The Effects of Hyperventilation on the Cardiovascular Responses to Pressure Breathing

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Introduction

- Background
- Aims and Objectives
- Methods
- Results
- Discussion
- Conclusion

Background

History

"I have nothing more to do than breathe, a great peace floods my whole being…I am nothing more than a single, narrow, gasping lung"

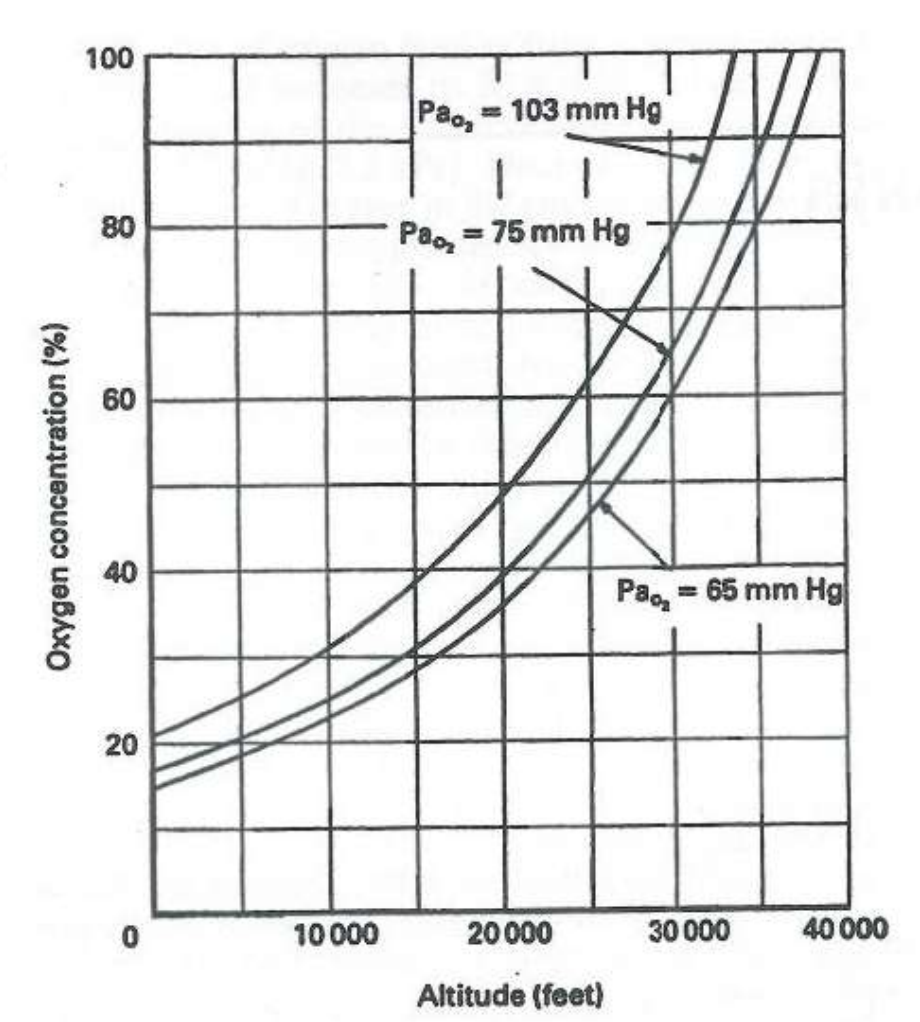
Reinhold Meissner, 1978

- The Early Years
- Mountaineering
- Balloonists

Background

History

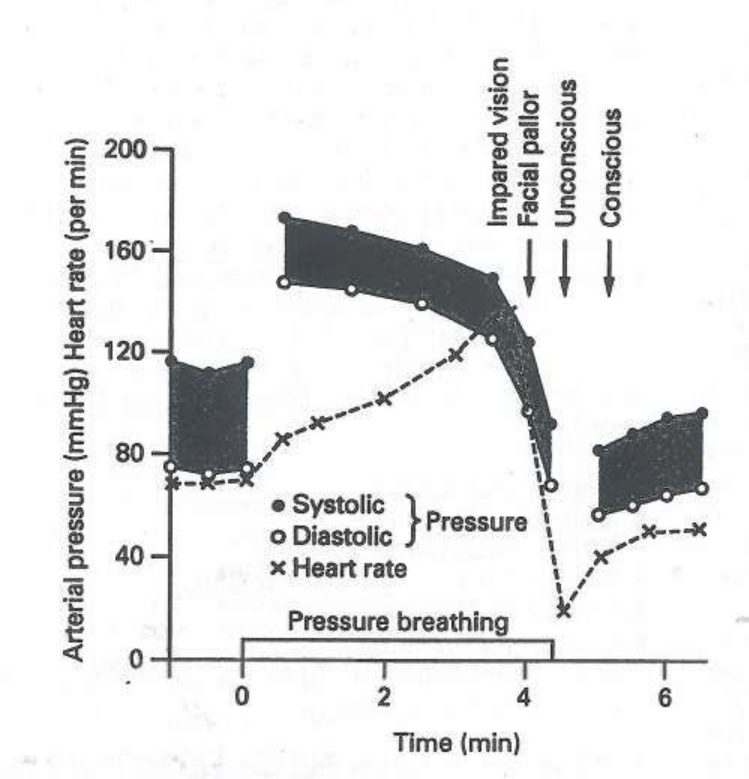
- Aviation
- Hypoxia and Effects
- Breathing Apparatus
- Positive Pressure Breathing (PPB)
- Modern Application



