Changes in lung function in Republic of Singapore Navy divers

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Key words
Occupational diving, pulmonary function, smoking, health surveillance, medical database

Abstract
(Chong SJ, Tan TW, Lim JYJ. Changes in lung function in Republic of Singapore Navy divers. *Diving and Hyperbaric Medicine*. 2008; 38: 68-70.)
Background: It is recognized that diving may result in long-term adverse effects on the lungs. In the Republic of Singapore Navy (RSN), divers undergo an annual examination, which includes spirometry to detect early any deterioration in lung function, to ensure that personnel are fit to continue their duties. There are few Asian studies on lung function, and none on Asian divers.
Objectives: To analyze the lung function of a group of RSN divers over a five-year period.
Methodology: This was a retrospective study based on the spirometric results of RSN divers during their annual recertification in 2001 and in 2006. There were 116 subjects who underwent the spirometry at the same centre in both 2001 and 2006.
Results: The divers showed a statistically significant increase in mean forced vital capacity (FVC) from 86.1% to 89.5% of predicted ($P < 0.01$) over the five-year period. In addition, the mean forced expiratory volume in one second (FEV_1) improved significantly from 87.2% to 90.2% of predicted ($P < 0.01$). However, there was a statistically significant decrease in FEV_1/FVC ratio from 87.0% to 85.0% of predicted ($P < 0.01$). Mean peak expiratory flow rose from 100.1% to 111.00% of predicted ($P < 0.01$). We did not find any statistically significant relationship between years of service or smoking history and changes in lung function for the divers.
Conclusion: Despite being statistically significant, these findings are probably of minimal clinical significance, but do demonstrate that there is no decline in lung function in these divers over this period of time.

Introduction

It is recognized that diving may result in long-term adverse effects to the lungs. The causes include pulmonary barotrauma and pulmonary oxygen toxicity.[1] Thus, occupational divers must meet rigorous medical criteria because of the physical demands that will be placed on them as well as the potentially hazardous environment in which they work. In the Republic of Singapore Navy (RSN), divers undergo an annual recertification, which includes simple spirometry to detect early any deterioration in lung function, to ensure that personnel are fit to continue their duties. There are few Asian studies on lung function, and none on Asian divers. The purpose of this study was to analyze the lung function of a group of RSN divers over a five-year period.

Subjects and methods

This is a retrospective study comparing the spirometric results of 116 RSN divers during their annual diving medical examinations in 2001 and in 2006. Permission to review these data anonymously was obtained from the Chief Naval Medical Officer and the Commanding Officer, Naval Diving Unit, RSN.

Spirometry was performed at the Diving Medicine Section, Navy Medical Service, using a Vitalog Compact 2™ spirometer procured in 1998, which undergoes monthly self-preventive maintenance. Naval medics from the Diving Medicine Section were trained to use a standard operating procedure for conducting the spirometry to minimise inter-tester variability. Forced vital capacity (FVC, L), forced expiratory volume in one second (FEV_1, $L.sec^{-1}$) and peak expiratory flow (PEF) rate ($L.min^{-1}$) were measured and the FEV_1/FVC ratio calculated. All values were normalised to the percentage of mean predicted values based on the European Respiratory Society's predicted values for males for standardised lung function testing. Mid-expiratory flow rates were not measured.

The results from the subjects' spirometry for the two periods were analyzed. Each spirometry included information about the subject's sex, age, weight, height, years of service and smoking history. Smoking history assessed whether the subject was a non-smoker, had smoked for fewer than 10 years, or smoked for 10 or more years.

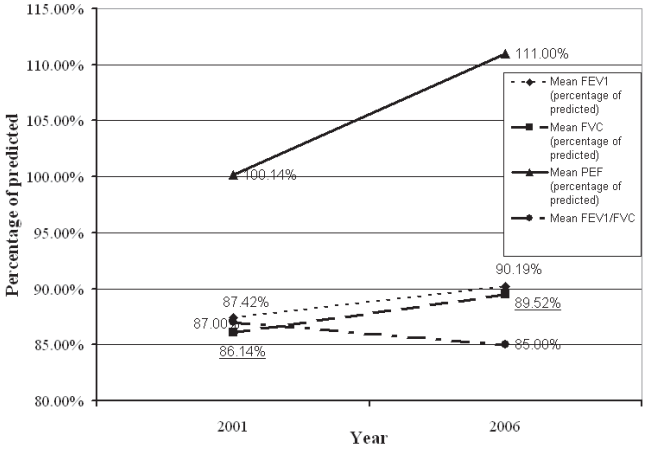
Data input, analysis and tabulation were performed using SPSS for Windows version 10.1. Lung function parameters in 2001 and 2006 were compared by paired *t*-tests. Comparisons between mean years of service and smoking history with lung function parameters were done using the Kruskal Wallis test. The level of significance was chosen to be 0.05.

