

UNITED STATES ARMY AEROMEDICAL RESEARCH LABORATORY



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## **The Portable Helicopter Oxygen Delivery System (PHODS) in the Altitude Chamber: Cerebral and Peripheral Blood Oxygen and Perceptual Vigilance**

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Leonard Temme, Bobby Bowers, Amanda Hayes, Paul St. Onge, Aaron McAtee, Frank Petrassi, & Dennis Ard

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<b>13. SUPPLEMENTARY NOTES</b> <sup>1</sup> U.S. Army Aeromedical Research Laboratory; <sup>2</sup> Goldbelt Frontier, LLC; <sup>3</sup> School of Army Aviation Medicine					
<b>14. ABSTRACT</b> Introduction: The Portable Helicopter Oxygen Delivery System (PHODS) is a hypoxia countermeasure that provides supplemental oxygen (O <sub>2</sub> ) to Army aviators in unpressurized aircraft at altitudes up to 18,000 feet (ft) above mean sea level (MSL). The present document is the presentation provided to the Vertical Flight Society Forum 78 (Fort Worth TX, May 2022) describing USAARL's test and evaluation (T&E) of the PHODS conducted in the altitude chamber. Methods: The PHODS T&E monitored: (1) peripheral blood O <sub>2</sub> saturation (SpO <sub>2</sub> ) using standard pulse oximetry, (2) regional cerebral blood O <sub>2</sub> saturation (rSO <sub>2</sub> ) using infrared spectroscopy, and (3) Psychomotor Vigilance Task (PVT) performance, a tedious, intentionally boring visual monitoring task that reports visual reaction time as well as errors due to missed targets and false anticipatory responses. These measures were recorded at pressure altitudes (PA) of 14,000 and 17,800 ft above MSL as well as at ground level (GL). At each altitude, Army aircrew (N = 22) tested PHODS functionality and effectiveness during 10 minutes (min) of the PVT, 5 min. of verbalized text reading (TR), and 2 min of a physical workload (WL) task; i.e., self-paced squats.					
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14. Abstract (continued)

In addition to mean and standard deviations on the  $rSO_2$  and  $SpO_2$ , linear regressions calculated  $rSO_2$  and  $SpO_2$  slope over the testing periods of 10 min of PVT, 5min TR, and 2 min. WL.

Results: With PHODS average  $SpO_2$  fell by about 6% and  $rSO_2$  by about 5 units at both 14,000 & 17,800 ft PA relative to GL, a statistically significant difference.

1. This relatively modest drop in  $SpO_2$  and  $rSO_2$  occasioned a delay of about 33 ms in PVT reaction times relative to reaction time seen at GL; i.e., a delay of about 10% in the simplest response of the visual system to the sudden unpredictable onset of a light.
  2. Data suggest a cumulative PVT fatigue or tedium at both 14,000 ft and 17,800 ft such that, on average, PVT response time during the last 5 minutes of PVT testing interval was statistically slower than response time recorded during first 5 minutes of PVT testing, an effect not seen at GL, possibly indicating a compound hypoxia and fatigue effect.
  3. If these results indicate a slowing of neural processing through the central nervous system, the delays may be compounded and possibly disrupt normally synchronous signals and overt behaviors such as those supporting the ocular motor system as well as display refresh rates.
  4. The  $SpO_2$  data did not parallel the  $rSO_2$  data in that  $rSO_2$  fell over time during WL at 14,000 and 17,800 ft but  $SpO_2$  did not fall.
  5. The fall-off slope was related directly to altitude: the greater the altitude, the steeper the fall off.
  6. Fall-off time course, severity, practical importance, and recovery rates remain to be assessed for WL durations longer than 2 minutes
- Consequently, PHODS has shortcomings as a hypoxia countermeasure. We recommend enhancements for future Army aircraft particularly when aircrew workload is involved.



# The Portable Helicopter Oxygen Delivery System (PHODS) in the Altitude Chamber: Cerebral and Peripheral Blood Oxygen and Perceptual Vigilance

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# Problem Statement

Hypoxia remains one of the most important hazards in aviation, particularly for aircrew in non-pressurized aircraft at altitude.



# Outline

1. Required oxygen use: Army Flight Regulation 95-1 a.(1) and a.(2)
2. Brief description of the PHODS
3. Description of PHODS test and evaluation methods
  - a. Performance metric (Psychomotor Vigilance Test [PVT])
  - b. Blood oxygen metrics
4. Results
  - a. Performance metric (PVT)
  - b. Blood oxygen metrics
5. Conclusions



# Army Regulation 95-1 Flight Regulations: Chapter 8 Aviation Life Support

“Approved oxygen systems will be used as follows:

“8-6: *a. Unpressurized aircraft.* Oxygen will be used by aircraft crews and occupants for flights as follows:

(1) Aircraft crews.

(a) On flights above 10,000 feet pressure altitude (PA) for more than 1 hour.

(b) On flights above 12,000 feet pressure altitude for more than 30 minutes.

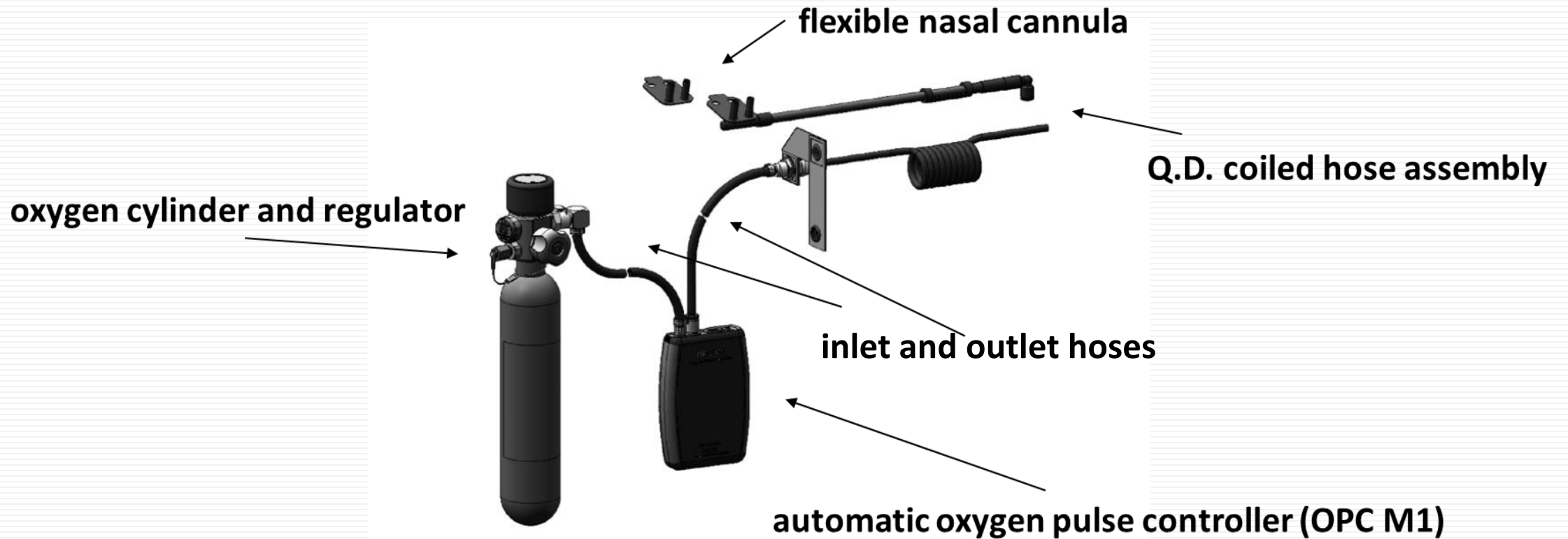
(2) Aircraft crews and all other occupants.

(a) On flights above 14,000 feet pressure altitude for any period of time

(b) For flights above 18,000 feet pressure altitude, oxygen pre-breathing will be accomplished by aircrew members.”



