



Pulmonary Oxygen Toxicity after Dry Exposure to $PO_2 = 200$ kPa

B.E. Shykoff

Navy Experimental Diving Unit
Panama City, FL



- Even asymptomatic effects of oxygen may add to effects of new exposure.
- Divers exposed repeatedly to elevated oxygen partial pressure (PO_2) walk the line between accumulating toxic effects of oxygen or delaying dives unnecessarily.
- Large-scale goal: to define recovery times after dives including deep excursions or oxygen-accelerated decompression.
- Specific goal: to describe insult or and recovery from exposures to $PO_2 = 200$ kPa.



Premise:

Pulmonary oxygen toxicity effects that are below a detection threshold become measurable when they are added to the effects of a second exposure.

Approach:

- 1) Find a dive just severe enough to provoke mild changes in pulmonary function and/or mild symptoms.
- 2) Repeat the exposure after various surface intervals (SI) and measure accumulated effects.

SI chosen:

1x, 2x, and 6x exposure duration

Also, a series of three 30-min dives with SI = 2 hours



Methods



- $PO_2 = 200$ kPa is safe for dry exposure but not for use in the water.
- Pulmonary oxygen toxicity effects are independent of submersion.¹
- This study was conducted in a dry hyperbaric chamber.
 - Up to four U.S. Navy divers at a time, plus a tender
 - Humidified O_2 by hood (Amron).
 - (Chamber atmosphere was air.)
 - Divers seated at rest
 - No air breaks

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.



Methods



Pulmonary function tests:

Forced flow-volume maneuvers: FVC, FEV₁, FEF₂₅₋₇₅

Baseline, before and after each dive, day+1, and day+2

Single breath diffusing capacity: D_LCO

Baseline, after the last dive of the day, day+1, and day+2

Values considered to be depressed if outside of NEDU's measured non-diving variability:²

FVC:	-7.7%	FEV ₁ :	-8.4%
FEF ₂₅₋₇₅ :	-17.0%	D _L CO:	-14.2%

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.



Methods



Respiratory symptoms queried:

Chest pain or tightness
Shortness of breath
Rapid shallow breathing
Inspiratory burning
Cough

Hourly during dives, before and after each dive, day+1,
and day+2.



Methods



Safety measurements

Visual refraction, Snellen chart acuity

CNS symptoms questions:

Vision changes, Ringing or roaring in the ears,
Nausea, Tingling or twitching,
Light-headedness or dizziness, Irritability.

-- Hourly during dives

Also asked about fatigue and exercise intolerance



Results



Single two-hour dives (n =12):

- No divers had depressed pulmonary function indices.
- No divers reported respiratory symptoms.
- (Two divers reported fatigue and exercise intolerance)

Single three-hour dives (n =27):

- Two divers had depressed pulmonary function indices.
- Eight divers reported respiratory symptoms.

