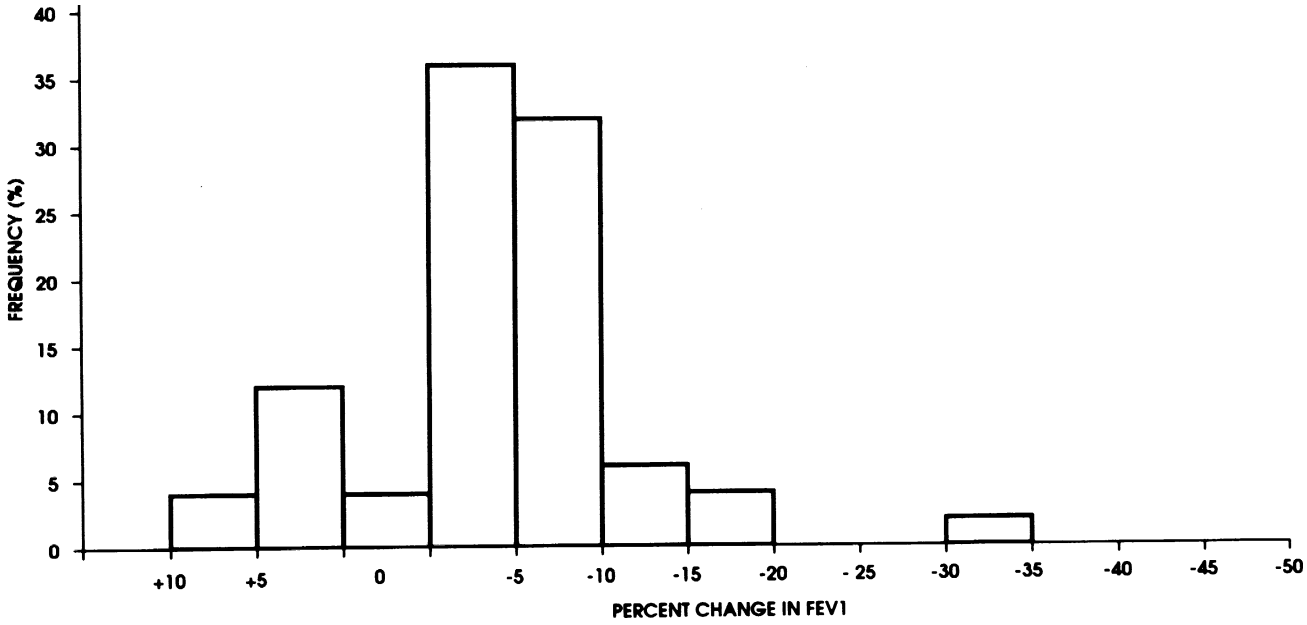


**Figure 1.** The percentage change in $FEV_1$ in response to 4.5% saline in 50 current and experienced scuba divers.

underwent routine spirometry using a Welch AlIyn pneumotachograph including expiratory flow volume loops. History included recording of total number of dives and of any problems encountered during diving. All subjects underwent a standard bronchial provocation test with 4.5% hypertonic saline[9] using an Omron NE-U06 ultrasonic nebuliser followed by administration of 5 mg nebulised salbutamol at the end of the test. 47 subjects also had a bronchial provocation test with histamine to a total dose of 7.8 μmoI.[10] Normal predicted values used for spirometric indices were those of Knudsen.[11] All subjects gave informed consent. The protocol included a guarantee of confidentiality of the individual results but subjects showing possibly abnormal results were given full counselling about the theoretical implications of their results. The study was approved by the local ethical committee.

## Results

Of the 50 divers studied, 38 were male and 12 female. Mean age was 37 years (range 26-58). Five divers gave a history of current asthma and one of past asthma in childhood. A further 22 had either a family history of asthma or a past or family history of other atopic disease. 24 were recreational divers and the remaining 26 were occupational divers. Overall 23 were smokers (10 (42%) of the recreational divers and 13 (50%) of the occupational divers smoked). Smoking was slightly more prevalent (50% v 45%) in women (6) than in men (17). Smoking was more prevalent in those with abnormal respiratory function tests (RFT).