# Portable Helicopter Oxygen Delivery System (PHODS)



**Note:** Crewmember mask not depicted



# PHODS

- Man-mounted
- Attached to survival vest and helmet
- Approved for use on
  - Chinook (CH-47)
  - Black Hawk (UH-60)
- Provides supplemental oxygen (O<sub>2</sub>) at altitudes up to 18,000 feet (ft) above mean sea level (MSL)
- Question whether PHODS is still available





# Manufacturer's Recommended Use of PHODS

		DELIVERY MODE MATRIX															
		PILOTS/LOW WORK LOAD				CE/FE/HEAVY WORKLOAD											
		Delivery Method	Nasal Cannula	Nasal Cannula	Mask	Mask* #	Nasal Cannula	Nasal Cannula	Mask	Mask* #							
OPC Mode		ON	F20	F20	R/M	ON	F20	F20	R/M								
Flight Altitude	8K																
	10K																
	12K																
	14K																
	16K				**	**											
	18K				**	**	**		**								
		Preferred Mode and Delivery Method		* R/M may be used below 10k for heavy smokers or while flying at night for increased night vision # R/M mode greatly reduces consumption at all Altitudes													
		<table border="1"> <thead> <tr> <th colspan="2">Duration Color Code</th> </tr> </thead> <tbody> <tr> <td></td> <td>Normal Duration</td> </tr> <tr> <td></td> <td>Short duration only</td> </tr> <tr> <td>**</td> <td>Do not use</td> </tr> </tbody> </table>								Duration Color Code			Normal Duration		Short duration only	**	Do not use
Duration Color Code																	
	Normal Duration																
	Short duration only																
**	Do not use																

Note. PHODS nasal cannula or mask configuration depends altitude & workload.



# Test and Evaluation of PHODS Efficacy

## Independent variable: Altitude

- Ground level (GL), 14,000, 17,800 ft (School of Army Aviation Medicine [SAAM] Altitude Chamber)

## Tasks / Challenges

- Psychomotor Vigilance Test (PVT) (10 minutes) – boring sedentary task
- Verbalized text reading (5 minutes) – speech challenge disrupting nasal breathing, decreasing cannula effectiveness
- Squats in place (2 minutes) – physical workload

## Dependent variables

- Pulse oximetry (SpO<sub>2</sub>) (continuous)
  - NONIN Life Sense Model LS1-9R
- Near Infrared Transcranial Spectroscopy (NIRS) (rSO<sub>2</sub>) (continuous)
  - NONIN Equanox Model 7600
- PVT Performance (visual reaction time in milliseconds [ms])



# School of Army Aviation Medicine Altitude Chamber



## Altitudes tested

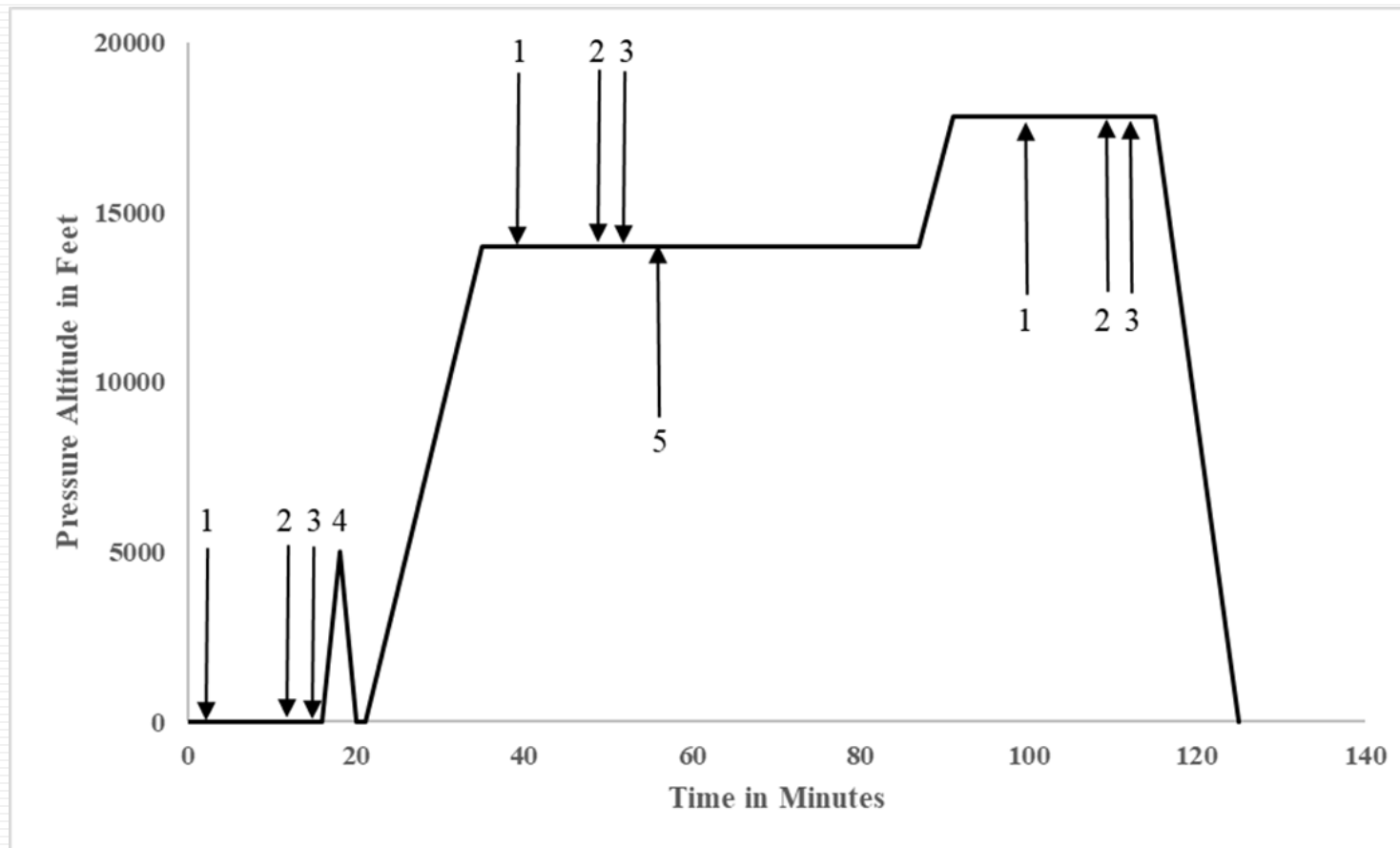
- Ground Level (PHODS inactive)
- 14,000 ft (PHODS active)
- 17,800 ft (PHODS active)

## Personnel

- 4 Aircrew PHODS Testers (Total  $N = 22$ )
- 2 Test Coordinators
- 1 Chamber Observer



# Altitude Chamber Flight Profile & Events

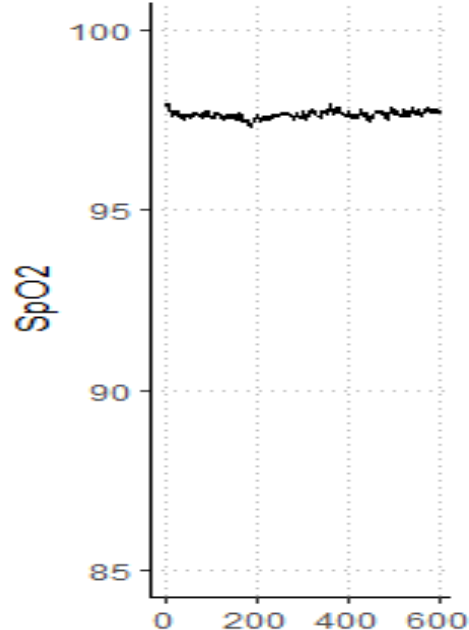


1. **PVT**
2. Text reading
3. Squats
4. Ear & sinus check
5. 30 minutes pre-breathing

