Lung Function in Divers

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Abstract

Correct lung function is indispensible to perform work underwater. Thus, spirometric tests of lung function remain an important element in the process of selecting candidates for professional diving. Studies conducted in the population of divers identified the phenomenon called 'large lungs', which is often associated with spirometric indices characteristic of obstructive impairment of lung function. This study investigated selected parameters of lung function in the population of divers and candidates for professional divers. Fifty two male subjects were examined as part of the selection process. Basic spirometric tests: forced expiratory volume in 1 s (FEV1; dm^3), forced vital capacity (FVC; dm^3), forced expiratory flow in the range 25–75 % of FVC (FEF25-75; $dm^3\ s^{-1}$), and FEV1/FVC (%) were compared with compared with the predicted reference values estimated by the European Coal and Steel Community. The results demonstrate differences in FVC and FEF25-75 in divers, which may correspond to functional hyperinflation. The effects of 'large lungs' observed in divers, if persisting for an extended period of time, may lead to lung ventilation impairment of the obstructive type.

Keywords

Divers • Hyperinflation • Forced vital capacity (FVC) • Forced expiratory flow (FEF) • Large lungs • Lung function • Spirometry

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1 Introduction

Effective functioning of the respiratory system is one of the most important elements of human physiology, especially in divers, in whom it has a considerable influence on the ability to perform useful work underwater. It is commonly known that any breathing resistance decreases the comfort of individuals working in aquatic environments (Vail 1971). Analysis of life function parameters will be useful to characterize this particular professional group against other groups in the society. This is an important issue as the majority of available medical literature points to the phenomenon called 'large lungs, which is often associated with spirometric indices characteristic of lung ventilation impairment of the obstructive type (Skogstad et al. 2000, 2002; Watt 1985; Davey et al. 1984; Crosbie et al. 1977, 1979). Any possible deviations observed while performing spirometric tests gain special importance in the aspect of legally regulated requirements for work as a professional diver. In the Polish Armed Forces spirometry has been routinely conducted for many years, while in the civilian environment an obligation to perform such tests was imposed in 2008 (Regulation of the Minister of Health 2007).

The aim of the present study was to perform a descriptive analysis of selected lung function parameters in divers and candidates for professional divers. The analysis was carried out on the basis of medical tests which are compulsory for all candidates willing to work as professional divers. The results were then compared with those obtained by other researchers dealing with the above subject matter.

2 Methods

2.1 Subjects

The study was approved by the Ethics Committee of the Military Institute of Medicine in Warsaw, Poland. The study population consisted of 52 men, divers, and candidates for professional divers, who were required to be medically examined before they were declared fit to dive. The group consisted of 42 certified professional divers ($n = 42$) and ten candidates for professional divers ($n = 10$). All candidates for professional divers had some diving experience in the field of recreational diving, confirmed by at least a basic level certificate issued by a diving federation. The study population consisted of individuals aged 20–49. There was a minor difference between the mean (31.3 years) and the median (30.5 years), causing a slight skewness of the age distribution. Approximately 80 % of the study population consisted of divers and candidates for professional divers were 20–38 years old. The distribution of body weight in the study group was 61–114 kg. There were no significant differences between the mean (83.5 kg) and the median value (84 kg). Approximately 80 % of the study population consisted of divers and candidates for professional divers with body weight of 70–95 kg. Height of the studied individuals was 167–195 cm; the mean value was 180.2 cm, and the median value 180.0 cm. The distribution of height in the study population was uniform; approximately 80 % of the group consisted of divers and candidates for professional divers were 168–190 cm tall. Body mass index (BMI) was 19.9–31.6 $kg \cdot m^{-2}$. The mean BMI amounted to 25.7 $kg \cdot m^{-2}$, and the median value was 25.0 $kg \cdot m^{-2}$. Approximately 80 % of the study population consisted of divers and candidates for professional divers had BMI close to normal, i.e., 20–28 $kg \cdot m^{-2}$.

