Royal Netherlands Air Force

After Effects of High-Gz+ Exposure on Airway Reactance and Resistance Fighter Pilots.

Human centrifuge research

Royal Netherlands Air Force
Centre for Man and Aviation
ENS Simon Cornelissen
Military Working student - Medical Intern

The ‘Raptor’ cough

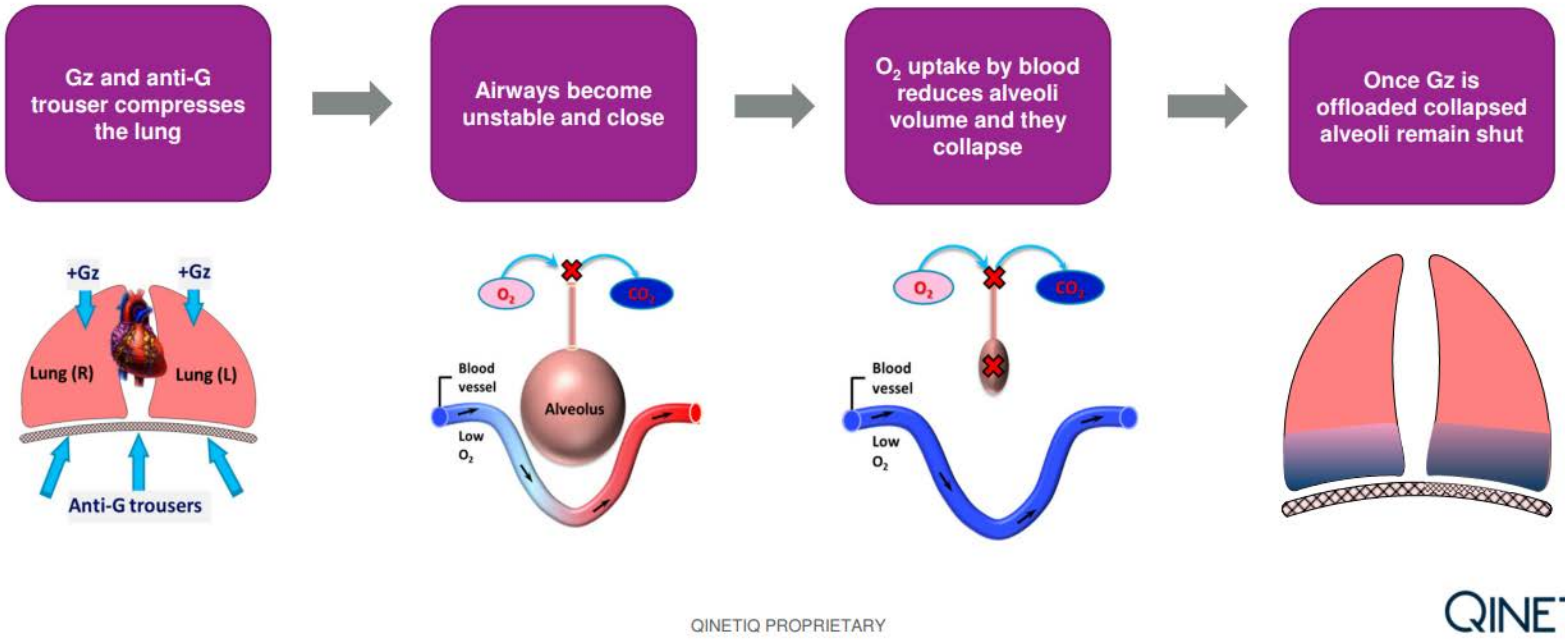
abc NEWS

F-22 Fighter Pilots Battle Mysterious 'Raptor Cough'

WIRED

The coughing -- which, to be clear, is a totally separate issue from hypoxia -- is due to a condition known as "acceleration atelectasis," Maj. Gen. Charles Lyon, who headed the Air Force's Raptor investigation, wrote in response to questions submitted following a September testimony before a House subcommittee. "Acceleration atelectasis results from pilots breathing high concentrations of oxygen (above 60 percent) while wearing anti-G trousers, and exposure to G-forces," Lyon explained.

