



Pulmonary Oxygen Toxicity after Dry Exposure to PO₂ = 200 kPa

Barbara E. Shykoff

Navy Experimental Diving Unit, Panama City, FL U.S.A.



BACKGROUND

Knowledge about pulmonary effects of exposures to elevated PO₂ and the time to recovery from them is slowly accumulating. Because even asymptomatic effects of oxygen may add to effects of new exposure, divers exposed repeatedly to elevated oxygen partial pressure (PO₂) walk the line between accumulating toxic effects of oxygen or delaying dives unnecessarily. A goal of the larger effort is to better define recovery times for divers who may include deep excursions or oxygen-accelerated decompression in their dive days. The goal of this specific effort was to describe the after-effects of exposures to PO₂ = 200 kPa.

Pulmonary oxygen toxicity is unaffected by immersion.¹ Thus, this work was conducted in a dry chamber.

METHODS

- The study was approved by NEDU's Institutional Review Board.
- Subjects were qualified U.S. Navy divers.
- Divers sat in a dry hyperbaric chamber, up to four at a time.
- Chamber pressure was 202 KPa (33 feet of sea water).
- Divers at pressure breathed humidified 100% O₂ open circuit from hoods (Model 8891, Amron International, Vista, CA).
- Oxygen breathing was continuous without air breaks.
- Dive combinations and numbers are listed in Table 1.

- Flow-volume parameters, specifically forced vital capacity (FVC), forced expired volume in 1 second (FEV₁), forced expired flow from 25% to 75% of volume expired (FEF₂₅₋₇₅) and diffusing capacity of the lung for carbon monoxide (D_LCO) were measured in triplicate (CPL, nSpire Health, Longmouth CO). Averages values were assessed.
- Flow-volume values were obtained at baseline, immediately before end after each dive, and for two days following. Baseline and pre-dive 1 were pooled.
- D_LCO was measured at baseline, after the final dive of the day, and on follow-up days.
- Individual values were considered to be depressed if they fell below the 95% confidence limits of normal variability previously measured at NEDU,² namely 7.7% for FVC, 8.4% for FEV₁, 17% for FEF₂₅₋₇₅, and 14.2% for D_LCO.
- Average values were compared across testing sessions using repeated measures analysis of variance and Bonferonni-corrected t-tests. Significance was determined as p < 0.05.

Table 1. Dive combinations and numbers of experiments completed.

Dive combinations		n	n first dives
2-hr	Single dive	12	12
3-hr	Single dive	27	127
3-hr	3-hr SI	36	
	6-hr SI	33	
	overnight SI (15 to 18 hrs)	31	
30-min	2-hr SI, 3 dives	27	27

RESULTS

Table 2. Average changes immediately after single dives

mean (SE)	%ΔFVC	%ΔFEV ₁	%ΔFEF ₂₅₋₇₅	%ΔD _L CO
2-hour n=12	-0.5 (0.8)	0.2 (1.0)	2.4 (2.9)	-2.7 (1.4)
3-hour n=127	-1.2 (0.2) *	-1.6 (0.3) *	-0.3 (0.7)	1.3 (1.4) n=57
30-min n=27	-1.4 (0.5) *	-1.2 (0.8)	0.9 (2)	N/A

* Indicates significantly different from 0.

Significant differences not on the figures:

- After the series of 30-minute dives, mean FEF₂₅₋₇₅ on Day+1 was 4.8% lower than baseline.
- After a single 2-hour dive, mean FVC on Day +1 was 2% lower than baseline.