## Spirometry and saline provocation testing

No subjects had either $FEV_1$ or forced vital capacity (FVC) of less than 80% of predicted normal. Ten subjects had $FEV_1$/FVC ratio of less than 75%. Five of these also had maximum mid-expiratory flow rates (MMEF) of less than 70% of predicted as did one subject in whom this was an isolated abnormality. Results of bronchial provocation tests are shown in Table 1

Using the most rigid criteria for exclusion from diving,[3] five subjects would be excluded for current asthma, a further ten for abnormal ventilatory function tests and a further eight for a greater than 10% drop in $FEV_1$ on

**TABLE 1**

**RESPONSES OF 50 EXPERIENCED DIVERS TO BRONCHIAL PROVOCATION TESTING WITH HISTAMINE (47) AND SALINE (50)**

| Fall in $FEV_1$ | Histamine | Saline | Responding to either |
|---|---|---|---|
| Less than 10% | 32 | 32 | 27 (54%) |
| 10% to 14% | 10 | 13 | 15 (30%) |
| 15% to 19% | 3 | 4 | 6 (12%) |
| 20% or greater | 2 | 1 | 2 (4%) |
| **Totals** | **47** | **50** | **50 (100%)** |

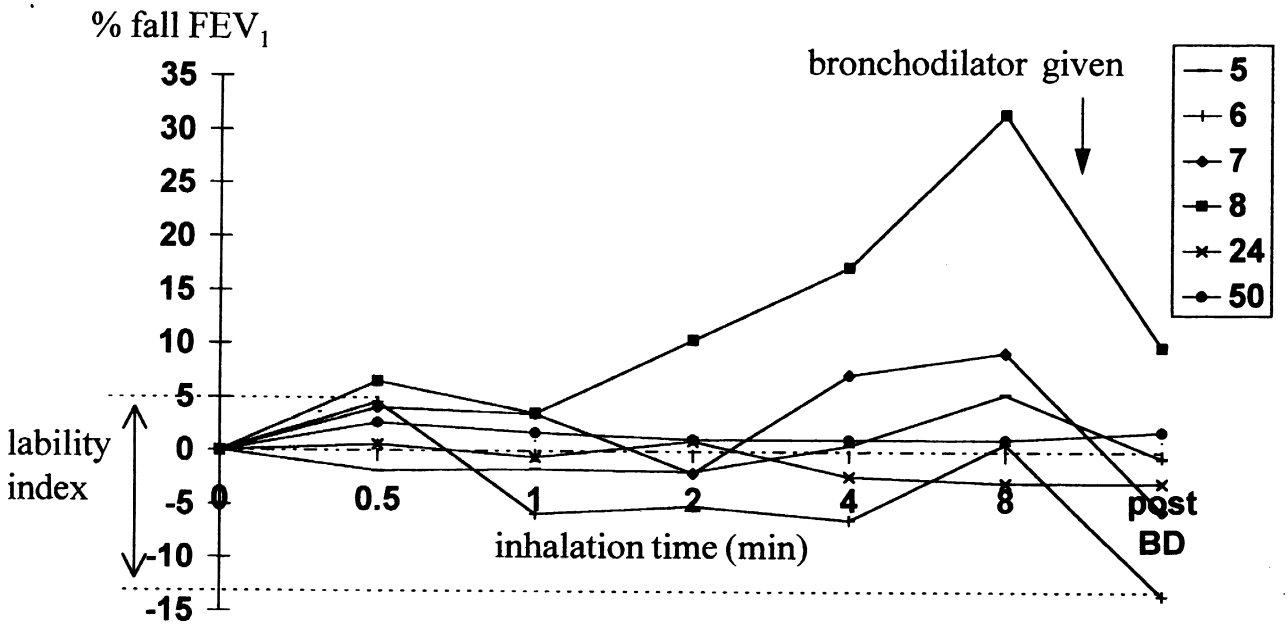


**Figure 2.** Changes in $FEV_1$, expressed as % change from baseline, in response to inhaled 4.5% saline followed by bronchodilator in 6 divers with a history of asthma.

