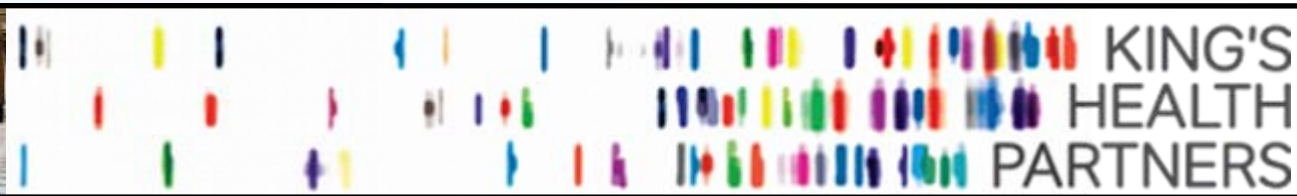


Decreased psychomotor performance resulting from moderate exercise performed at 17,500ft

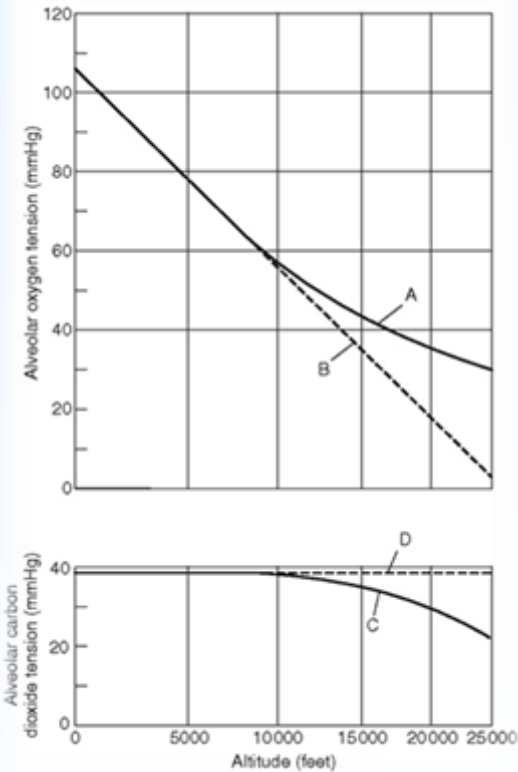


Plt Off J Britton, Dr D Green PhD & Wng Cdr N Green
Presented with the permission of OC RAF CAM



Background

- Increased altitude = decreased alveolar oxygen
- At $\approx 10,000$ ft ventilation increases
- This causes a deviation of the curve
- And also results in a fall in carbon dioxide

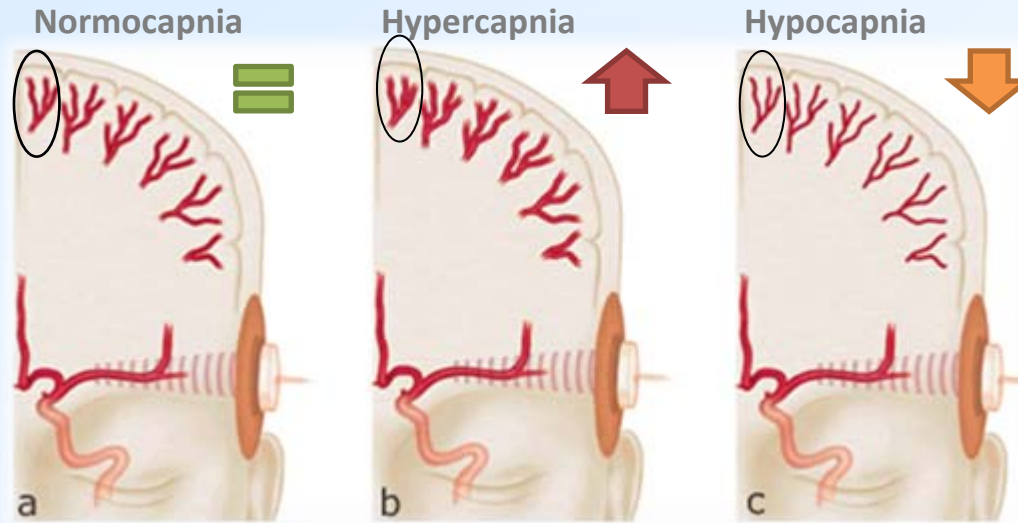


Ernsting's Aviation Medicine p44



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Background



<http://depts.washington.edu/uwtcdlab/co2.html>

- Decreased carbon dioxide causes hypocapnic cerebral vasoconstriction
- This decreases cerebral perfusion
- Oxygen supply to the brain is therefore relative not only to hypoxia but also to carbon dioxide