2.2 Spirometry

The study was based on spirometry performed in 2010–2011. The measurements were taken by the same spirometer and the same operator. Lung function measurements were made with a SpiroUSB spirometer (Cardinal Health, Dublin, OH) and Spida-5 software (CareFusion Health, Basingstoke, UK). In accordance with generally accepted principles, the test was performed in a sitting position. Each subject was carefully instructed before the test, and each was informed that in case of any problems with proper performance, the test would be repeated, which is of no

health consequences. This information has a positive psychological influence on the quality of measurements (Gondorowicz and Siergiejko 2004), especially in subjects who have their lung function measured for the first time, are uncertain about the results, or for whom the results may have important legal implications. The spirometer was calibrated before each measurement according to the manufacturer's recommendations.

2.3 Case Definitions, Statistics

Spirometric indices were standardized and compared with predicted reference values according to the European Coal and Steel Community (ECSC) guidelines (Quanjer et al. 1993; Roca et al. 1988). The following lung function parameters were measured:

- FEV1 – forced expiratory volume in 1 s (dm^3),
- FVC – forced vital capacity (dm^3),
- FEF25-75 – forced expiratory flow rate in the range 25–75 % of FVC ($dm^3\ s^{-1}$).

The point of reference was the range of predicted values consistent with 90 % confidence interval for the population of healthy individuals studied by ECSC. All of the above-mentioned parameters were automatically calculated by spirometric software. Due to relatively small sample size (42 divers and 10 candidates for professional divers), the methods of descriptive statistical analysis were used to characterize the results.

3 Results

3.1 Forced Vital Capacity

The mean FVC was 5.6 dm^3, with a minimum at 4.3 and maximum at 7.3 dm^3. The distribution of FVC by divers' age is shown in Fig. 32.1, in which the FVC results also were compared with the 90 % confidence intervals for a sample of healthy subjects studied by ECSC. Over 95 % of the divers were more than 30 % above the predicted FVC values and 11.5 % of them

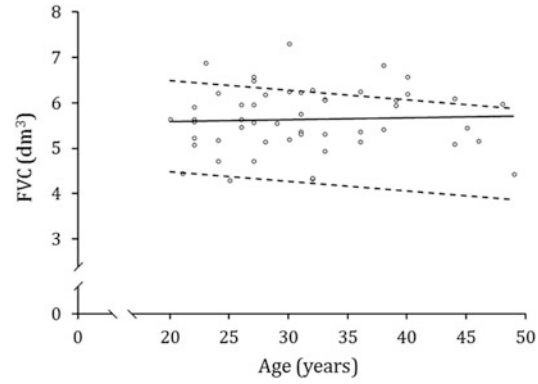

Fig. 32.1 Trend in forced vital capacity (FVC) in relation to divers' age (*solid line*) compared with 90 % confidence intervals for FVC_{max} and FVC_{min} (*dashed lines*) obtained in healthy individuals by ECSC, taken as reference

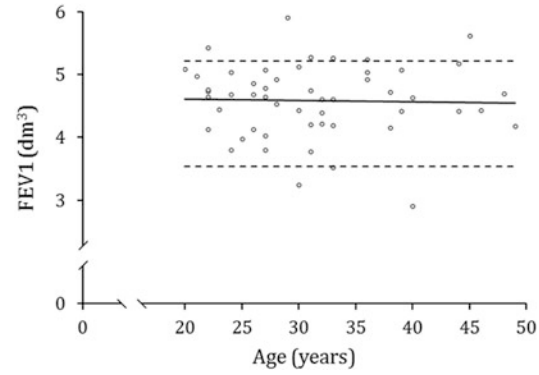

Fig. 32.2 Trend in forced expiratory volume in 1 s (FEV1) in relation to divers' age (*solid line*) compared with 90 % confidence intervals for $FEV1_{min}$ and $FEV1_{max}$ (*dashed lines*) obtained in healthy individuals by ECSC, taken as reference

(n = 6) were above the maximum FVC values with reference to the 90 % confidence interval for healthy individuals studied by ECSC.