Results

The subjects comprised 116 divers. They had a mean age of 31.26 (± 5.34) years and mean duration of service of 11.11 (± 5.82) years.

The divers showed a statistically significant increase in mean FVC from 86.1% to 89.5% of predicted ($P < 0.01$) over the five-year period. In addition, the mean FEV_1 improved

Figure 1
Changes in spirometry in 116 RSN divers between 2001 and 2006; FVC – forced vital capacity (L); FEV_1 – forced expiratory volume in one second ($L.sec^{-1}$); PEF – peak expiratory flow rate ($L.min^{-1}$)



significantly from 87.2% to 90.2% of predicted ($P < 0.01$) and the mean PEF improved significantly from 100.1% to 111.0% of predicted ($P < 0.01$). However, there was also a statistically significant decrease in the calculated FEV_1/FVC ratio from 87.0% to 85.0% ($P < 0.01$). The results are summarized in Figure 1.

We did not find any statistically significant difference in lung function between divers less than 30 years old and divers who were 30 years or older. In addition, there was no statistically significant change in lung function with years of service for the study group.

With respect to smoking, there were 62 non-smokers (53.4%), 19 who had smoked for fewer than 10 years (16.4%) and 35 who had smoked for 10 years or more (30.2%) among the divers. There was no statistically significant relationship between the years of smoking and spirometry results ($P > 0.05$). The results are presented in Table 1.

Table 1
Relationship between smoking history and spirometric results; FVC – forced vital capacity (L); FEV_1 – forced expiratory volume in one second ($L.sec^{-1}$); PEF – peak expiratory flow rate ($L.min^{-1}$)

Spirometric parameters	Non-smoker	Smoker < 10 years	Smoker ≥ 10 years
Mean FVC ± SD	4.09 ± 0.46	4.00 ± 0.46	4.02 ± 0.40
Mean FVC (% predicted)	90.1%	86.7%	89.6%
Mean FEV_1 ± SD	3.48 ± 0.43	3.40 ± 0.43	3.44 ± 0.39
Mean FEV_1 (% predicted)	91.2%	86.5%	90.1%
Mean FEV_1/FVC ratio ± SD	85.0% ± 7	84.0% ± 5	84.0% ± 6
Mean PEF ± SD	582 ± 83	561 ± 80	583 ± 78
Mean PEF (% predicted)	111.9%	105.4%	111.7%

Discussion

The work of breathing at pressure is increased due to factors such as increase in density of gas and increased turbulence of flow.[1] Continued exposure to dense gas, as encountered in divers, may cause an adaptive response. However, it is also known that diving may result in long-term adverse effects to the lungs, secondary to conditions such as pulmonary barotrauma and pulmonary oxygen toxicity.[2]

A number of longitudinal lung function studies in divers have shown equivocal results. However, there has been a paucity of studies done on Asian divers. In 404 commercial divers employed by companies operating in the North Sea FVC was 120.4% of the predicted value.[3] Although their FEV_1 was also increased, it was to a lesser extent. Thus the FEV_1/FVC ratio was reduced. It was the authors' belief that divers develop large lungs due to hyperinflation of the alveoli. As the proximal airways do not dilate in proportion, the relationship between FVC and the FEV_1/FVC ratio therefore changes.[4] This finding that divers have unusually large lung volumes and a low ratio of FEV_1/FVC suggestive of obstructive airways disease or airflow limitation was subsequently replicated in several cross-sectional studies.[5–7]

On the other hand, a longitudinal study of 39 military oxygen divers showed no accelerated decline in lung function over a six-year period.[8] This result was in line with another cross-sectional study that had reported no differences in lung function between a group of 65 military oxygen divers and 67 control subjects.[9]

Our findings are similar to those for commercial North Sea divers.[3] RSN divers demonstrated increased FVC and, to a lesser extent, increased FEV_1 over five years, but a reduced FEV_1/FVC ratio. This is likely to be due to physiological hyperinflation of the distal airways, with smaller dilation of the larger airways. The measured values for FVC and FEV_1 in the present study were lower than predicted values based on European norms. Reference values derived from adult Chinese have been reported to be 5 to 19 per cent lower than those for Europeans.[10] Overall, the findings of this study, despite being statistically significant, are probably of minimal clinical significance, but do demonstrate that there is no decline in lung function in these divers over this period of time.

There are certain limitations to our study. Firstly, we cannot rule out some kind of healthy worker effect, where people with significantly poorer lung function were removed from the selection pool. In addition, we used historical data for comparison rather than conducting a prospective longitudinal study. This meant that data such as diving experience, which is not documented prior to spirometry at our centre, could not be analyzed. This is less than ideal and we aim to follow up with a long-term, prospective study on this topic in the near future.

Conclusion

Overall, these findings, despite being statistically significant, are probably of minimal clinical significance, but do demonstrate that there is no decline in lung function in these divers over this period of time.

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