Background

- Some debate over what altitude causes a dangerous reduction in psychomotor performance
- Recommendations for pilots place 10,000ft as a maximum operating altitude without supplementary oxygen
- Current/future operations may require the use of helicopters above 10,000ft



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Background

- For pilots performing a low-moderate exercise rate (27W)¹ with a demand regulator this is not an issue²
- However, different story for aircrew performing higher rates of exercise
- The oxygen system for these aircrew is to be replaced. Full understanding of the physiology involved is key to optimising the new system



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1 Norris P. Pilots' Respiration During a Standard Flight Profile. London: Ministry of Defence (Air), RAF Institute of Aviation Medicine, 1964; Report No. 271.

2 Unpublished Study, RAF CAM and KCL – No effect of 30W exercise at 17,500ft on psychomotor performance



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Background

- Exercise complicates the issue of cerebral oxygen supply
- The increased metabolism of skeletal muscles causes a higher oxygen demand and redirection of blood flow
- ...but also produced carbon dioxide at an increased rate
- Few conclusive studies to examine the effect of this balance on psychomotor performance
- If decreased, there could be a reduction in ability to perform necessary safety actions



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Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Aim

○ Hence:

○ To investigate whether moderate exercise at 17,500ft causes a further reduction in psychomotor performance than exposure to altitude alone



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Methods

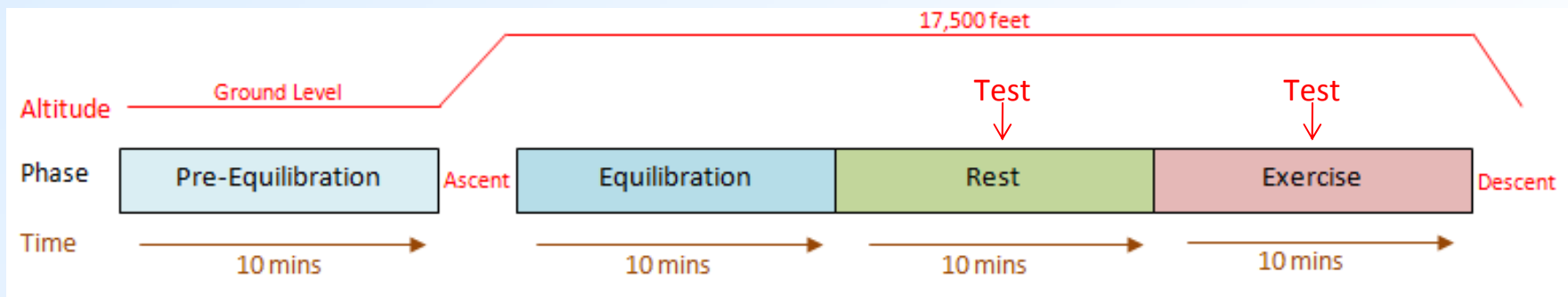
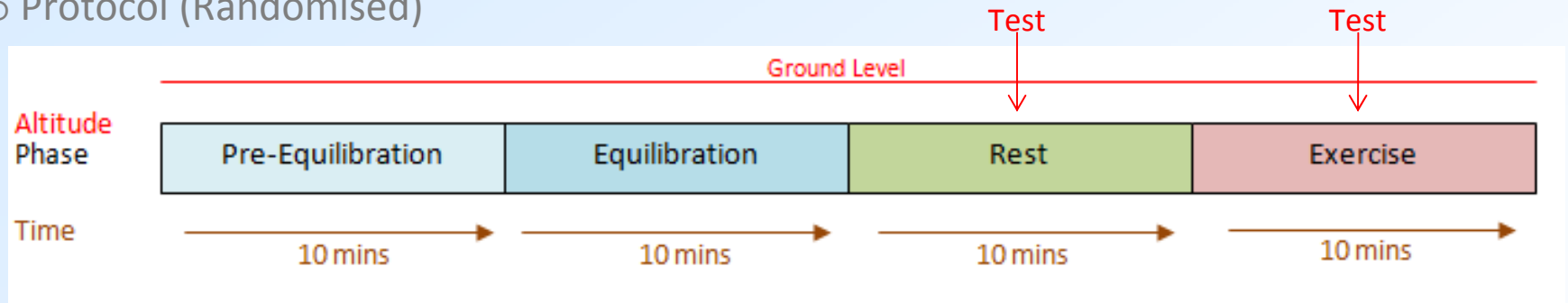
- 12 subjects (8 ♂. 174 ± 7 cm; 71.4 ± 9.4 kg; 22 ± 1 yrs)
- Preparation
 - Medical clearance
 - Hypoxia training given in advance at RAF CAM with rapid decompression to 25,000ft
 - Training on CogScreen Hypoxia Edition (HE) to prevent test learning during expt
 - Subjects agreed to comply with alcohol restrictions in line with current Air Staff Instruction for pilots (<3 units within 24 hours, none within 10)
 - Medical check on day of tests
- Altitude Exposure
 - 17,500ft equivalent altitude using a hypobaric chamber at RAF CAM
 - Both ground runs and altitude runs were performed in the same environment