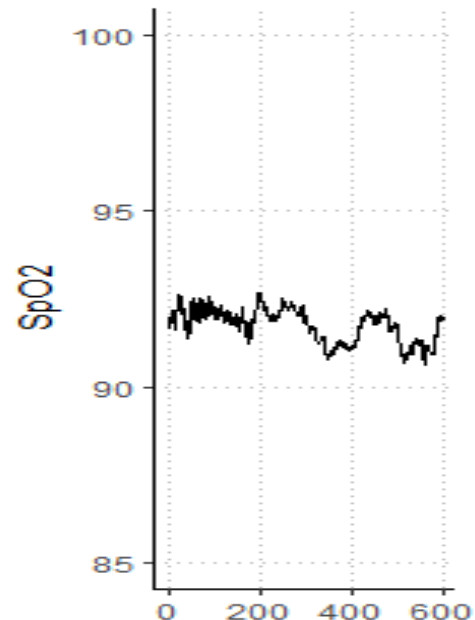


# SpO<sub>2</sub> during PVT

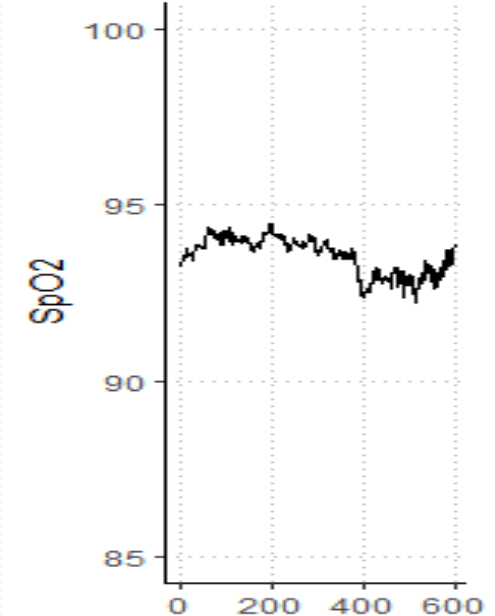
Ground Level



14,000 ft



17,800 ft

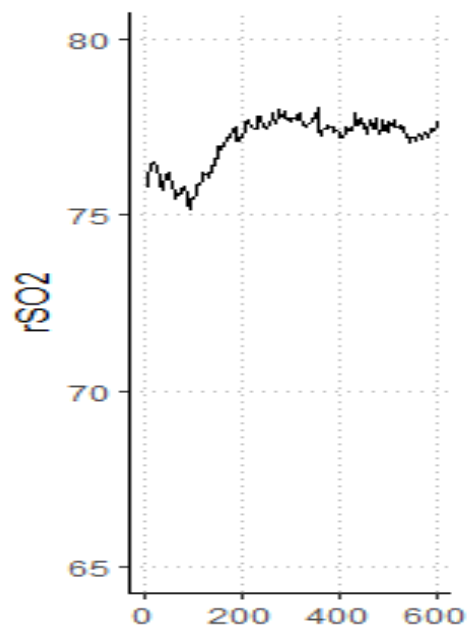


Time (10 minutes)

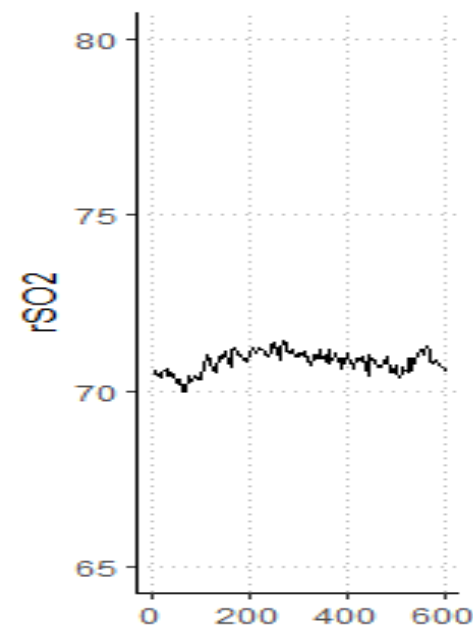


# rSO<sub>2</sub> during PVT

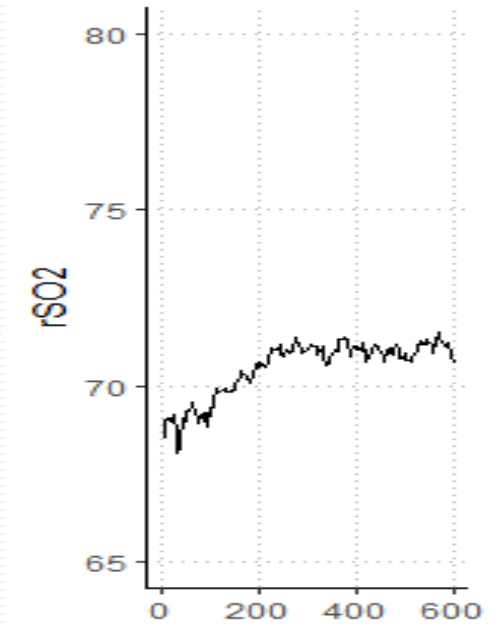
Ground Level



14,000 ft



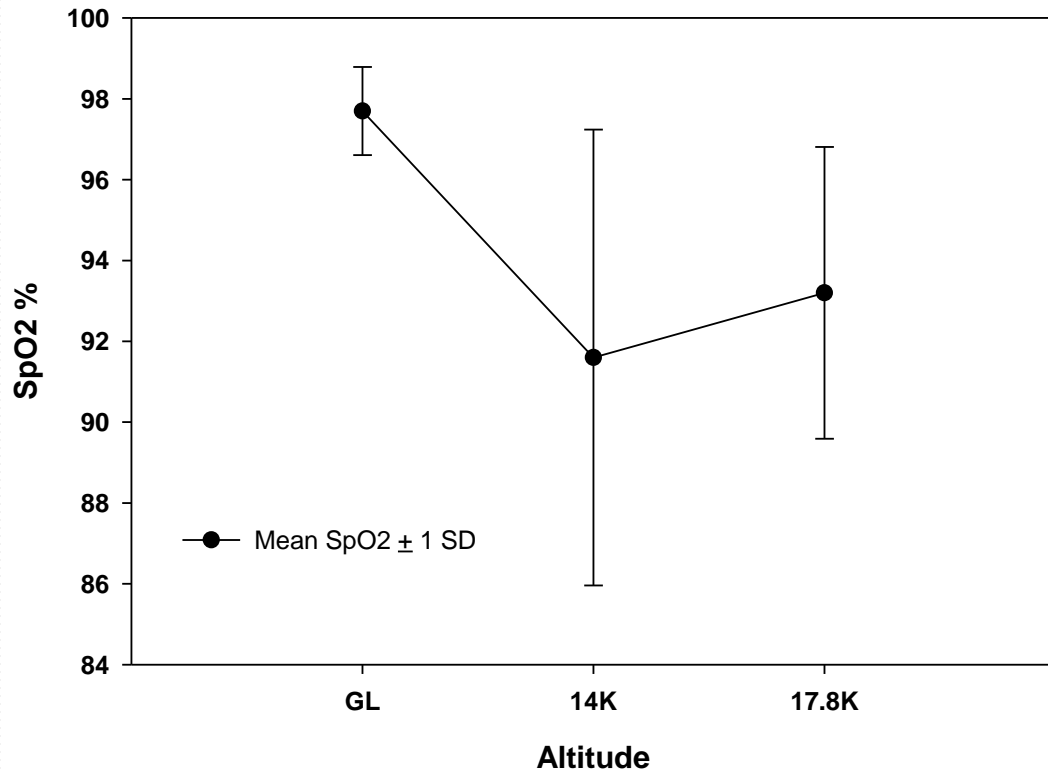
17,800 ft



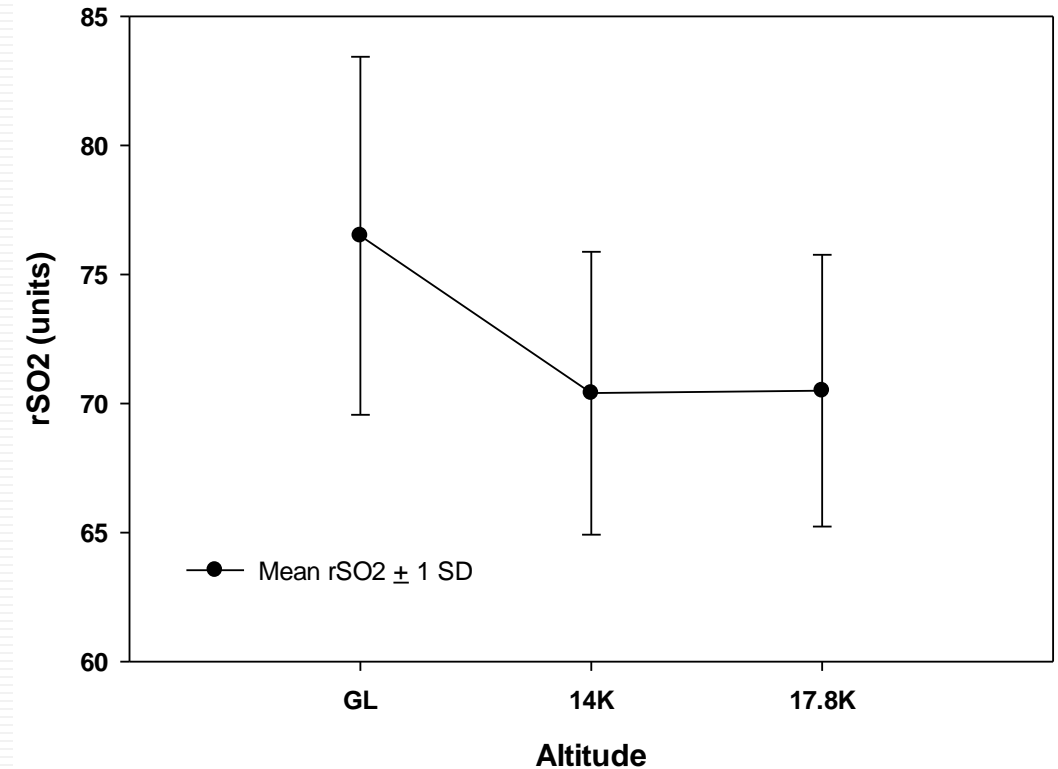
Time (10 minutes)