Acceleration Atelectasis



QINETIQ

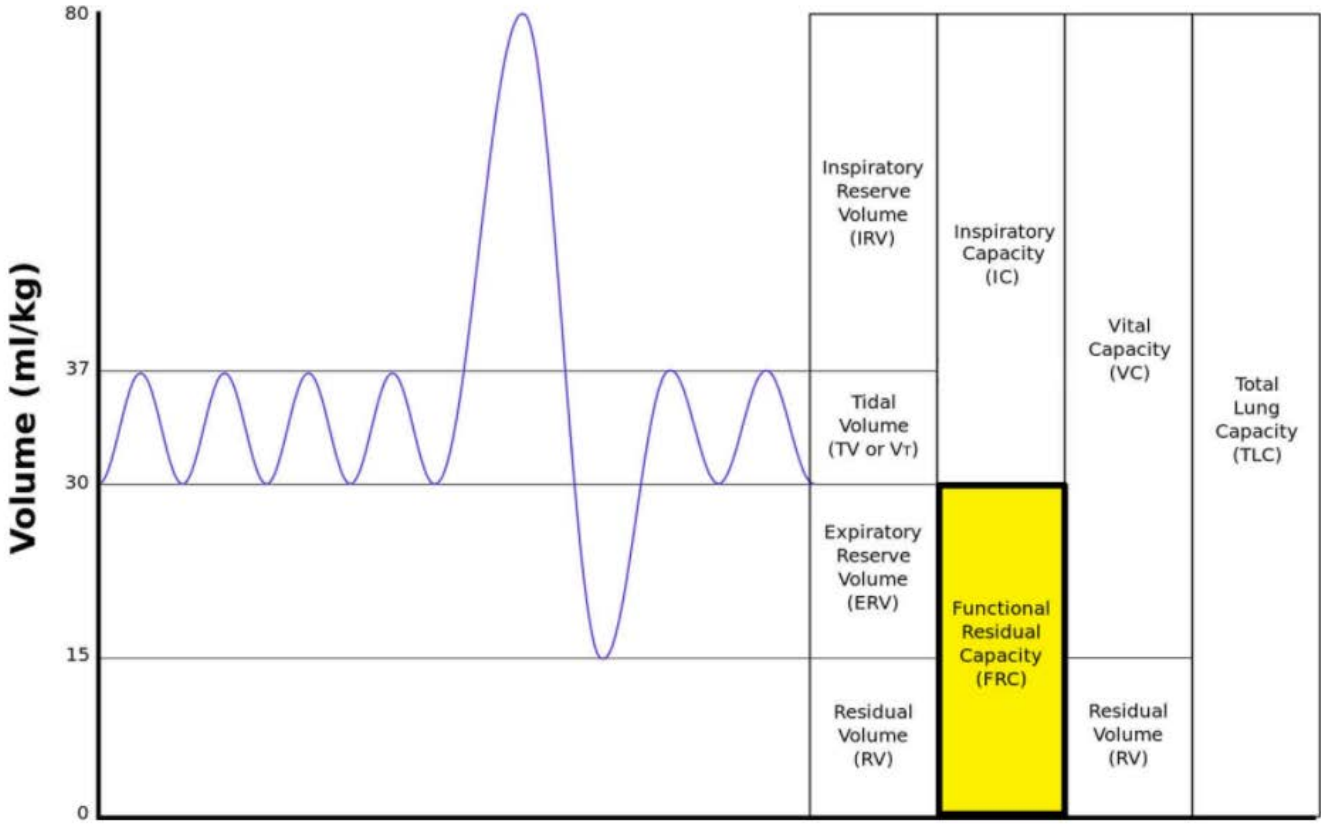
Higher Gz → bigger Ventilation/Perfusion mismatch? & more collapse?

Dr. R. Pollock, Dr. A. Stevenson. Acceleration Atelectasis: New risk from an old friend. 2018. https://www.safeeurope.co.uk/media/7901/n-dr-ross-pollock_acceleration-atelectasis-new-risks-from-an-old-friend.pdf

Research question

What is the isolated effect of high-Gz exposure on pulmonary function?