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Methods

o Protocol (Randomised)



= Four Runs:

Ground + Rest,

Ground + 70W exercise

Altitude + Rest,

Altitude + 70W exercise



Methods

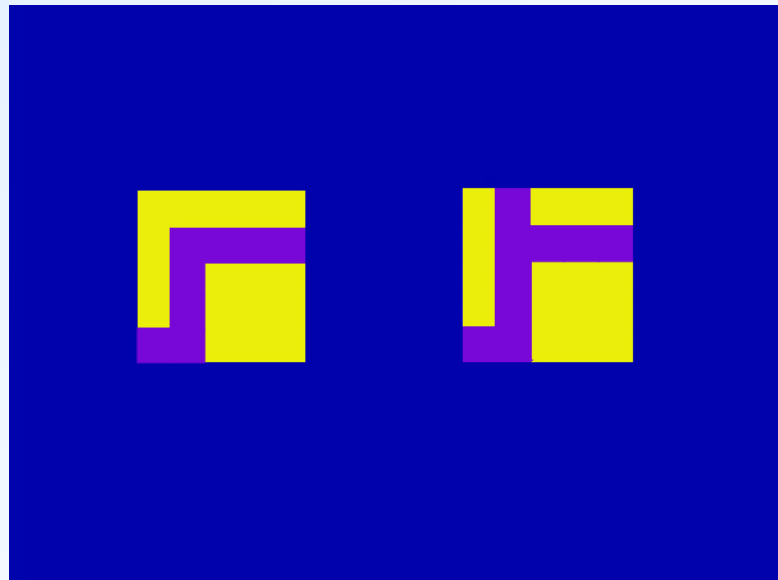
○ Physiological Variables

Variable	Equipment
O ₂ Saturation	Ear lobe pulse oximeter (Kontron)
Heart Rate	Ear lobe pulse oximeter (Kontron)
End tidal O ₂ and CO ₂ concentration	LR-1 respiratory mass spectrometer
Inspiratory Flow	Fleisch flowmeter
Inspiratory gas volume	Integrated flow data (Hugo Sachs Elektronik)
Continuous arterial blood pressure waveform	Finometer (referenced to heart level)
Altitude	Celesco differential pressure transducer
Cognitive Function	CogScreen Hypoxia Edition (HE)
Temperature and Humidity	Digital thermometer
Symptoms of hypoxia	Symptom questionnaire



Methods

- Psychomotor Performance
 - CogScreen HE
 - Battery of tests
 - Data output for reaction time, accuracy and throughput (correct responses/min)
 - Individual test results to be published



Visual Search and Attention Test (VSAAT)