Background

Cardiovascular Responses to Pressure Breathing

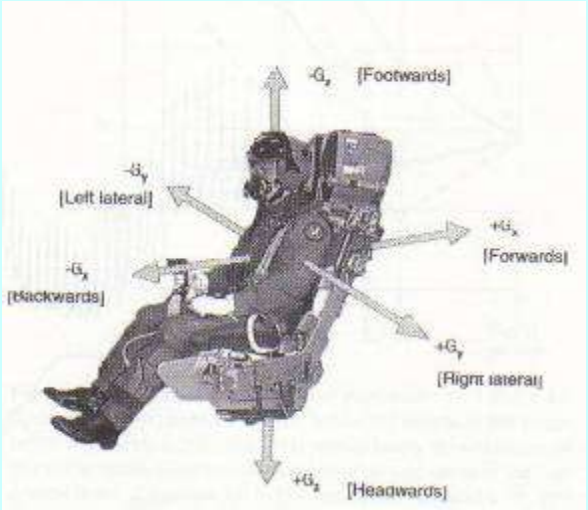
- Mechanism of Effects
  - Blood Flow and Venous Pressures
  - Receptors
- Heart Rate and Cardiac Output
- Arterial Blood Pressure
- Pressure Breathing Syncope

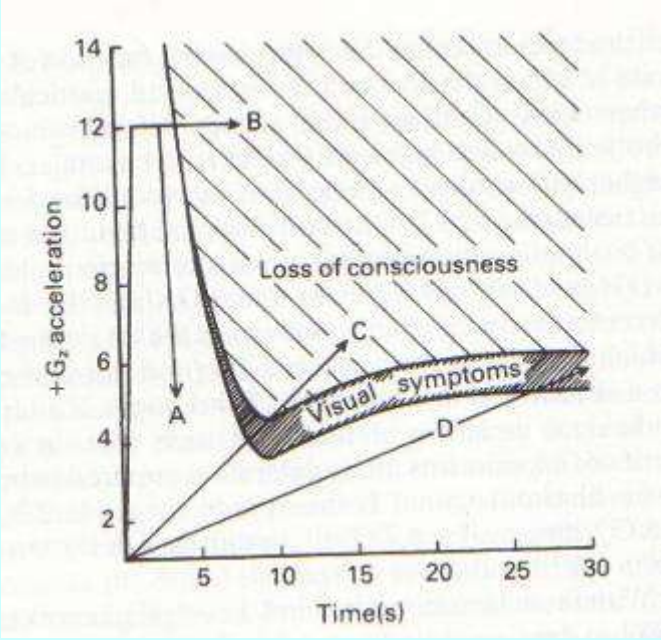


Background

Use as Protection Against Accelerative Forces

- Headwards Acceleration and Reaction
- Mechanism





- Visual Symptoms and G induced Loss of Consciousness
- Protection

Background

Cardiovascular Responses to Hyperventilation

- Definition and Historical Perspective
- Heart Rate and Cardiac Output
- Arterial Blood Pressure
- Peripheral Blood Flow
- Cerebral Blood Flow