3.2 Forced Expiratory Volume in 1 s

The mean FEV1 was 4.6 dm^3, with a minimum at 2.9 and maximum at 5.9 dm^3. The distribution of FEV1 by divers' age is shown in Fig. 32.2, in which, as was the case with FVC, the FEV1 results were compared with the 90 % confidence

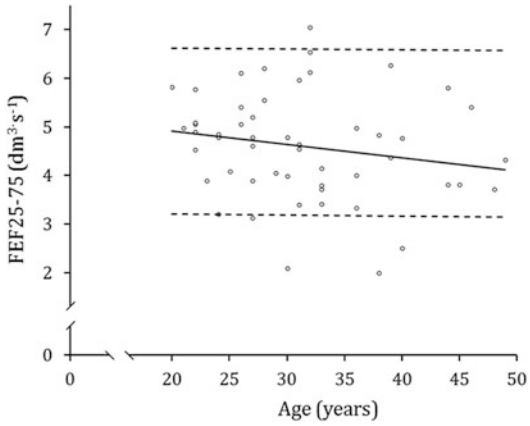

Fig. 32.3 Trend in forced vital capacity (FEF25-75) in relation to divers' age (*solid line*) compared with 90 % confidence intervals for $FEF25\text{-}75_{min}$ and $FEF25\text{-}75_{max}$ (*dashed lines*) obtained in healthy individuals by ECSC, taken as reference

intervals obtained in healthy subjects studied by ECSC. More than 70 % of the divers were in a range of 40–90 % of predicted FEV1 taken from the ECSC reference. Only did one diver not fall into the accepted 90 % confidence interval, and 10 % (n = 5) of them reached or exceeded the maximum interval values.

3.3 Forced Expiratory Flow

The mean FEF25-75 was 4.6 $dm^3\ s^{-1}$, with a minimum at 2.0 and maximum at 7.1 $dm^3\ s^{-1}$. The distribution of FEF25-75 by divers' age is shown in Fig. 32.3. The data indicate that 70 % of the divers were in a range of 50–70 % of predicted FEV1 taken from the ECSC reference. Eight percent of the divers (n = 4) did not reach and 2 % (n = 1) exceeded the accepted 90 % confidence intervals.

4 Discussion

Studies point to the phenomenon of 'large lungs' consisting of the above-average FVC values in the absence of 'air trap' markers. Lung function tests may, however, demonstrate a reduced FEV1/FVC ratio in reference to predicted values, which may indicate lung ventilation impairment of the obstructive type (Adir et al. 2005; Skogstad et al. 2000, 2002; Watt 1985; Davey et al. 1984; Crosbie et al. 1977, 1979). Deviations from the norm in spirometric tests, performed as part of a routine medical examination of divers, may be a reason to declare unfitness for work as a professional diver. However, it is not quite clear where the normal values end and abnormal begin. Some authors have pointed out that a majority of professional divers (particularly those less than 30 years old), exhibit the above-average FVC values. Still, there is a disagreement over the cause of such a phenomenon and whether a co-existing reduced FEV1/FVC ratio should be regarded as a spirometric index of pathology (Crosbie et al. 1979).

A number of studies show that spirometric indices which reflect the phenomenon of 'large lungs' in divers ought to be considered as a short-term effect this profession or a long-term negative effect of diving (Watt 1985; Davey et al. 1984; Crosbie et al. 1977, 1979). On the other hand, Bouhuys and Beck (1979) argue that the above-average FVC values in young men are observed not only among divers but also in other professional groups and in the general population. There is a belief that among individuals of the same age, similar height and weight, the major cause of this phenomenon are differences in muscle strength, which is supposed to be greater in physically trained individuals and in professionals predisposed to forced expiration training. Respiratory muscles training is the primary reason for the capability to generate increased volumes of air and increased expiratory force, which, in turn, results in the above-average FVC parameters (Clanton et al. 1987). This effect is associated with distention of alveoli and alveolar ducts, confirmed by post-mortem examination (Calder et al. 1987). Some authors suggest that the 'large lung' phenomenon is a measurable exponent of natural selection for diving rather than a sequel of diving training (Adir et al. 2005). In the present study, we found that FVC in divers was slightly increasing with age, and thus with diving experience, compared with