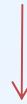


Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Statistics

o Four Way Anova

	Rest	Exercise
Ground		
Altitude		



Anova

Exercise	Altitude	Interaction
≤0.05	0.051-0.07	>0.07

o T tests where applicable

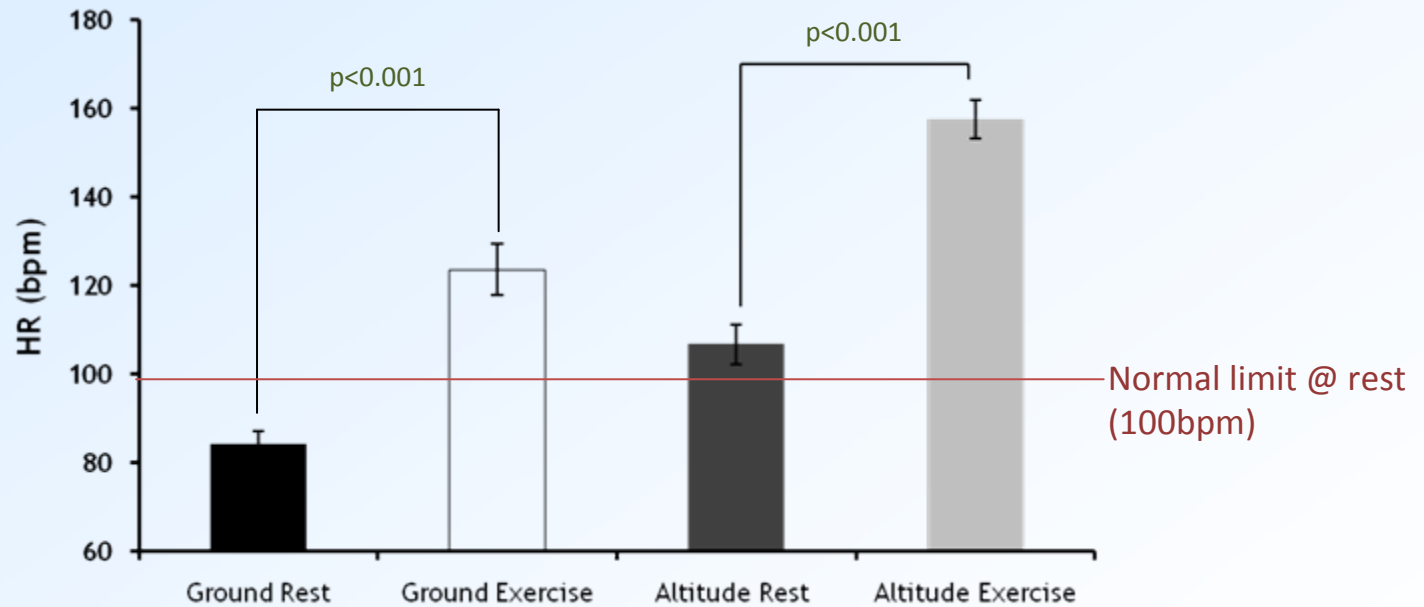


Physiological Results



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Results: Heart Rate



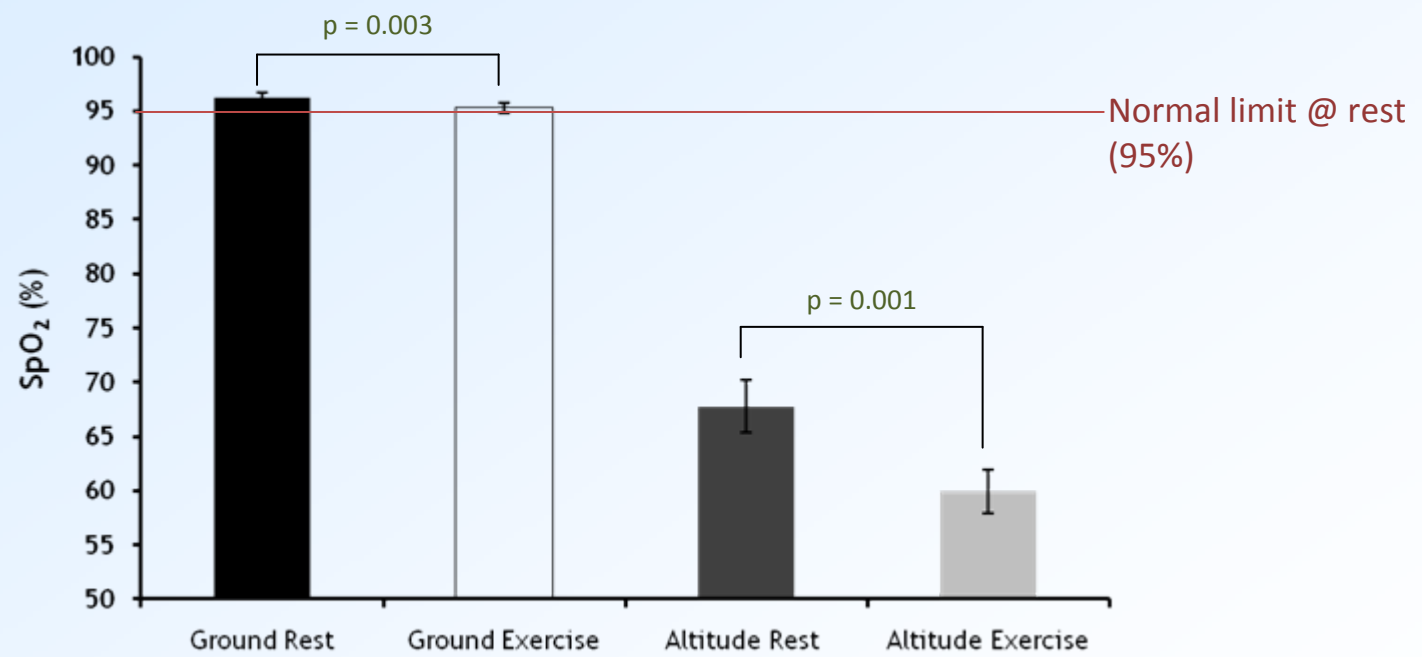
Anova

Exercise	Altitude	Interaction