Background

Previous Studies

- "Mess Trick" and the "Fainting Lark"
- Hyperventilation during pressure breathing
- Valsalva Manoeuvre and Hyperventilation
- Pressure breathing and Hyperventilation

Aims and Hypotheses

1. Voluntary hyperventilation does not affect the arterial blood pressure and heart rate responses to positive pressure breathing

2. Hypocapnia (low CO_2 in blood), which results from hyperventilation, does not affect the arterial blood pressure and heart rate responses to pressure breathing

Methods

Subjects

- Recruitment from King's College London and Royal Air Force Centre of Aviation Medicine
- Total 7 Subjects (six male, one female) aged between 21 and 36
- Medical Fitness
- Training

Methods

Protocol

Condition A

	Rest	PPB at 40mmHg	Rest
Duration (mins)	**5**	**3**	**2**
$P_{ET}CO_2$ (mmHg)	Normal	Normal	Normal
Gas Mixture	Air	Air	Air

Condition B

	Rest	HV	PPB at 40mmHg	Rest
Duration (mins)	**5**	**2**	**3**	**2**
$P_{ET}CO_2$ (mmHg)	Normal	25	25	Normal
Gas Mixture	Air	Air	Air	Air

Condition C

	Rest	HV	PPB at 40mmHg	Rest
Duration (mins)	**5**	**2**	**3**	**2**
$P_{ET}CO_2$ (mmHg)	Normal	38	38	Normal
Gas Mixture	Air	4 % CO_2	4 % CO_2	Air

Methods

Equipment

- Consent and Explanation
- Balanced Experimental Design (B and C)
- Pressure Breathing Rig – 40mmHg
- Real time visual End Tidal Carbon Dioxide Display
- P/Q Mask and Type G RAF Cloth Helmet
- RAF Pressure Jerkin and Mk1A external G trousers
- Seated in RAF Crew Seat

Methods

Recorded Variables

- Ventilation – Fleisch Flowmeter and Morgan Integrator
- Mask Cavity Pressure
- Fractional Concentration of Carbon Dioxide – calculate End Tidal Carbon Dioxide
- Cardiovascular Variables (Heart Rate, Arterial Blood Pressure, Cardiac Output, Stroke Volume) - Finometer
- Recorded via Chart on Laptop and Pen Recorder
- Pre and Post Calibrations