Lung volumes



Hopkins E, Sharma S. Physiology, Functional Residual Capacity. [Updated 2019 Mar 14]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2019 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK500007

Airway physiology (impedance)

Compliance (Reactance)

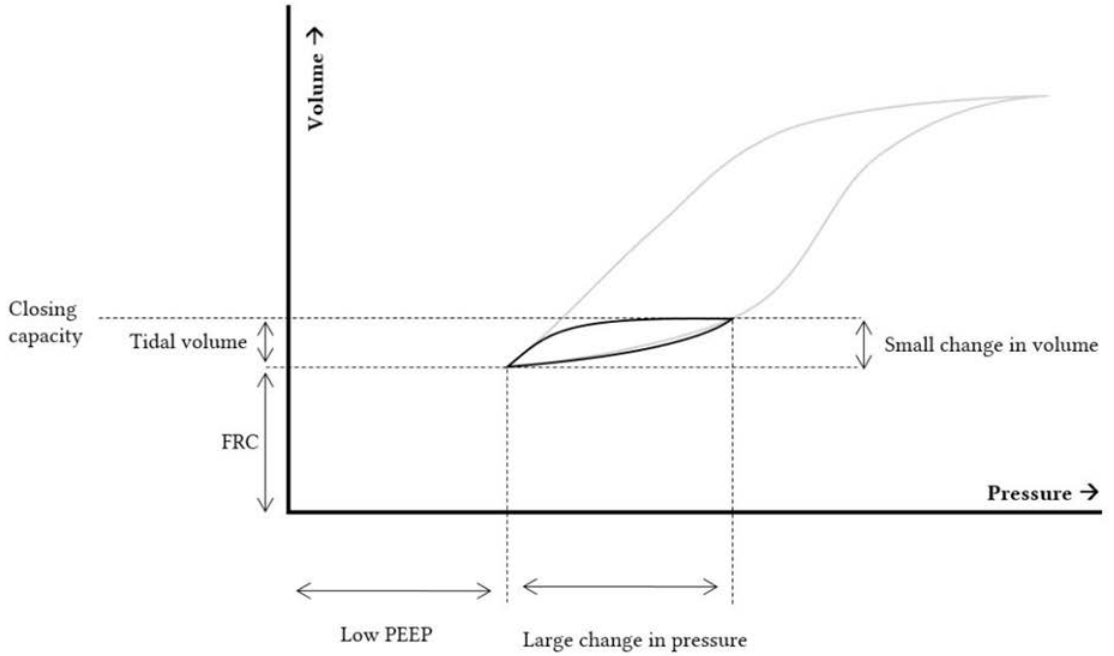
"The change in volume divided by the change in pressure"

Compliance = ΔV / ΔP

Acceleration atelectasis:

ΔV↓ (FRC) → C↓

C = Compliance
V = Volume
P = Pressure
FRC = Functional residual capacity



Guyton. Medical Physiology (2016).
Deranged physiology. Effects of pressure ventilation on pulmonary physiology (2015).

Airway physiology (impedance)

Resistance

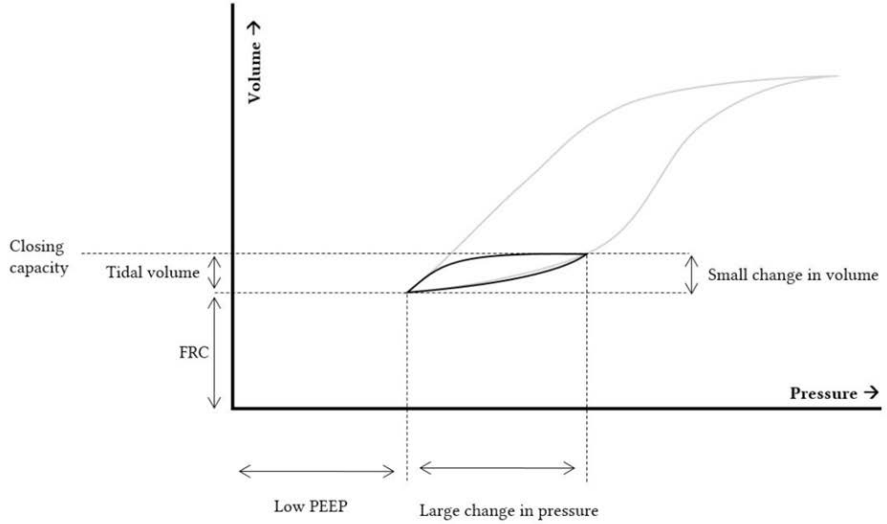
Rohrer's equation: $Rrs = Rt + K_1 + K_2\dot{V}$