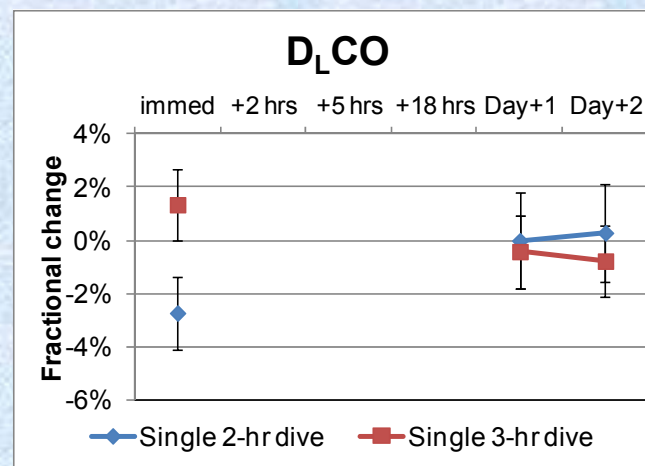
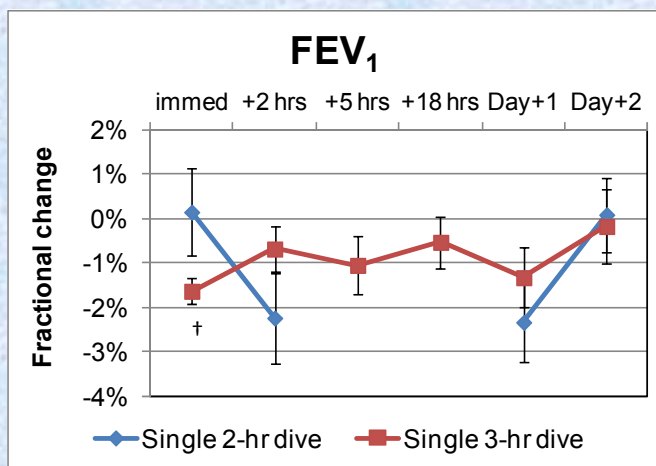
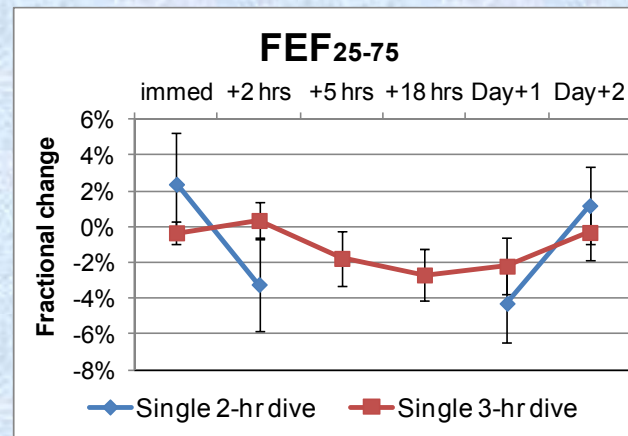
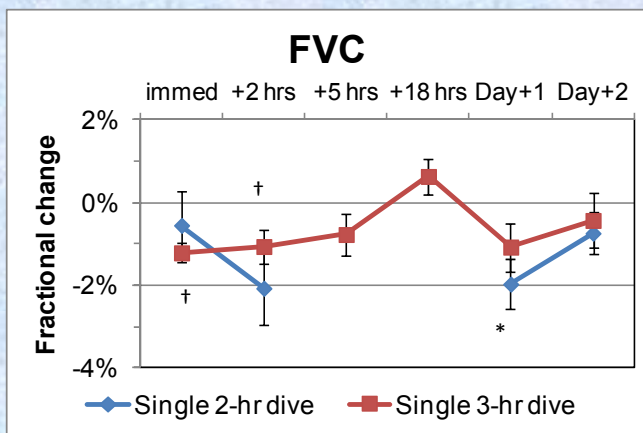
-- Used three-hour dives