Methods

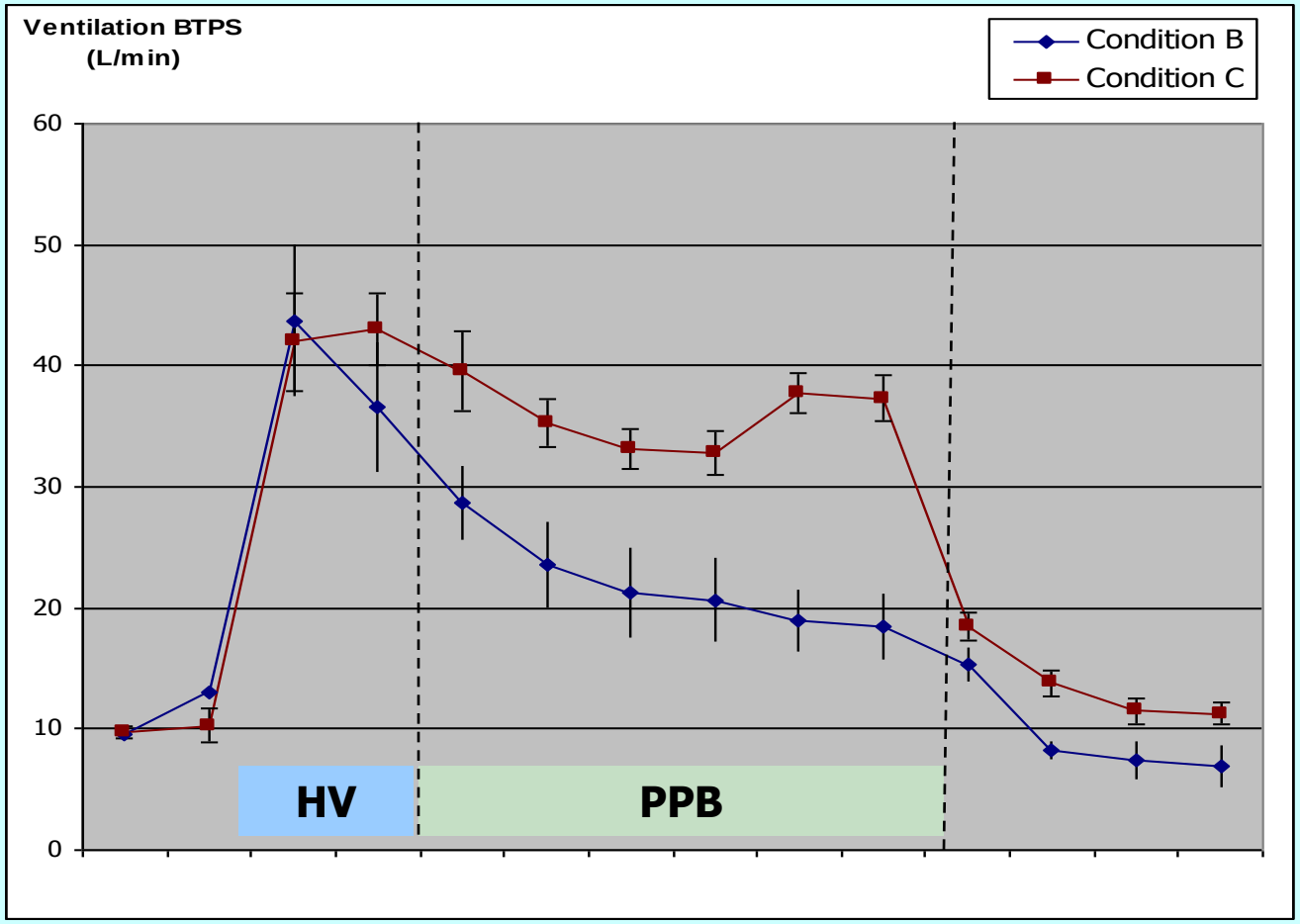
Subject During Experiment

Methods

Equipment Set-up During the Experiment

Results

Ventilation



- Condition A results showed a rise from 10.3±1.1L/min to 16.1±1.0L/min
- Middle 2 minutes of pressure breathing showed a 13.1 ±2.5L/min difference between hypocapnic (condition B) and isocapnic hyperventilation (condition C)