- Rt: Resistance from deformation of lungs and chest wall
- K_1: Constant for gas viscosity & density
- $K_2\dot{V}$: Flow as volume/unit time

Acceleration atelectasis

$\Delta V \downarrow (FRC) \rightarrow C \downarrow$

$C \downarrow \rightarrow \Delta P \uparrow \rightarrow Flow \uparrow \rightarrow Rrs \uparrow$



C = Compliance
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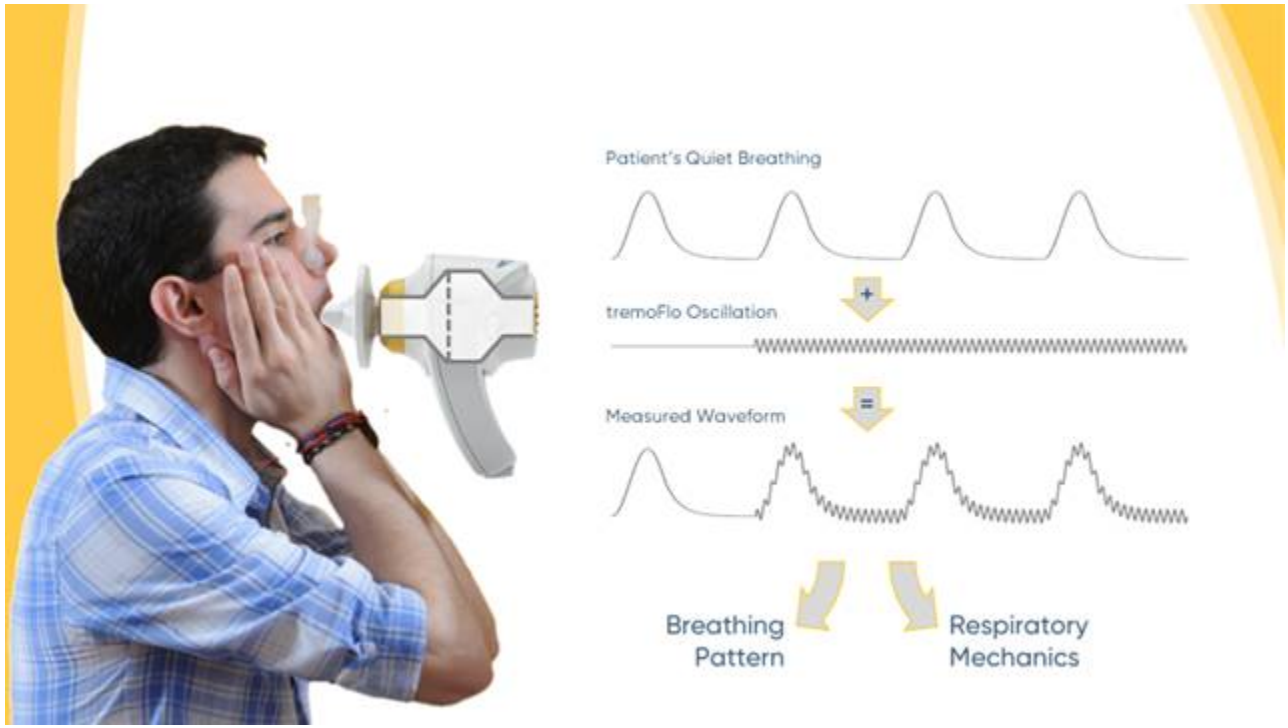
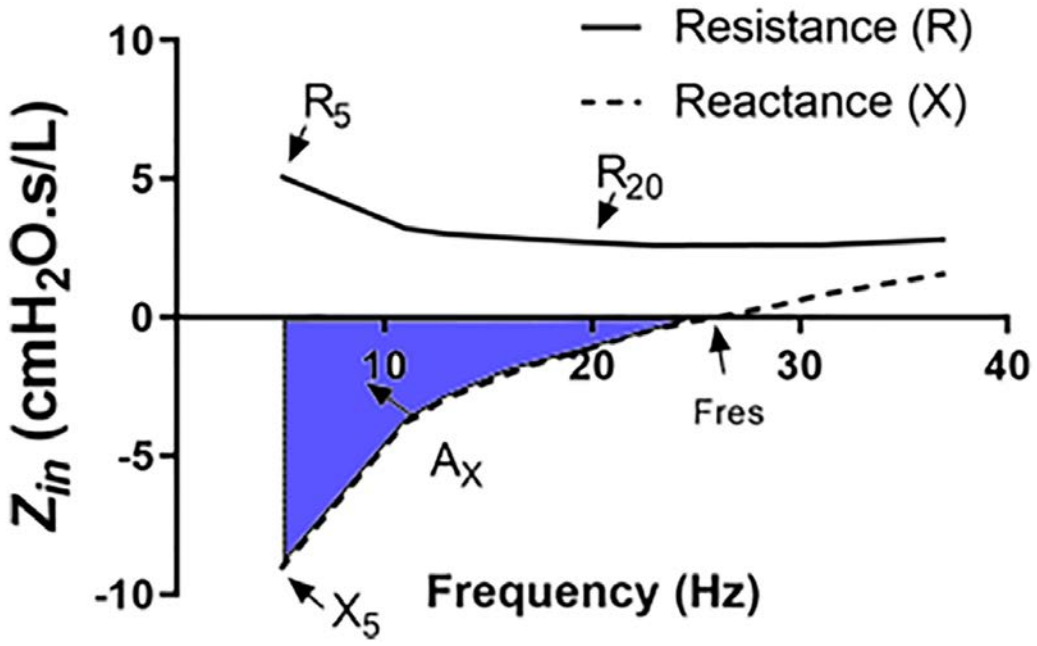
THORASYS® tremoFlo® C-100 Airwave Oscillometry System™ (AOS)