# Mean SpO<sub>2</sub> & rSO<sub>2</sub> During PVT (10 minutes)



Mean SpO<sub>2</sub>  
Altitude ( $F(2, 42) = 31.63, p < 0.01$ )  
SpO<sub>2</sub> GL > 14K & 17.8K,  $p < 0.01$



Mean rSO<sub>2</sub>  
Altitude ( $F(2, 42) = 43.47, p < 0.01$ )  
rSO<sub>2</sub> GL > 14K & 17.8K,  $p < 0.01$



# Psychomotor Vigilance Test (PVT)

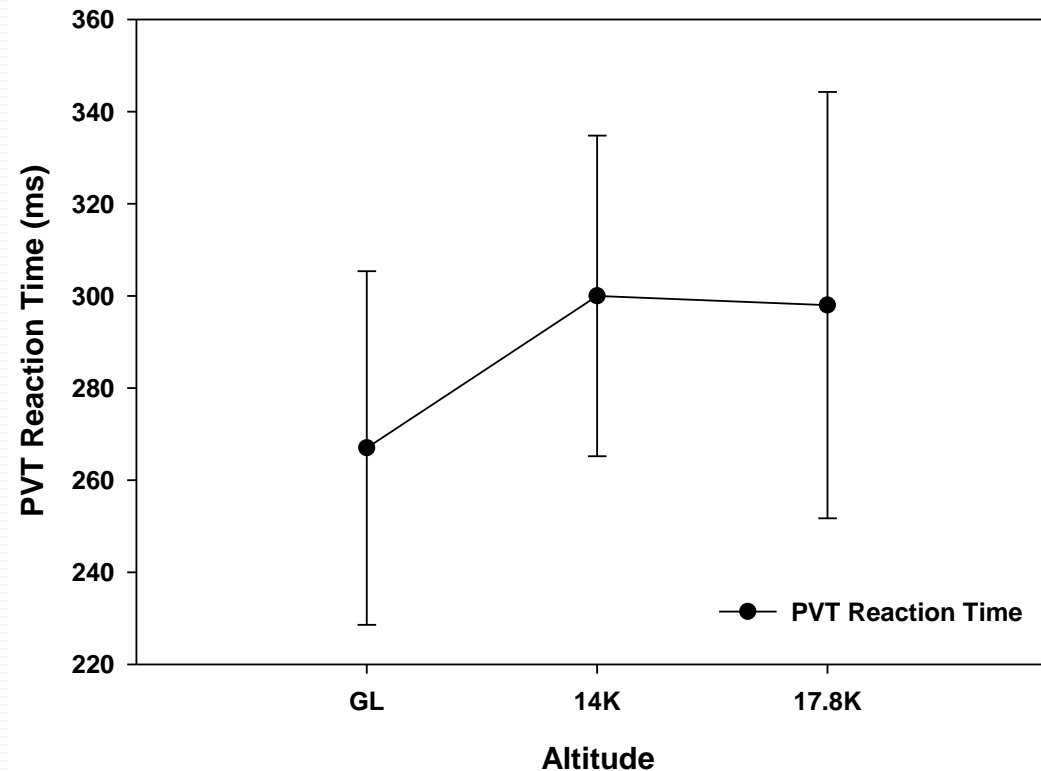


PVT trial is 10 minutes of repeated visual reaction, recorded in milliseconds, to a stimulus onset occurring randomly between 2 to 10 second intervals.

On average, the database recorded 100 such reaction times (RT) for each trial.



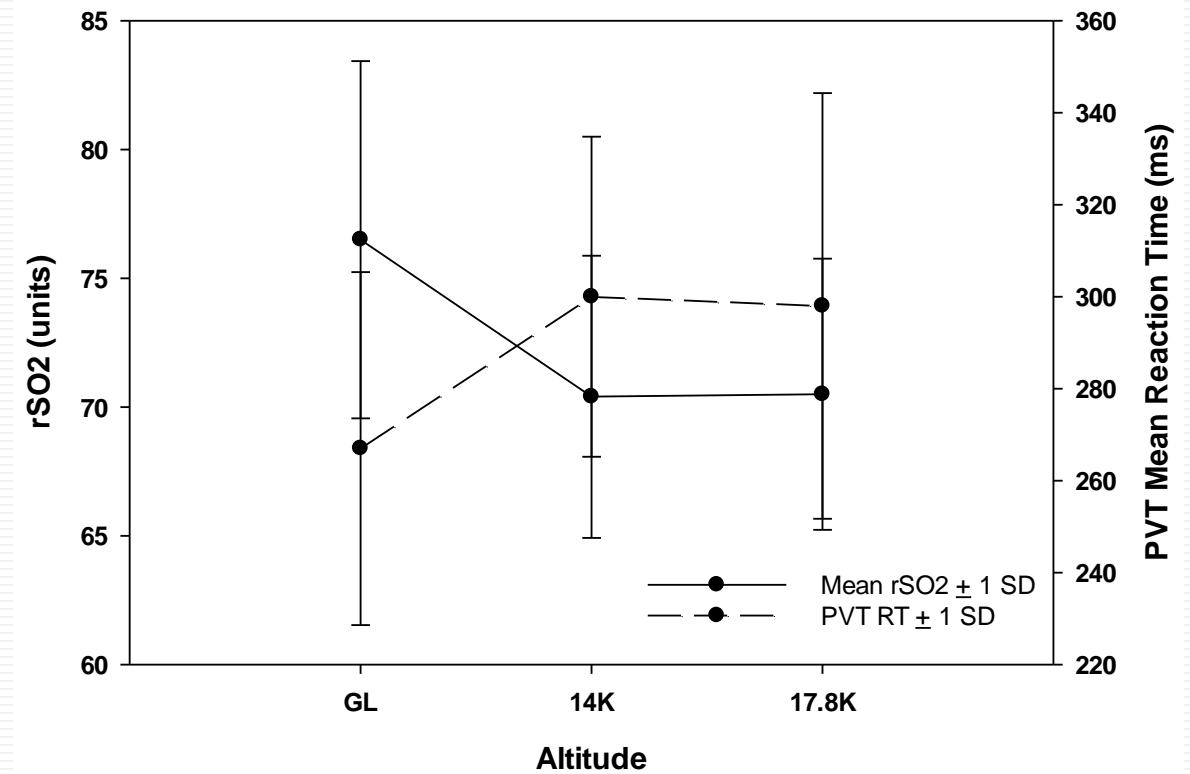
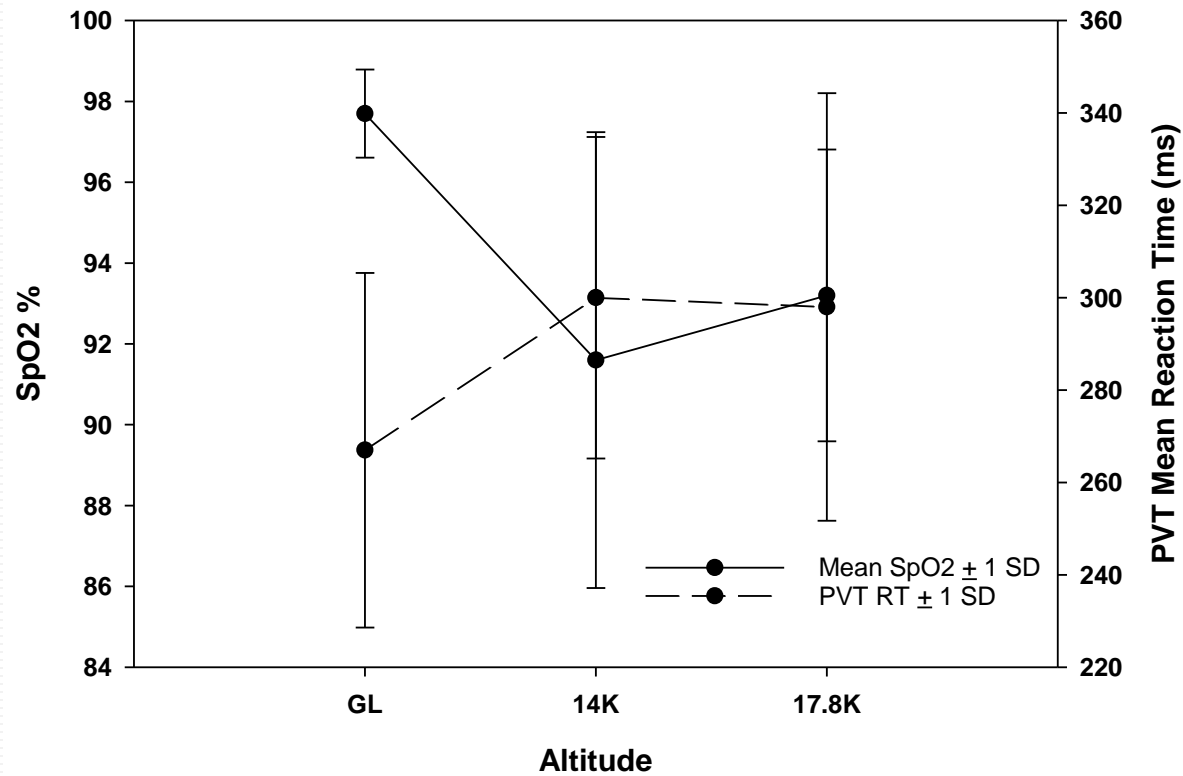
# Mean PVT Reaction Time (ms)