Values are plotted every 30 second intervals

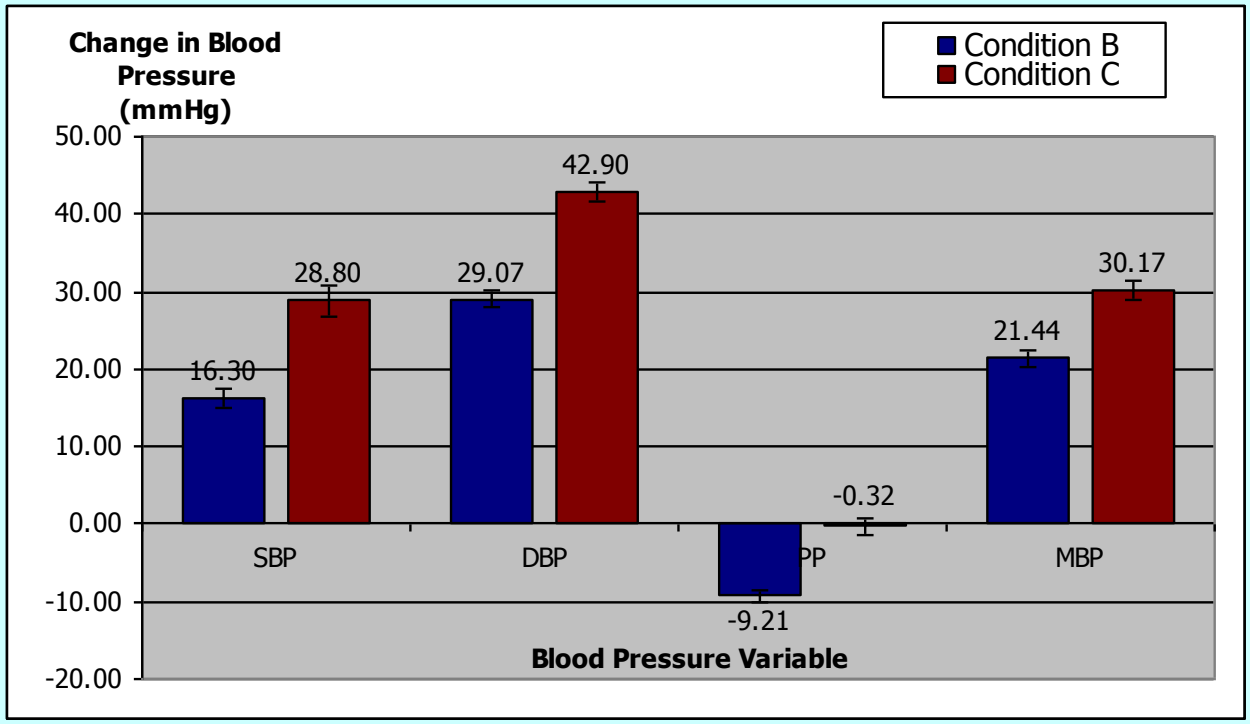
Results

End Tidal Partial Pressure of Carbon Dioxide $P_{ET}CO_2$ *(mmHg)*

Period	Condition B - Hypocapnic Hyperventilation (mean ±SE)	Condition C - Isocapnic Hyperventilation (mean±SE)
Rest	39.3±0.7mmHg	38.6±0.7mmHg
Hyperventilation	26.2±1.0mmHg	38.6±0.7mmHg
Pressure Breathing	23.4±0.2mmHg	38.3±0.1mmHg