tremoFlo® C-100 Technical Specifications (English) Montreal, Quebec, Canada: THORASYS Thoracic Medical Systems Inc.; 2015, 26-01-2015.

Airwave Oscillometry

- R5 Total Rrs
- R20 Central Rrs
- R5-20 Peripheral Rrs
- X5 Lung stiffness (compliance)
- AX Elastance and obstruction



Lundblad LKA, Siddiqui S, Bossé Y, Dandurand RJ. Applications of oscillometry in clinical research and practice. Canadian Journal of Respiratory, Critical Care, and Sleep Medicine. 2021;5(1):54-68.

High-Gz training
(in accordance with STANAG 3827)

1. AGSM training in classroom
2. Gz profiles in Human Centrifuge

Anti-G Straining Manoeuvre (AGSM)

Continuous isometric full-body muscle contractions

+

Repeated ‘Hook’ manoeuvre
(Breath in → “Hoo..” → Hold +/- 3 sec → Strongly exhale “..K”)

=

Maintaining intracerebral blood pressure

Human Centrifuge

(2021). "Centrum voor Mens en Luchtvaart." from https://www.defensie.nl/organisatie/luchtmacht/vliegbases-en-luchtmachtonderdelen/cml.

High G training (in accordance with STANAG 3827)

		Profile	Maximum Gz	Onset	Duration of maximum Gz
High-G	*Run 1*	RELG	-	0.1 Gz/sec	-
	Run 2	HSG-6	6 +Gz	0.33 Gz/sec	30 sec
	Run 3	HSG-8	8 +Gz	1.0 Gz/sec	15 sec
	Run 4	ACM-9/8	9 +Gz & 8.5 +Gz	3.5 Gz/sec	10 sec & 15 sec

AGSM

Table 1: Structure of the High G physiological protection training profile used in the present study.