Mean PVT Reaction Time  $\pm$  1 SD  
( $F(2, 40) = 19.7, p < 0.01$ )  
GL RT < 14K & 17.8K,  $p < 0.01$



# PVT with Mean SpO<sub>2</sub> & rSO<sub>2</sub>





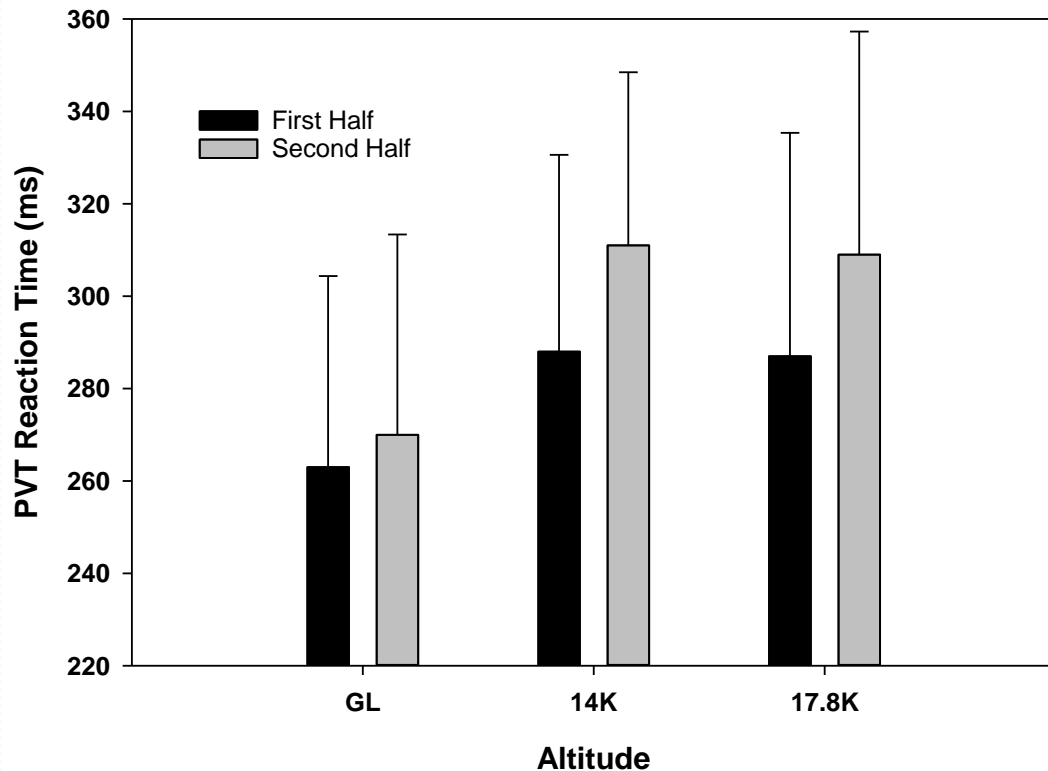
# PVT Over Time

Does PVT reaction time change over the 10-minute task duration?



# PVT Over Time

Does PVT reaction time change over the 10-minute task duration?



YES

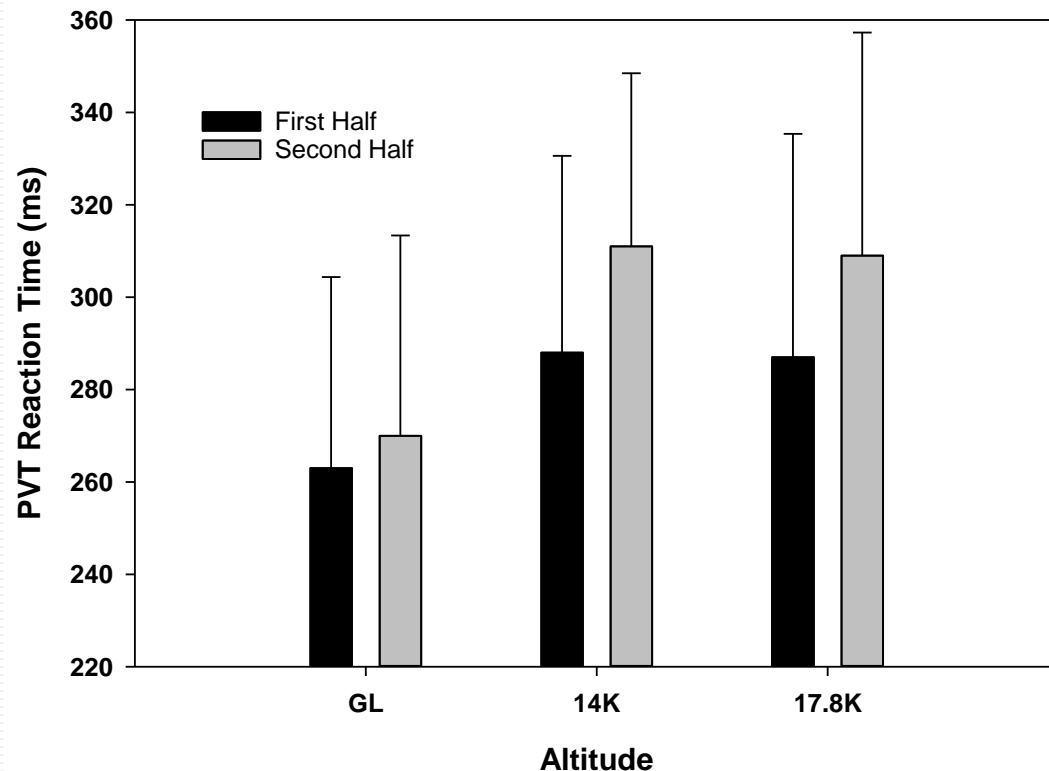
Altitude:  $F(2, 124) = 23.0, p < 0.01$

First vs. Second Half:  $F(1, 124) = 10.8, p < 0.01$



# PVT Over Time

Does PVT reaction time change over the 10-minute task duration?