bronchial challenge testing using the % fall in $FEV_1$ from baseline after saline plus the % rise from baseline in $FEV_1$ after bronchodilator to arrive at the percentage change (e.g. 9 % fall + 14% rise = 23% lability). Figure 1 shows the changes in $FEV_1$ in the whole sample.

The asthmatic subjects numbered five (10% of the sample). There were three men and two women with the mean age of 35 years (range 26-44). Another male had a past history of childhood asthma. In total they had logged approximately 2,600 dives. One had had an episode of decompression illness not apparently related to pulmonary barotrauma and he also had had an episode of wheezing on the surface. Two of the asthmatics were maintained on inhaled steroids, one on sodium cromoglycate with theophylline and the remaining two took only bronchodilators as necessary. One asthmatic had a low $FEV_1$/FVC ratio and also failed the bronchial provocation test at the 20% level. Another also failed the provocation tests at the 20% level. The three asthmatics on prophylactic medication had no. abnormalities on spirometry nor on provocation testing. Figure 2 shows the responses of the six divers with a history of asthma.

**Results of testing asthmatic divers**

Diver 5, a recreational diver with 30 dives, regularly used salbutamol and budesonide. 6 hours after the last dose Diver 5 had a small improvement for the first 4 minutes of saline inhalation, then dropped to 5% of baseline before bronchodilator which returned the $FEV_1$ to baseline.

Diver 6, a recreational diver with 30 dives, had recent onset asthma, was on salbutamol, beclomethesone and an antihistamine. 1 hour after the last dose Diver 6 had a fall of 5% after 30 seconds, but at 1, 2 and 4 minutes gained 5% above baseline, at 8 minutes this had dropped to baseline and then improved to 14% above baseline with bronchodilator.

Diver 7, a recreational diver with 2,000 dives, took theophylline, salbutamol and sodium cromoglycate regularly. 12 hours after the last dose Diver 7 had an 8% fall with saline and recovered to 5% above baseline with bronchodilator.

Diver 8, a recreational diver with 200 dives, only needed salbutamol intermittently. 2 weeks after the last dose Diver 8 had a 32% fall in $FEV_1$ after saline and with bronchodilator only recovered to -10% of baseline.

Diver 24, an occupational diver with 350 dives, had used salbutamol in childhood and had had no treatment for 25 years. Diver 24 had a small rise in $FEV_1$ in response to saline and no change with bronchodilator.

Diver 50, an occupational diver with 400 dives, had intermittent wheezing after viral infections when budesonide and terbutaline were used. One month after the last dose Diver 50 had negligible change with saline and no response to broncholdilator.