a natural downtrend in FVC values observed in the population of healthy individuals studied by ECSC (Fig. 32.1). The trend is consistent with the references quoted above. It should be pointed out that our results were unlikely to be distorted by the presence of candidates for professional divers among the individuals studied because all of them had extensive diving experience in recreational diving; therefore, the entire group had undergone respiratory muscles training. As regards the FEV1, the results are unambiguous. None of the studies have reported any differences due to profession done compared with the general population, e.g., divers, police officers, or submarine crews. Yet, there are certain differences in the trends developing over time (Skogstad et al. 2002; Watt 1985). A considerable reduction in FEV1 as a function of years of diving experience has been demonstrated by Tetzlaff et al. (2006) in their study of smoking divers who initially had FEV1 at a normal high level. In the present study, FEV1 in divers decreased slightly with age compared with the unchanged reference values derived from 90 % confidence interval for the population of healthy individuals studied by ECSC (Fig. 32.2). Data from the literature show a reduction the forced expiratory flow rate, particularly in the lower 25–50 % range of FVC, in divers with longer diving experience. This finding may suggest a progressive pathology of small bronchi as a function of time (Thorsen et al. 1990; Tetzlaff et al. 1988; Davey et al. 1984). Extended studies conducted in Norway in police divers beginning their careers and continued for 6 years have demonstrated a diving-related flow impairment in small airways, as compared with non-diving officers (Skogstad et al. 2000, 2002). Similar conclusions were reached by Adir et al. (2005) who examined a relatively large, but not fully representative due to specific selection criteria, group of 109 Israeli military divers. Our present findings clearly indicate that FEF25-75 in divers decreases with age (Fig. 32.3). That was a consistent tendency and it was incomparably stronger than that in case of 90 % confidence interval for the population of healthy individuals studied by ECSC.

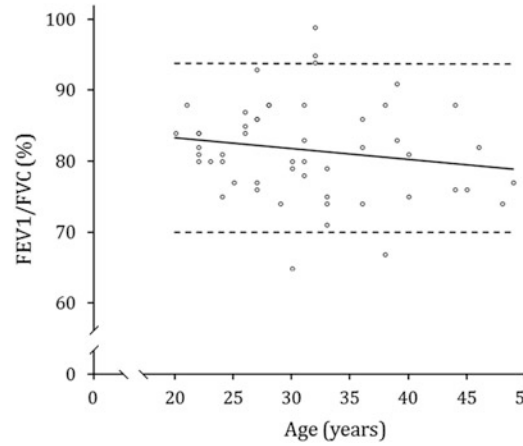

Fig. 32.4 Trend in FEV1/FVC ratio in relation to divers' age (*solid line*) compared with 90 % confidence intervals for $FEV1/FVC_{min}$ and $FEV1/FVC_{max}$ (*dashed lines*) obtained in healthy individuals by ECSC, taken as reference

The present study has limitations, stemming mostly from a single measurement technique employed. Nevertheless, the findings that support the existence of 'large lungs' in divers are consistent with the data reported by other authors. It seems that the absence of a natural downward trend in FVC in older divers, which in our study is synonymous with greater diving experience, may indicate that occupational diving leads to functional distention of a certain number of alveoli or alveolar ducts which are not normally used while breathing. However, such functional lung distention may, in the long-term, lead to ventilation impairment of the obstructive type (Thorsen 2003), a disorder which has repeatedly been observed in professional divers (Watt 1985; Davey et al. 1984; Crosbie et al. 1977, 1979). It seems that following the reduction in the FEV1/FVC ratio with time would be the best indicator of a possible progressive obstructive lung disease in professional divers (Swanney et al. 2008; Skogstad et al. 2000, 2002). In the present study, this reduction did not assume significance in older divers (Fig. 32.4). Thus, we cannot decisively state that professional divers would be prone to obstructive ventilation impairment as they continue their career until we perform longitudinal testing in the same individuals over a period of several years.

5 Conclusions

Due to a relatively small number of subjects, only were descriptive analyses of selected parameters of lung function in divers and candidates for professional divers presented in this chapter. The data are part of the medical tests which all divers must undergo before they are declared fit to dive. The present study demonstrates some differences between divers and the general population as assessed by spirometric measurements. The FVC tends to be on the higher side and FEF25-50 on the lower side in divers compared with the reference data of the general population. The results lend support for the presence of the phenomenon of 'large lungs' in professional divers. Functional hyperinflation persisting for an extended period of time may potentially lead to lung ventilation impairment of the obstructive type. Extending the observation period could demonstrate whether these trends would change after more years of diving experience. Therefore, analysis of lung ventilatory indices in divers should include the correlation of lung function as a function of years of diving experience, the nature of occupational activities carried out underwater, and the history of diseases and diving accidents.

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Conflicts of Interest The authors declare no conflicts of interest in relation to this article.

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