<0.001	<0.001	0.057



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Results: Oxygen Saturation



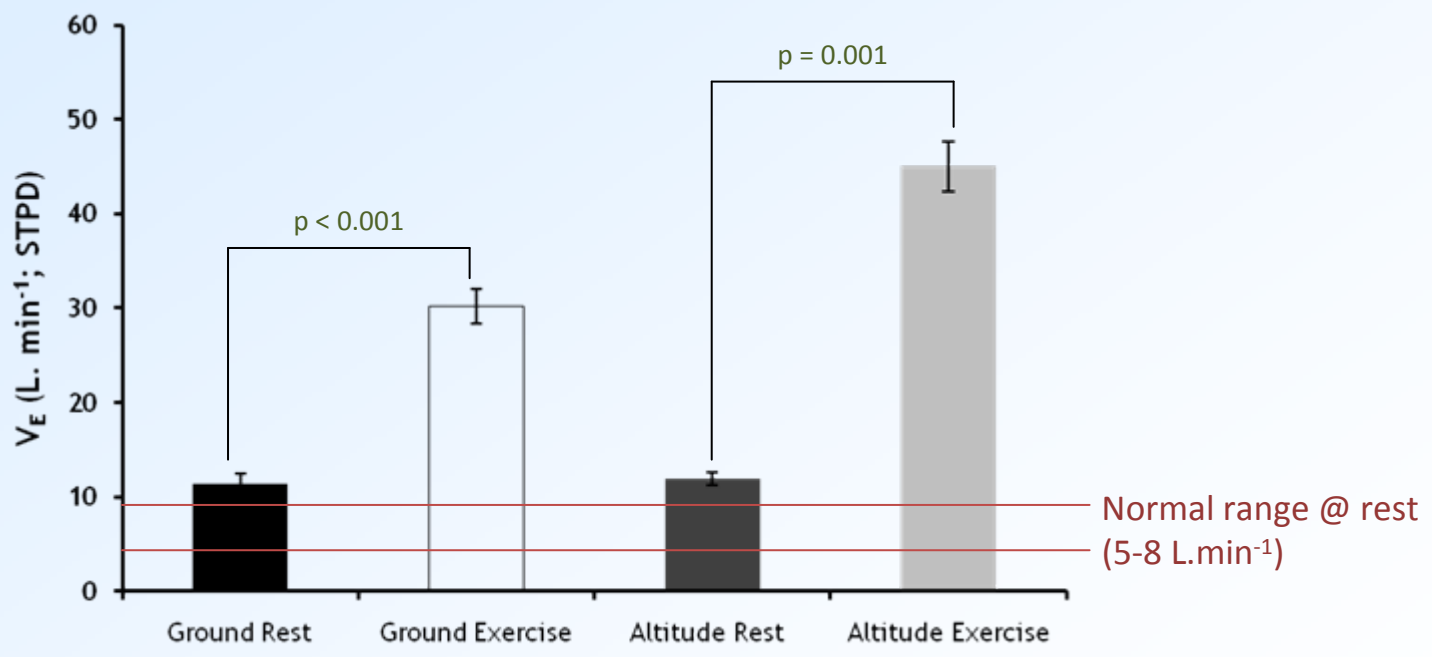
Anova

Exercise	Altitude	Interaction
<0.001	<0.001	0.001



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Results: Ventilation



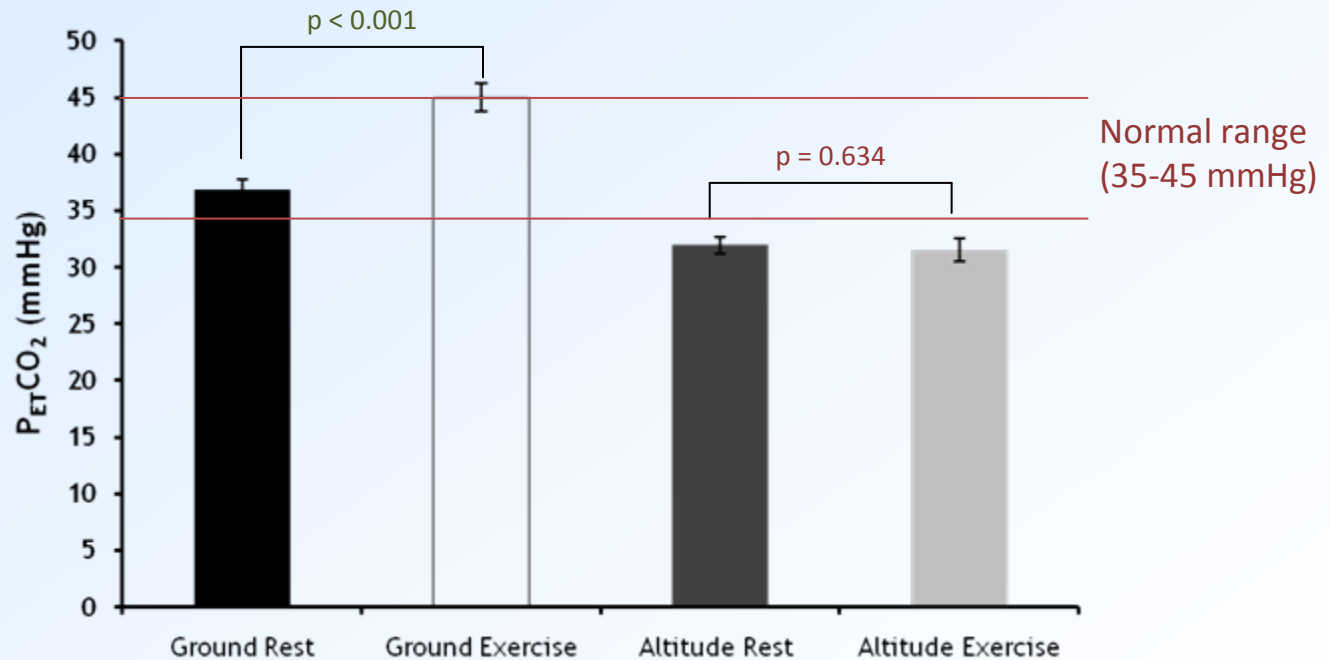
Anova

Exercise	Altitude	Interaction
<0.001	0.001	<0.001



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Results: End Tidal CO₂



Anova

Exercise	Altitude	Interaction