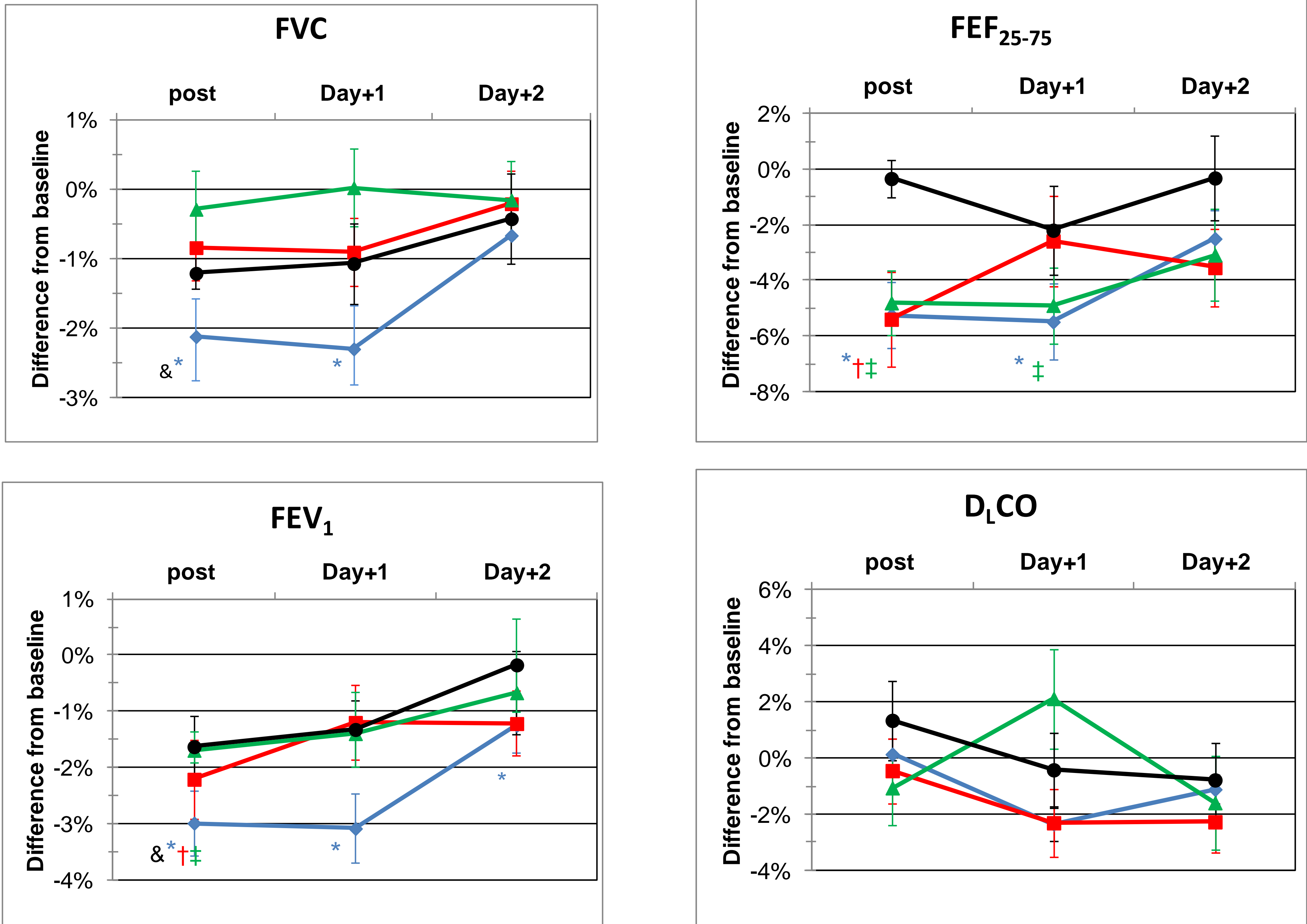


Figure 1. Three-hour dives: mean pulmonary function differences from baseline as functions of time after the final dive. Bars represent standard error. Colors and symbols distinguish SI. Differences from baseline are indicated when Bonferonni-corrected p < 0.05. ● single dive, & differs from 0; ▲ 18-hr SI, ▲ differs from 0; ■ 6-hr SI, ■ differs from 0; ◆ 3-hr SI, * differs from 0. For post dive FEF₂₅₋₇₅, all repeated dives differ from a single dive.

- The number s of changes detected in FVC, FEV₁, FEF₂₅₋₇₅, and D_LCO were 10, 16, 19, and 12, respectively.
- Not all subjects with ΔPF had symptoms, and vice versa.
- After all but single dives, some pulmonary function indices remained or became depressed on Day+2.

Table 3. Incidence of symptoms or signs of pulmonary oxygen toxicity

Dive combinations		Incidence of respiratory symptoms	Incidence of ΔPF
2-hr	Single dive	0%	0%
3-hr	Single dive	15%	5%
	3-hr SI, 2 nd dive	39%	17%
	6-hr SI, 2 nd dive	55%	27%
	18-hr SI, 2 nd dive	35%	16%
30-min	2-hr SI, 3rd dive	11%	11%

DISCUSSION

- Despite its high variability, FEF₂₅₋₇₅ appears to be the most sensitive of the indices evaluated here, both by frequency of change and by average difference from baseline.
- Even after an 18-hr SI, average FEF₂₅₋₇₅ after a second dive is depressed more than it is after a single dive (Fig. 1, top right panel).
- incidences of signs and symptoms of pulmonary oxygen toxicity after exposures to PO₂ = 200 kPa are not clearly ordered by SI (Table 3).
- Recovery of average changes appears to be slowest for the shortest SI, as expected.

CONCLUSIONS

- Both the average changes in pulmonary function and the incidences of signs and symptoms show that effects of exposure to PO₂ = 200 kPa for three hours combine with those of a subsequent exposure for >18 hours.
- Full recovery from pairs of dives requires more than two days in some subjects.

REFERENCES

1. Shykoff, B.E. *Pulmonary Effects of Six-Hour Dives: In-Water or Dry Chamber Exposure to an Oxygen Partial Pressure of 1.6 Atm.* Panama City (FL): Navy Experimental Diving Unit, 2005, NEDU TR 05-19.
2. Shykoff, B.E. *Pulmonary Effects of Submerged Breathing of Air or Oxygen.* Panama City (FL): Navy Experimental Diving Unit, 2002, NEDU TR 02-14.

ACKNOWLEDGEMENTS

This work was funded by Naval Sea System Command, Deep Submergence and Diving Biomedical Program. HM1 Tonji Paulk was task leader. and many Navy divers volunteered to be subjects..