-- n = 24 to 36 for each series



Results

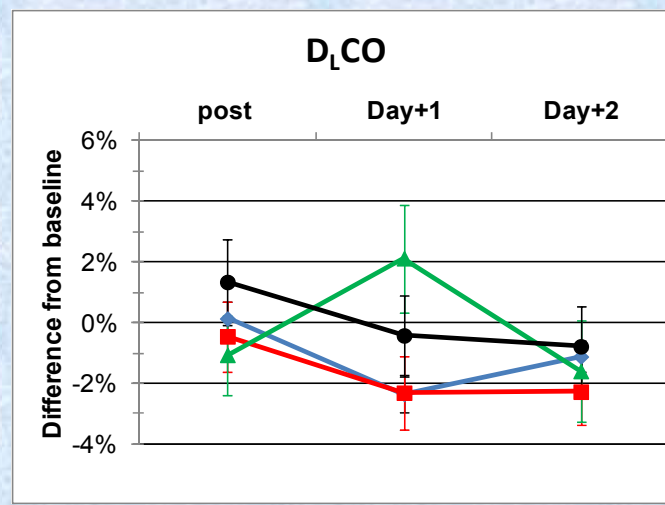
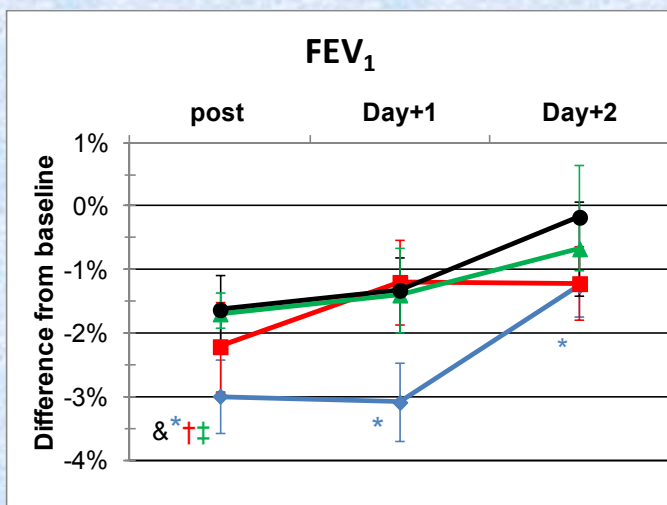
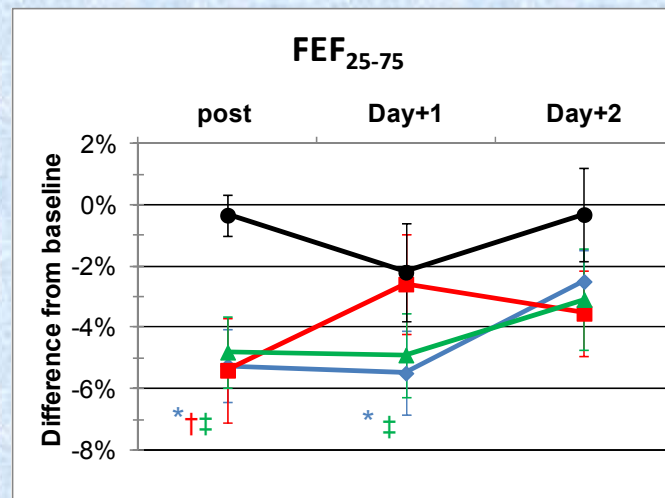
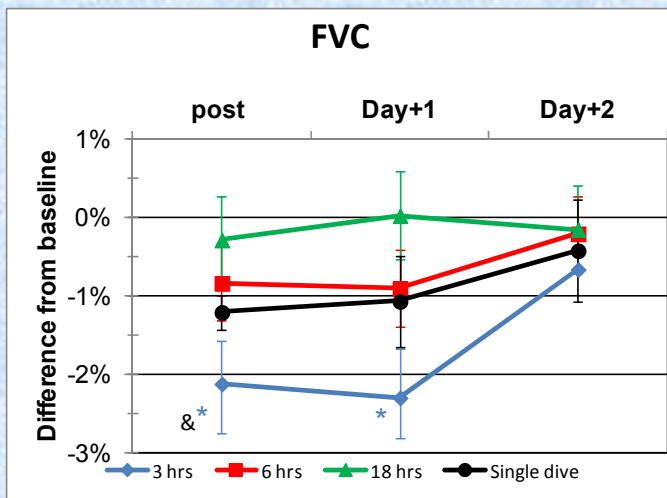
Averages, single dives





Results

Averages, dive pairs





Results

Rates of pulmonary effects



Dive combinations		Incidence of respiratory symptoms	Incidence of Δ PF
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, 3 rd dive	11%	11%



Discussion



- FEF_{25-75} appears to be the most sensitive of the indices evaluated here.
- Even after an 18-hr SI, average FEF_{25-75} after a second dive is depressed more than it is after a single dive.
- Recovery of average changes appears to be slowest for the shortest SI, as expected.
- Incidences of signs and symptoms of pulmonary oxygen toxicity after exposures to $PO_2 = 200$ kPa are not clearly ordered by SI.



Conclusions



- Effects of exposure to $PO_2 = 200$ kPa for three hours combine with those of a subsequent exposure for more than 18 hours.
- Full recovery from pairs of dives to this PO_2 requires more than two days in some subjects.