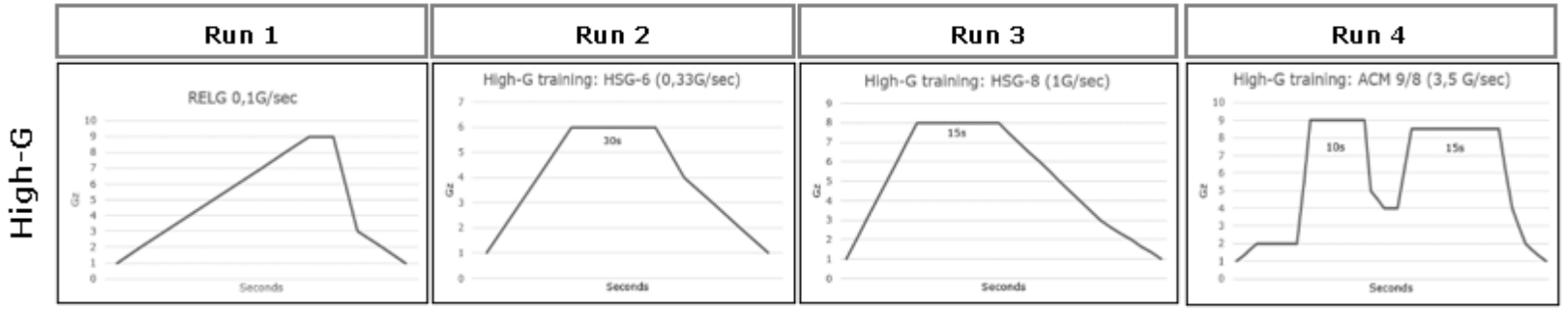


Figure 2: Graphical display of the High G-profiles used in the present study.

Baseline

Measurement

Set-up

Baseline Characteristics

- 22 Israeli
- 4 Dutch
- 2 Portuguese

	All (N =28)
Age (y)	23,3 ± 5,4
Male (%)	96,6%
Height (cm)	179,9 ± 5,3
Weight (kg)	76.9 ± 7,5
G-tolerance during RELG-profile	5,3 ± 0,9
Flight hours	244,2 ± 538,1

Table 2: Baseline characteristics. *Values are means ± SD.

Results

Index	Baseline	Post-exposure	Mean difference	Standard Deviation	Z-score	Sig. (2-tailed)
AX (cmH_2O/L)	6,640 ± 3,530	4,347 ± 1,704	2,293	2,490	-4,099	0,000*
R19 ($cmH_2O.s/L$)	2,755 ± 0,615	2,290 ± 0,460	0,465	0,542	-3,826	0,000*

Index	Baseline	Post-exposure	Mean difference	Standard deviation	Confidence interval	Sig. (2-tailed)
R5 ($cmH_2O.s/L$)	3,410 ± 0,834	2,769 ± 0,529	0,641	0,689	0,373 – 0,908	0,000*
X5 ($cmH_2O.s/L$)	-1,216 ± 0,299	-0,958 ± 0,220	-0,258	0,225	-0,345 - -0,171	0,000*
R5-19 ($cmH_2O.s/L$)	0,654 ± 0,349	0,479 ± 0,247	0,176	0,276	0,069 – 0,283	0,002*
R5-20 ($cmH_2O.s/L$)	0,669 ± 0,363	0,485 ± 0,247	0,184	0,294	0,070 – 0,298	0,003*
VT (L)	1,372 ± 0,343	1,603 ± 0,465	-0,230	0,368	-0,373 - -0,088	0,003*

P-values of AX & R19 obtained from Wilcoxon signed rank test. P-values of R5, X5, R5-19, R5-20 and VT obtained from paired samples t-test. *Significant difference from baseline measurement.