<0.001	<0.001	<0.001

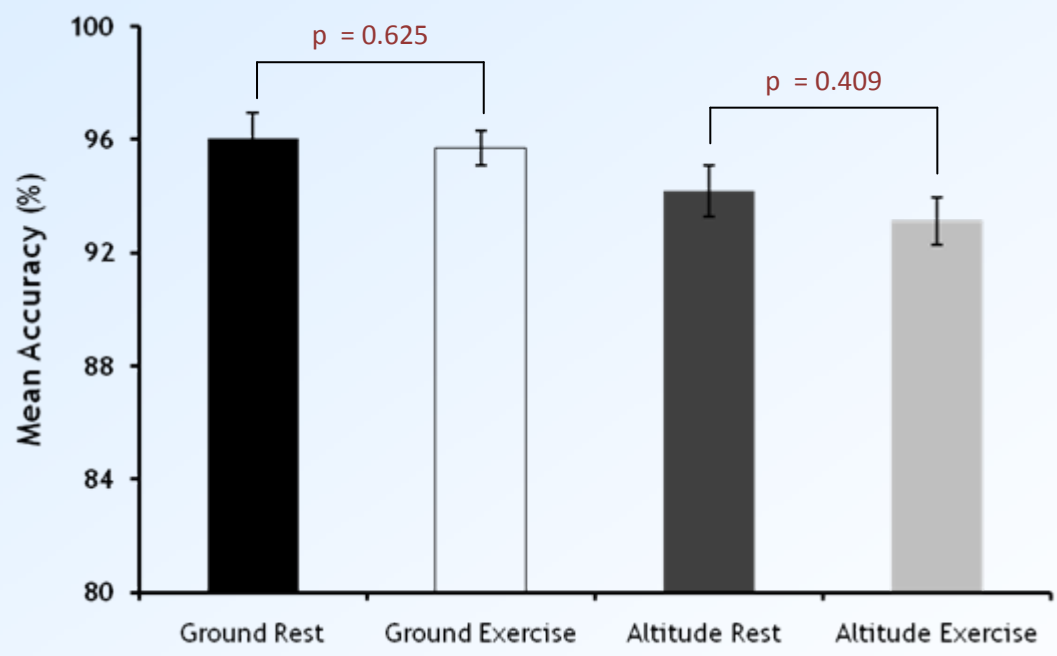


Psychomotor Results



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Results: Mean Accuracy



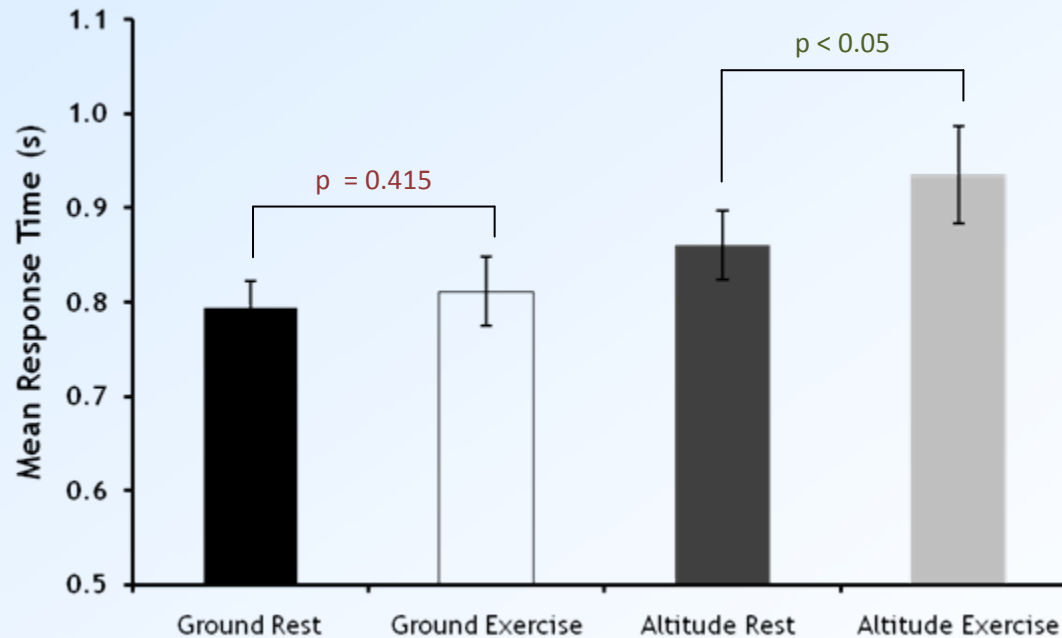
Anova

Exercise	Altitude	Interaction
0.331	0.027	0.605



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Results: Mean Reaction Time



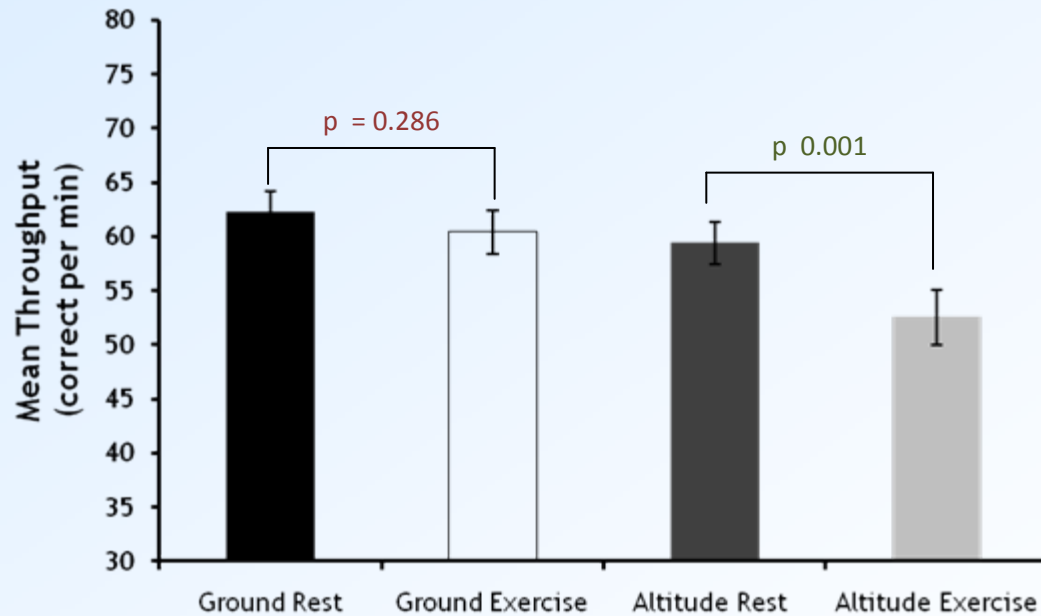
Anova

Exercise	Altitude	Interaction
0.016	0.085	0.125



Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Results: Mean Throughput



Anova

Exercise	Altitude	Interaction
<0.001	0.066	0.031



Discussion

Physiological Summary:

- Decrease in oxygen saturation was significantly greater when exercising at 17,500ft than at ground level
- Increased in pulmonary ventilation was significantly greater when exercising at 17,500ft than at ground level
- End tidal CO₂ increased when exercising at ground level
- But **did not** increase when exercising at altitude