YES

Altitude:  $F(2, 124) = 23.0, p < 0.01$

First vs. Second Half:  $F(1, 124) = 10.8, p < 0.01$

GL: First  $\approx$  Second Half ( $p = 0.31$ )

14k & 17.8K: First  $<$  Second Half ( $p < 0.01$ )

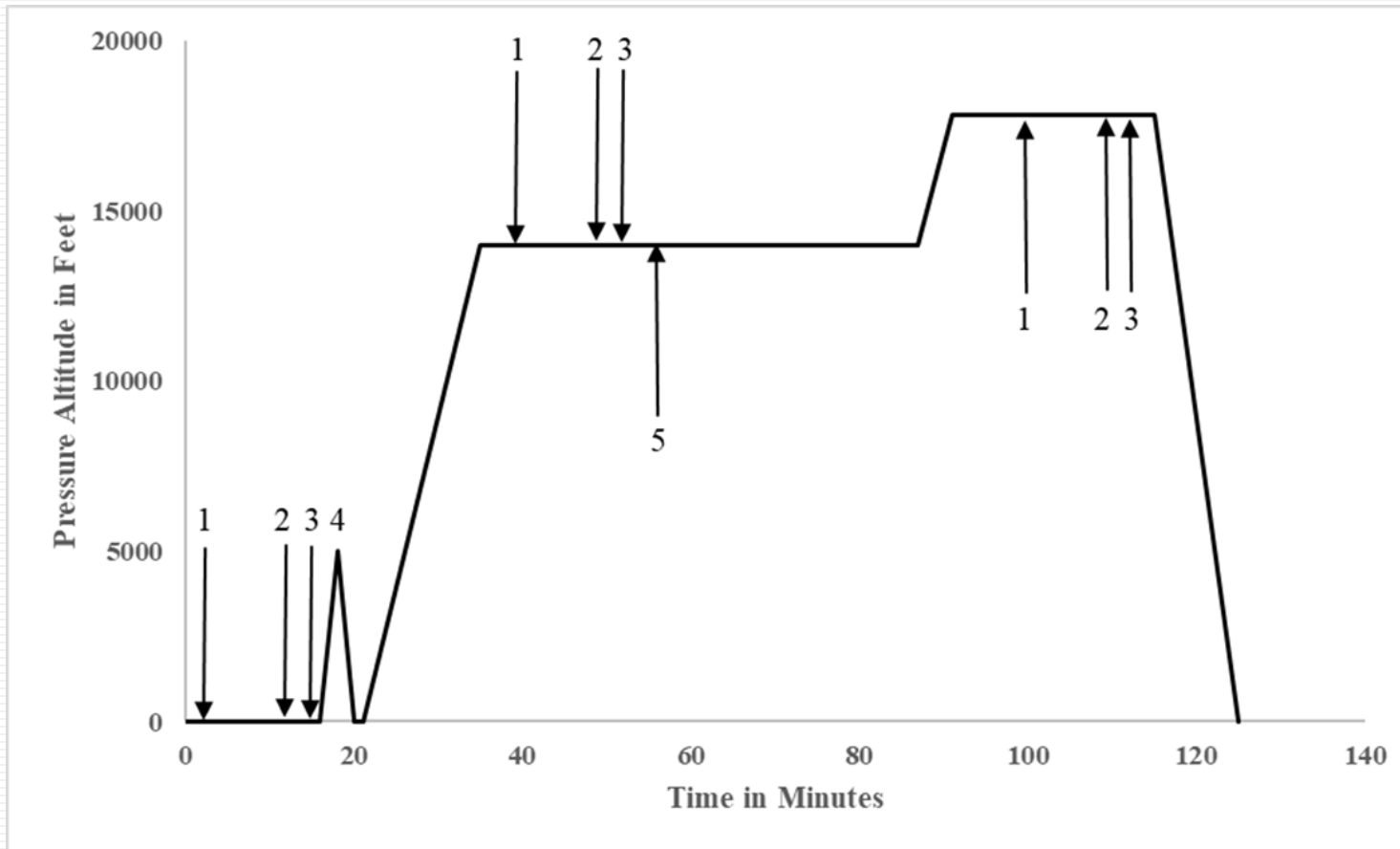


# Conclusions

1. With PHODS during PVT testing, SpO<sub>2</sub> fell by about 6% and rSO<sub>2</sub> by about 5 units at both 14,000 & 17,800 ft relative to GL.
2. This modest drop occasioned a delay of about 33 ms in PVT reaction times, i.e., a delay of about 10% in the simplest response of the visual system to the onset of a light.
3. If this is indicative of the slowing of neural processing through the central nervous system, the delays may be compounded and possibly disrupt normally synchronous signals and overt behaviors such as those supporting the ocular motor system.
4. Data suggest a cumulative PVT fatigue or tedium at both 14,000 ft and 17,800 ft such that, on average, reaction times recorded during the Second Half of PVT testing were statistically slower than reaction times recorded during for the First Half of PVT testing, an effect not seen at GL possibly indicating a compound hypoxia fatigue effect.



# Altitude Chamber Flight Profile & Events

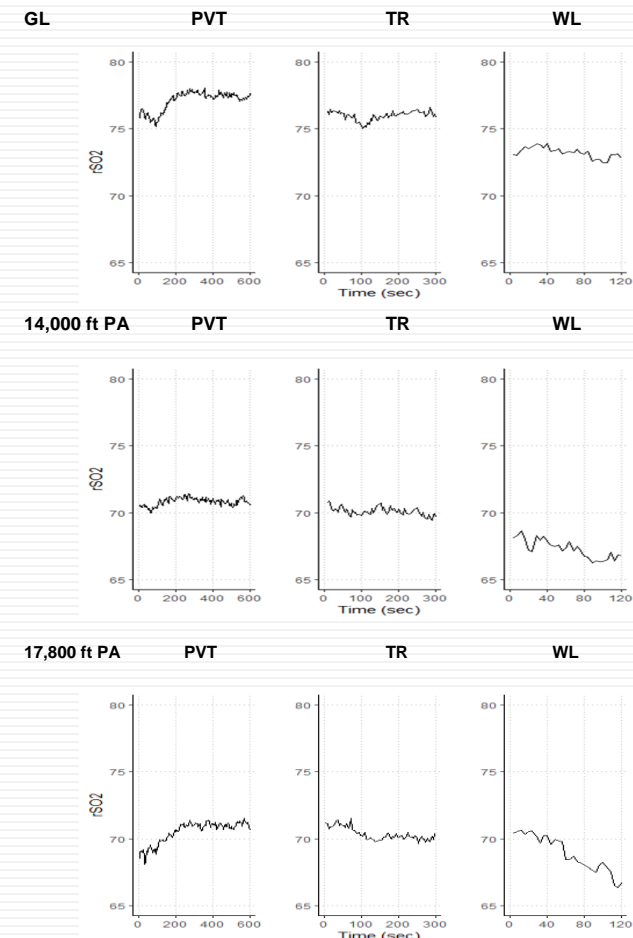
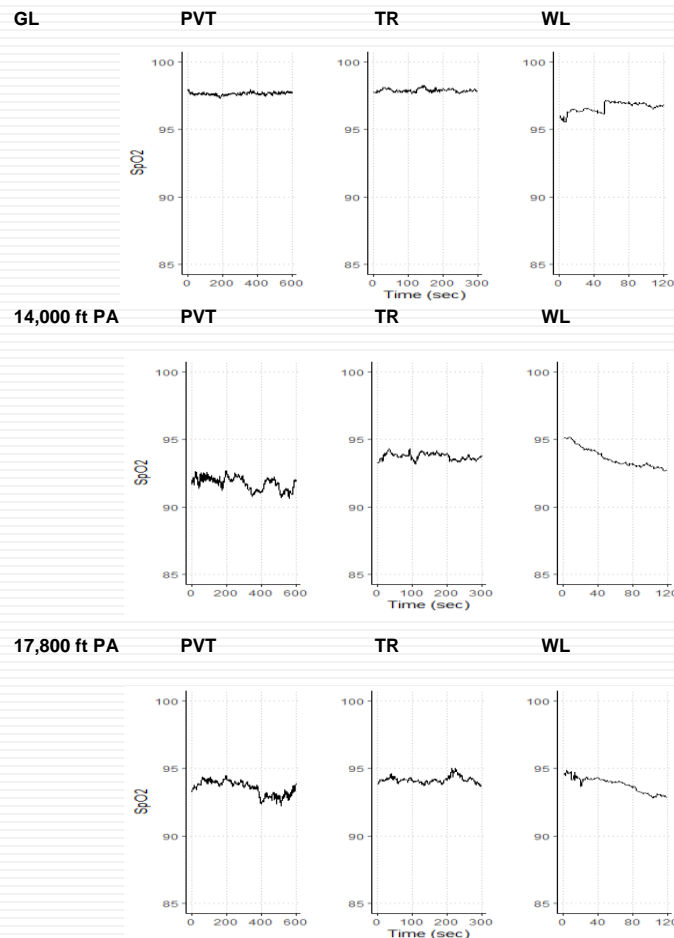