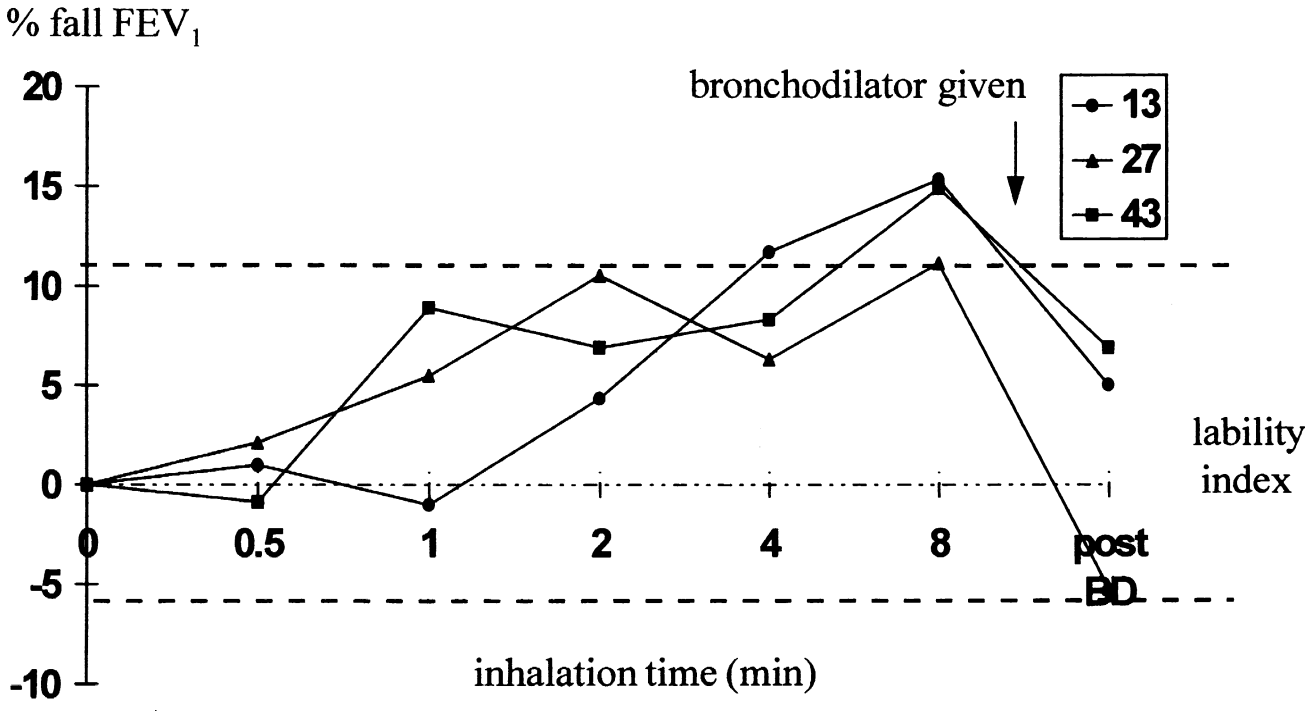


**Figure 3.** Changes in $FEV_1$, expressed as % change from baseline, in response to inhaled 4.5% saline followed by bronchodilator in 3 divers without a history of asthma.

**Non-asthmatic divers responding to saline**

Diver 13 had a low $FEV_1$/FVC ratio (70% of predicted), low mid expiratory flow rate (60% of predicted and a family history of asthma. Diver 13, a recreational diver who had done 140 dives without problems, developed a 15% fall in $FEV_1$ from the baseline after 8 minutes of saline and only recovered to -5% with bronchodilator.

Diver 27 had a low $FEV_1$/FVC ratio (73% of predicted)) and a family history of emphysema. Diver 27, an occupational diver with more than 2,000 problem free dives, developed a 11% fall in $FEV_1$ from the baseline after 8 minutes of saline and recovered to +6% with bronchodilator.

Diver 43 had a past history of hay fever and a family history of asthma. Diver 43, a recreational diver with 700 dives without problems, developed a 15% fall in $FEV_1$ from the baseline after 8 minutes of saline and only recovered to -7% with bronchodilator.

These results are shown in Figure 3. The group as a whole reported three episodes of decompression illness in over 70,000 logged dives (one occurring in an asthmatic). There were three episodes of salt water aspiration and one near drowning in addition to the wheezing episode at the surface occurring in one of the asthmatic subjects.

**Discussion**

Applying standards suggested in the current standard Australian text book on diving medicine, 23 (over 45%) of this group of unselected experienced scuba divers would be prevented from undergoing scuba diving training today. Despite this, this group has reported very few diving problems. lt is possible that this represents selection bias in that those subjects with hyperresponsiveness who were prone to problems may have given up diving, but at the very least such a high prevalence of apparent abnormality in those continuing to dive successfully suggests that the tests are a very poor predictor of problems. The 10% threshold for drop in $FEV_1$ on provocation testing seems inappropriately severe and this recommendation should be modified. The Thoracic Society recommendations of a 20% fall in $FEV_1$ seem more realistic,[9] but in this group of subjects, provocation testing seems to add nothing to a clinical history of current asthma.