Results

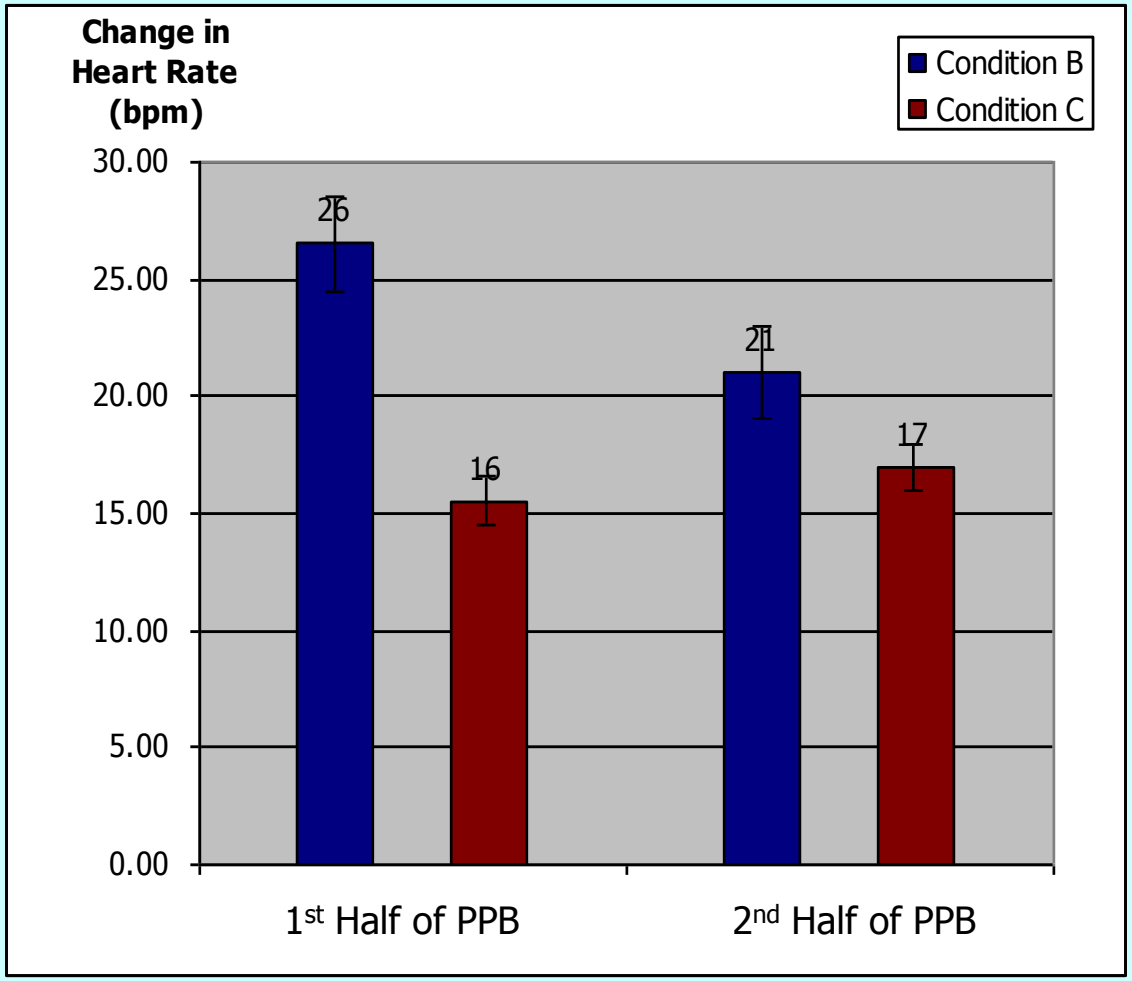
Arterial Blood Pressure



- Condition A, rose from 89.9±4.7mmHg at rest to an average of 104.1±3.0mmHg during the middle two minutes of pressure breathing ($p < 0.05$)
- Rise in blood pressure 29% less during condition B PPB than condition C PPB