1. Psychomotor Vigilance Test
2. **Text reading**
3. **Squats**
4. Ear & sinus check
5. 30 minutes pre breathing



# SpO<sub>2</sub>

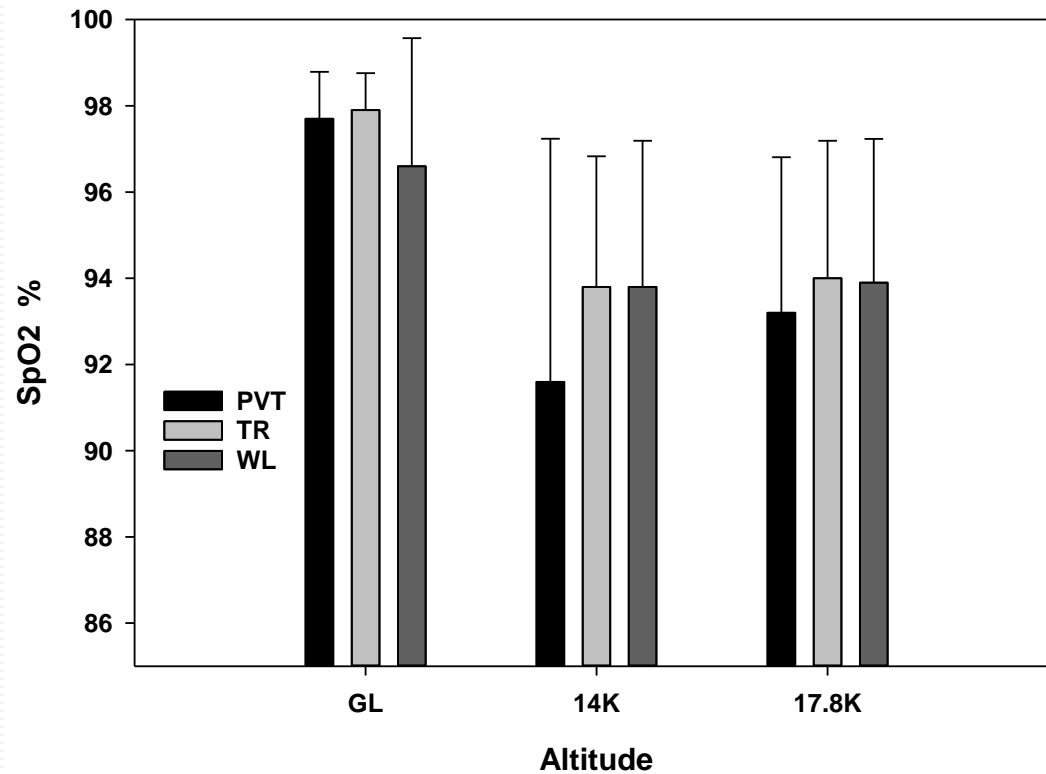
# rSO<sub>2</sub>





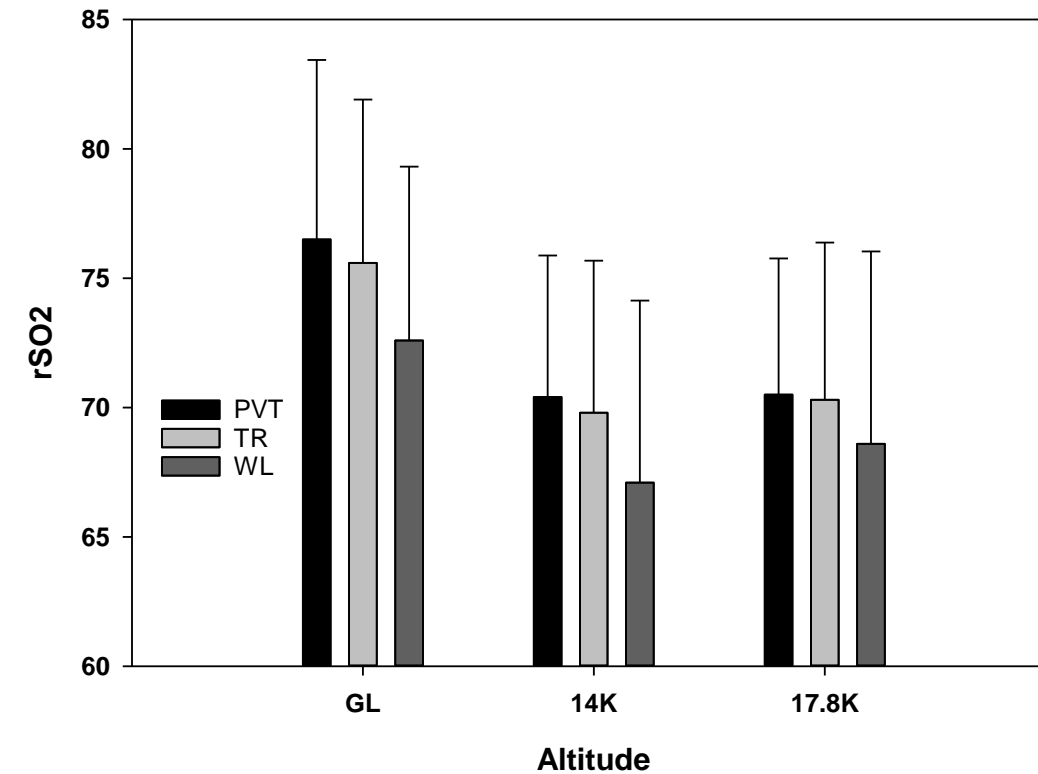
# Means

## SpO<sub>2</sub>



Altitude ( $F(2, 42) = 31.63, p < 0.01$ ),  
GL > 14K, 17.8K

## rSO<sub>2</sub>

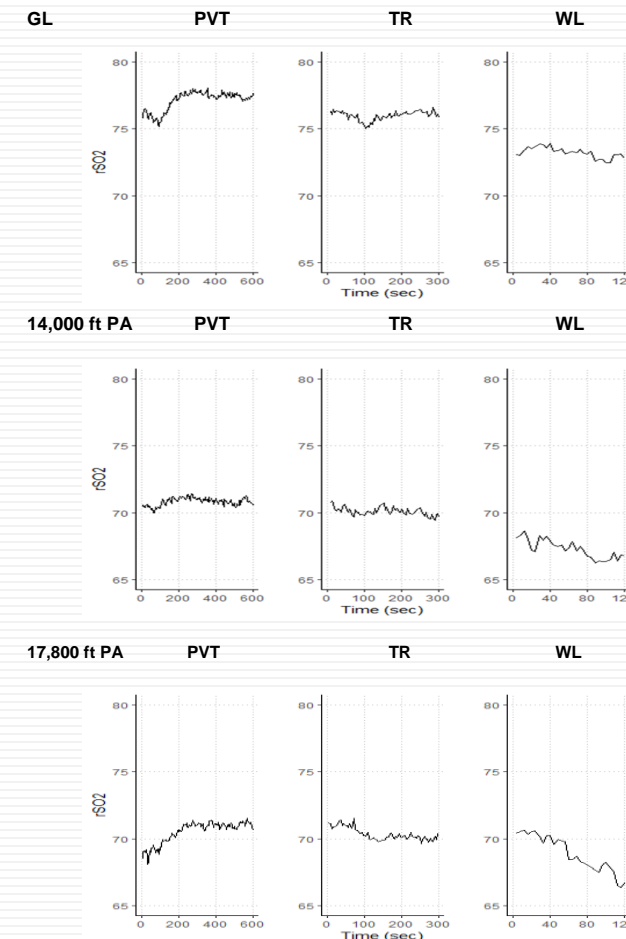
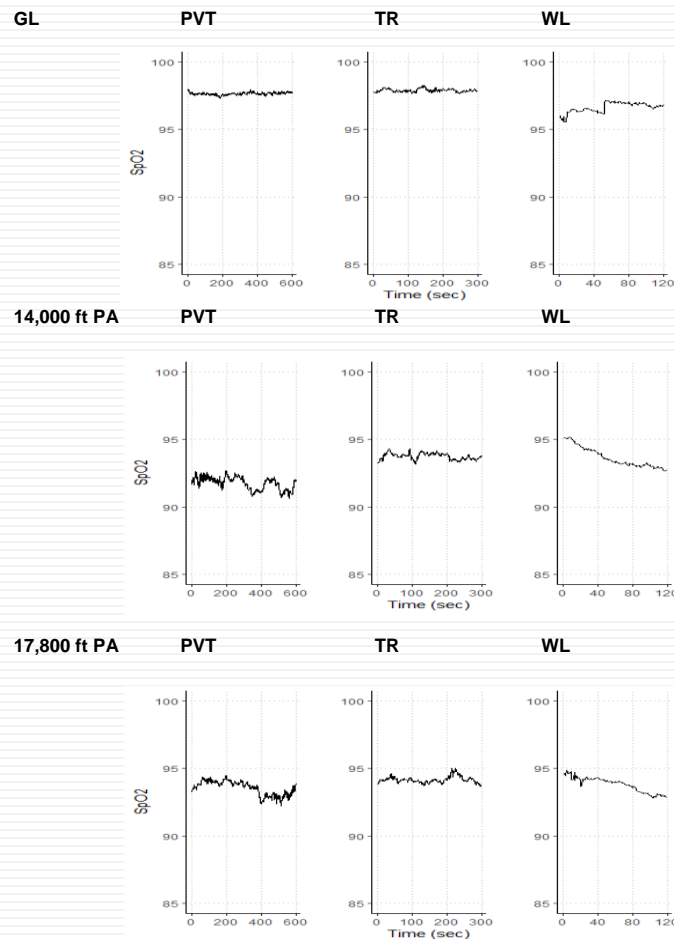