It is known that there is a very poor correlation between bronchial hyperresponsiveness and respiratory symptoms including symptoms suggestive of asthma. A recent study[12] using histamine found that only about half of those with moderate or severe bronchial hyperresponsiveness had any symptoms suggestive of asthma. In the same study, over 40% of subjects reported one or more chronic respiratory symptoms and over half of these did not show bronchial hyperresponsiveness. lf it is believed that bronchial hyperresponsiveness on

provocation testing is, in itself, a significant risk factor for scuba diving, then this poor correlation between symptoms and provocation test results should logically mean that all potential scuba divers should be tested. Spirometry alone does not seem likely to be helpful here. The commonest abnormality is a reduced forced expiratory ratio but this has been shown not to be predictive of an increased likelihood of bronchial hyper-responsiveness.[13]

In the absence of hard data on absolute risks there are only theoretical reasons for supporting bronchial provocation testing is the assessment of fitness to dive. A 10% threshold for provocation testing is clearly unworkable and most practitioners would probably be unhappy at passing as fit divers with a 20% fall in $FEV_1$ on bronchial challenge testing. One possible way forward would be to create a national or preferably international register of subjects who have a fall of between 10 and 20% on bronchial provocation testing and to follow their diving progress prospectively should they choose to continue scuba diving after explanation of the increased risks which they may be running. Until this or a similar study is performed no sensible advice to potential scuba divers can be given and it is likely that many people are being excluded from voluntary participation in a recreational activity on purely theoretical grounds.

Only with the results of such a prospective study will we be able to formulate sensible guidelines for the examination of novice scuba divers.

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**References**

1 Neuman TS in *Diving Medicine*. Bove AA and Davis JC. Philadelphia: WB Saunders, 1990
2 Gorman D. Fitness for diving. A review of the critical issues. *SPUMS J* 1994; 24 (1): 2-4
3 Edmonds C, Lowry C and Pennefather J. *Diving and Subaquatic Medicine 3rd edition*. Oxford: Butterworth Heinemann, 1993
4 Walker D. Asthma and diving. *SPUMS J* 1994; 24 (2): 88-90
5 Sykes JJW Medical aspects of scuba diving. *Brit Med J* 1994; 308: 1483-8
6 Farrell P. Asthmatic amateur divers in the UK. *SPUMS J* 1995; 25 (1): 22
7 *Training and certification of recreational divers. Part 1: Minimum entry-level scuba diving. AS 4005.1 - 1992* Sydney: Standards Australia, 1992
8 Jenkins C, Anderson SD, Wong R and Veale A. Compressed air diving and respiratory disease. *Med J Aust* 1993; 158: 275-279
9 Smith CM and Anderson SD. Inhalational challenge using hypertonic saline in asthmatic subjects; a comparison with responses to hypernoea, methacholine and water. *Eur Respir J* 1990; 3: 144-151
10 Yan K, Salome C and Woolcock J. Rapid method for measurement of bronchial responsiveness. *Thorax* 1983; 38: 760-765
11 Knudson RJ, Lebowitz MD, Holbert CJ and Barrons B. Changes in the normal maximal expiratory flow volume curve with growth and ageing. *Amer Rev Resp Dis* 1983; 127: 725-734
12 Kolnaar BGM, Janssen JLM, Folgering H, Van den Hoogen HJM and van Weel C. The relationship between respiratory symptoms and bronchial hyperresponsiveness in a population based sample of adolescents and young adults. *Respiratory Medicine* 1995; 89: 93-100
13 Kivity S, Solomon A, Schwartz Y, Trajber I and Topiloky M. Evaluation of asymptomatic subjects with low forced expiratory ratios ($FEV_1$/VC). *Thorax* 1994; 49: 554-556

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