Results

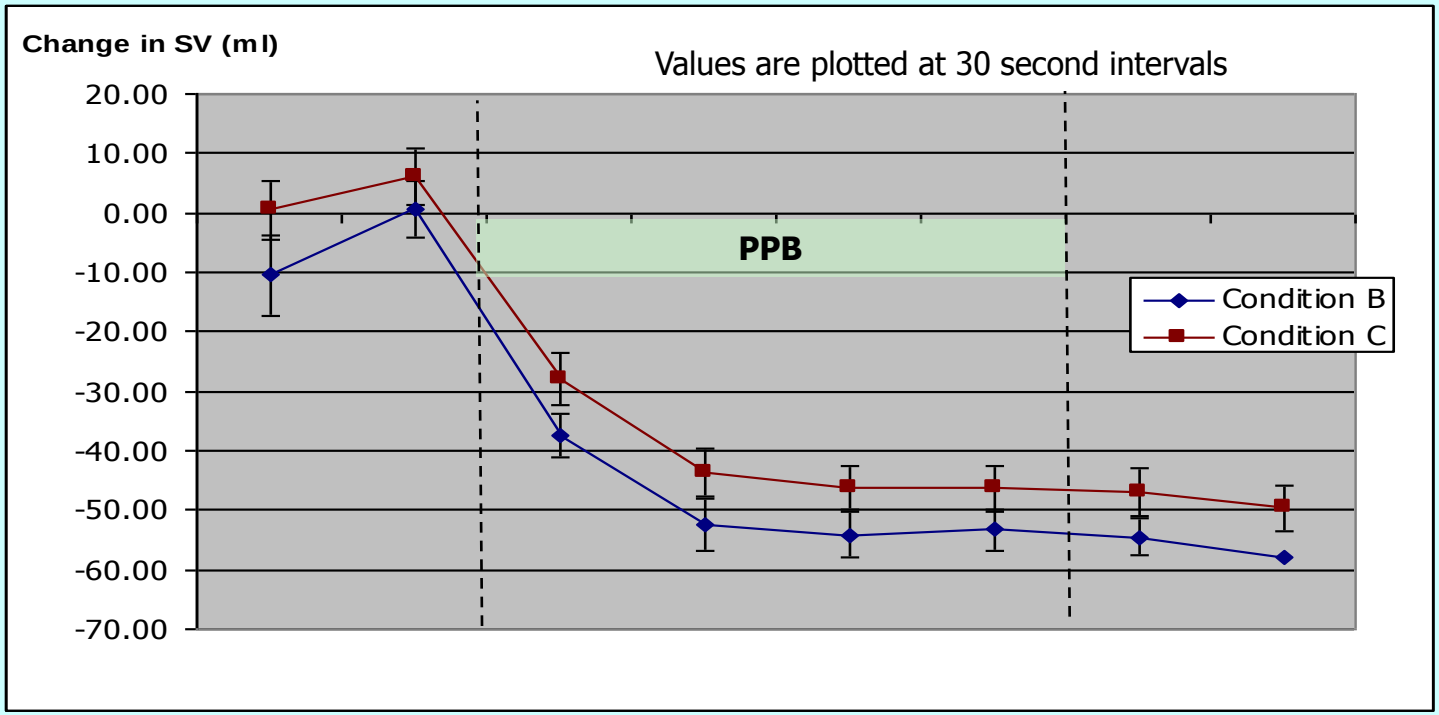
Heart Rate



- Hypocapnic Hyperventilation caused 24±3bpm rise in heart rate, whereas the isocapnic hyperventilation 12±2bpm
- HR rise in condition A PPB insignificant
- HR rise reduced in Condition C

Results

Stroke Volume and Cardiac Output



- Condition B HV caused fall in SV by 1.25±4.2ml/beat contrast with rise of 4.76±2.0ml/beat in Condition C
- Fall in SV less in Condition C (48±2.0ml/beat) and than Condition B (54±2.0ml) ($p < 0.05$)
- Mean cardiac output fell from resting levels by 2.8±0.2 L/min in condition B and by 2.36±0.2 L/min in condition C ($p < 0.05$)

Discussion

Points to Note

- Pressure breathing caused a 56% increase in ventilation (without voluntary control)

- Adequate $P_{ET}CO_2$ *(mmHg)* control

- Isocpanic hyperventilation pressure breathing ventilated at a rate of **13.1 ±2.5L/min** greater than hypocapnic hyperventilation pressure breathing

Discussion

Arterial Blood Pressure

		Effect of	
		Pressure Breathing	*Hyperventilation*
Source	*Literature*	↑	↓
	Experiment	↑	↔

Effect of Pressure Breathing and Hyperventilation	
Hypocapnic	↑ 71%
Isocapnic	↑

Discussion

Heart Rate

		Effect of	
		Pressure Breathing	*Hyperventilation*
Source	*Literature*	↑	↑
	Experiment	↑	↑

Effect of Pressure Breathing and Hyperventilation	
Hypocapnic	↑ ↑ 138% - 114%
Isocapnic	↑

Discussion

Stroke Volume & Cardiac Output

		Effect of	
		Pressure Breathing	*Hyperventilation*
Source	*Literature*	↓	↑
	Experiment	↓	↔

Effect of Pressure Breathing and Hyperventilation	
Hypocapnic	↓
Isocapnic	↓ 93%

Conclusion

- Further work required for absolute rejection of null hypothesis
- Reduced Tolerance to +Gz Acceleration
- Possible increase risk in pressure breathing syncope
- Implications for aircrew training

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