Altitude ( $F(2, 42) = 43.47, p < 0.01$ ),  
GL > 14K, 17.8K



# SpO<sub>2</sub>

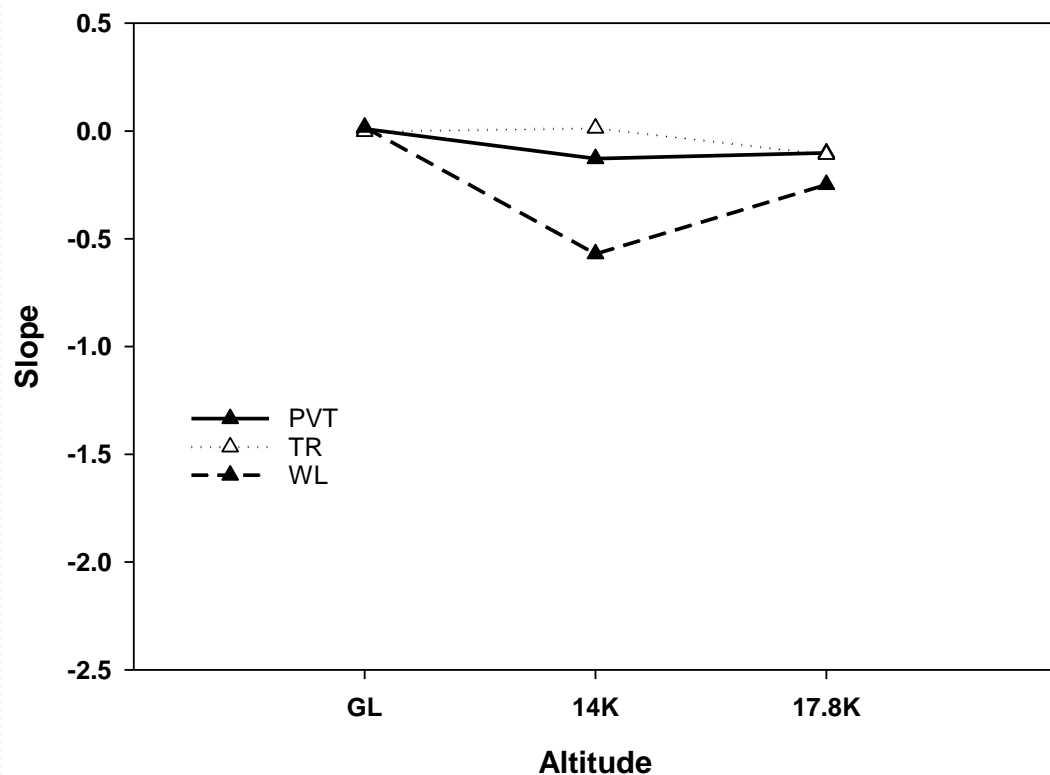
# rSO<sub>2</sub>





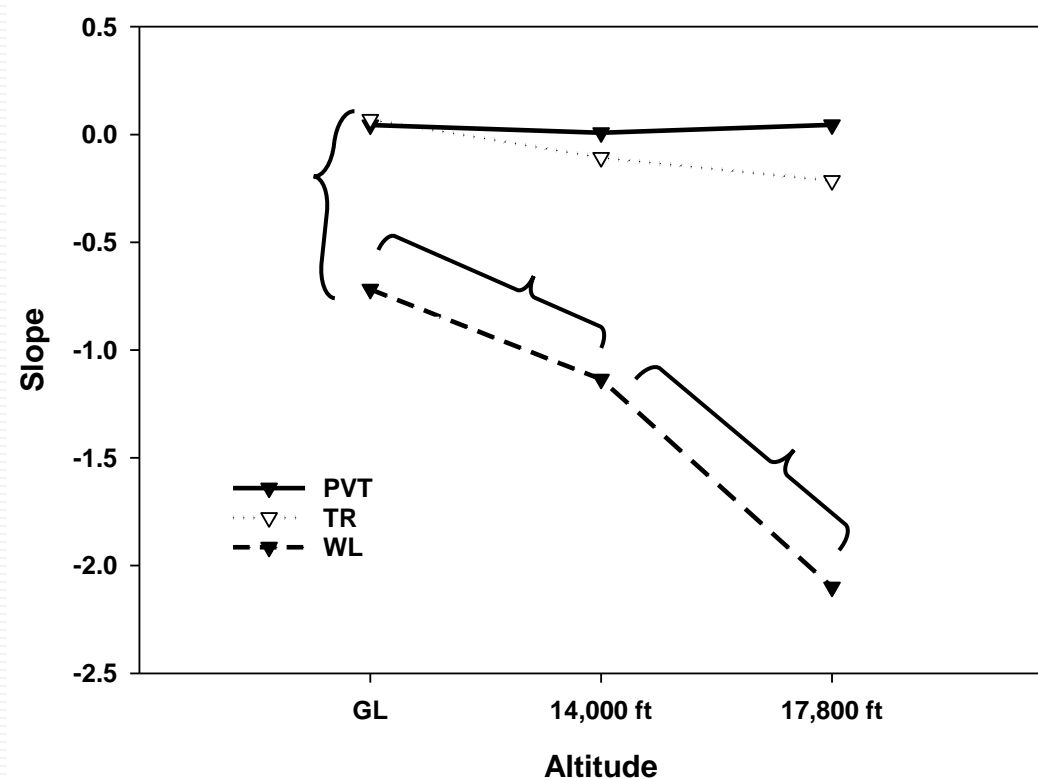
# Slopes

## SpO<sub>2</sub>



Altitude ( $\chi^2 = 5.77, p > 0.05$ )  
 Task ( $\chi^2 = 3.42, p > 0.05$ )

## rSO<sub>2</sub>



Altitude x Task ( $F(4,160) = 2.52, p = 0.04$ )



# Conclusions

## SpO<sub>2</sub> (Peripheral blood oxygen saturation) vs. rSO<sub>2</sub> (Regional cerebral blood oxygen)

- At 14,000 and 17,800 ft, when challenged by the PVT (10 minutes), TR interruption of nasal breathing (5 minutes), or WL (2 minutes), PHODS maintained a constant average SpO<sub>2</sub> albeit at levels lower than at MSL but generally considered adequate (90% < SpO<sub>2</sub>).
- SpO<sub>2</sub> does not predict rSO<sub>2</sub>
  - a. rSO<sub>2</sub> fell over time during WL at 14,000 and 17,800 ft but SpO<sub>2</sub> did not fall
  - b. fall-off slope was related directly to altitude: the greater the altitude, the steeper the fall off
- Fall-off time course, severity, practical importance, and recovery remain to be assessed for WL durations longer than 2 minutes

## Summary

- PHODS has shortcomings as a hypoxia countermeasure
- Recommend enhancements for future Army aircraft particularly when aircrew workload is involved



# Thank You for Your Attention.



## Questions, Comments?



Min (Clock)	Altitude	Event	Nasal Can	Aviator Mask	OFF	R/M	ON	F20 PHODS Mask
-45	GL	Verbal Briefs (USAARL/SAAM)			x			
-35	GL	Participant Signatures			x			
-30	GL	Equip prep (helmet mods, instrument participants), etc.			x			
1	GL	PHODS Ground Check	x			x		
2	GL	PVT (10 mins)	x		x			
12	GL	Script (5 mins)	x		x			
17	GL	Workload (2 mins)	x		x			
19	GL, 5K, GL	Ear and sinus check	x				x	
21	14000	Ascent to 14K (~1,000 fpm)	x				x	
35	14000	5 min Acclimation	x				x	
40	14000	PVT (10 mins)	x				x	
50	14000	Script (5 mins)	x				x	
55	14000	Workload (2 mins)						x
57	14000	Participants switch to chamber O2 x 30 min Hypoxia Questionnaire		x				
87	14000	Ascent to 17.8K (~1,000 fpm)		x				
91	17800	5 min Acclimation (don PHODS helmet for communication)	No supplemental oxygen					
96	17800	1 min Acclimation to NC	x				x	
97	17800	PVT (10 mins)	x				x	
107	17800	Script (5 mins)	x				x	
112	17800	Workload (2 mins)						x
114	↓GL	Hypoxia Questionnaire						x





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