Discussion

Hence:

- Increase in hypoxia greater when exercising at altitude
- **The increased ventilation caused by exercising at altitude balances any induced increase in CO₂ production**
- The state of hypocapnia seen at 17,500ft at rest is not significantly affected by exercise at this altitude. In both cases below normal levels of CO₂ are seen

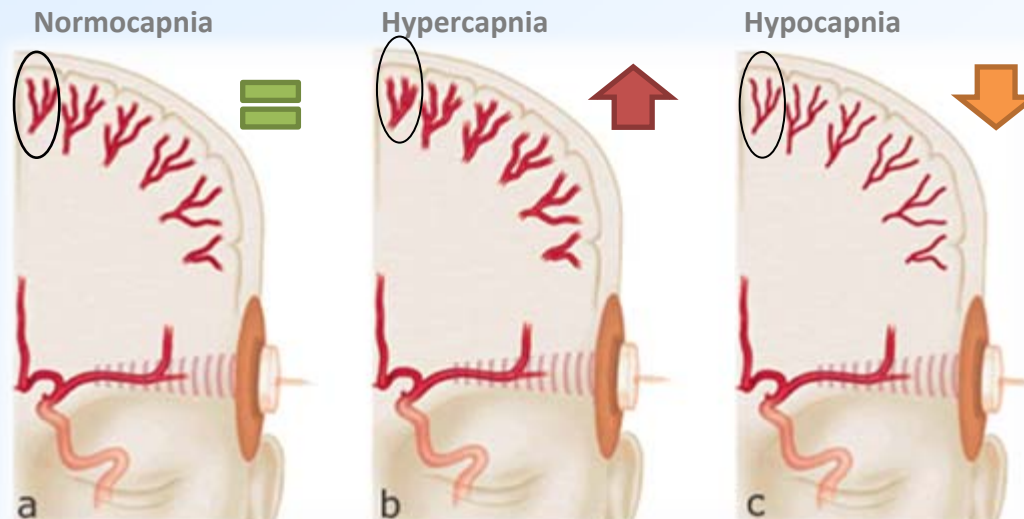


Decremental psychomotor performance resulting from moderate exercise performed at 17,500ft

Discussion

Therefore:

- Hypocapnic vasoconstriction is not improved by 70W exercise at 17,500ft
- **But** hypoxia is more severe
- Therefore there is a **greater decrease in cerebral oxygenation when exercising at altitude**



<http://depts.washington.edu/uwtcdlab/co2.html>



Discussion

Psychomotor Summary:

- Accuracy was decreased at 17,500ft but was not effected by 70W exercise
 - Due to hypoxia and hypocapnic cerebral vasoconstriction
- Reaction time increased with 70W exercise but not altitude equivalent to 17,500ft
 - Some decrease in oxygen saturation seen on exercise
 - But no effect on reaction time with severe hypoxia on ascent
 - Hence possibly due to distraction/mechanical restrictions (Yerkes-Dodson Law)
- Throughput decreased with exercise, showed a trend towards decreasing with altitude, with the effect significantly greater when exercising at altitude when compared to exercising at ground level
 - The combination of altitude and exercise had a compounding effect
 - Due to increasing hypoxia and maintained hypocapnia when exercising at altitude



Limitations

- Small, varied group
 - Highly individual responses to hypoxia
 - Different levels of fitness with a set workload, not %V_{max}
- Tests within a run always performed in same order
 - Mental fatigue towards the end of exercise tests may have had an effect
- CogScreen's ceiling effect¹
 - Designed to identify cognitive defects in aviators not fine variations
 - Tests so simple that very high marks (95-100%) were often reached, even under adverse conditions
 - May reduce the significance of results



¹Callister JD, King RE, Retzlaff PD (1996). Cognitive assessment of USAF pilot training candidates. *Aviation Space Environ Med* **67**, 1124-1129.

Further Studies

- Evaluation of sub-tests underway
 - Will show which areas of cognition affected most
- Further studies with different workloads and altitudes
 - Previous KCL study showed that 30W at 17,500ft had no effect
 - Suggests an incremental effect. Find threshold and crew average workloads
 - Investigate whether there is an workload at which increased ventilation no longer compensates for increased CO₂ production



Conclusions

- Psychomotor performance is adversely affected by moderate exercise at 17,500ft
- In an environment when decisions must be made and enacted within split-seconds, this could have serious ramifications
- Any changes in supplementary oxygen systems must take this into account to achieve optimum performance and safety



Armymomstrong.com



Decrement in psychomotor performance resulting from moderate exercise performed at 17,500ft

Thank You



Any Questions?