Results

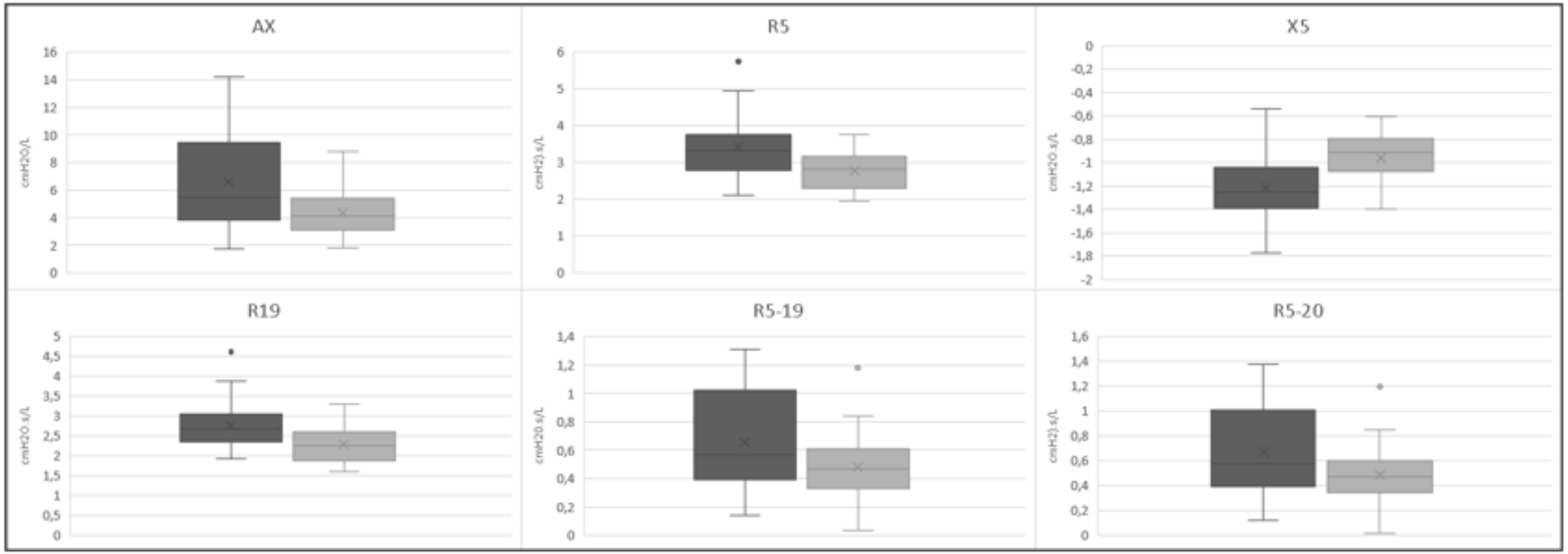
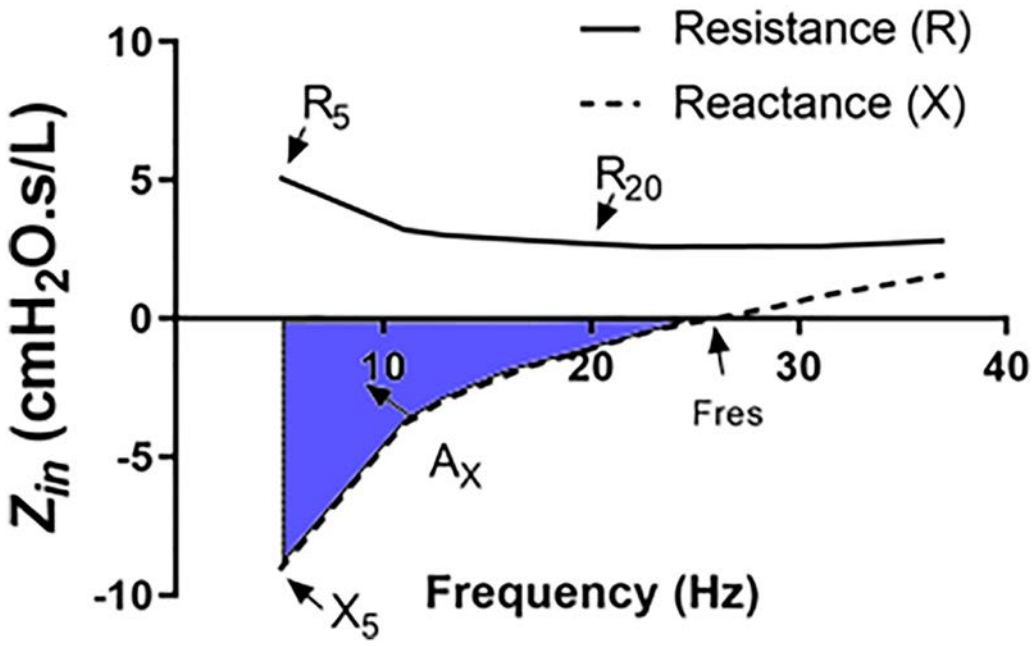


Figure 5: Boxplots of impedance measures.

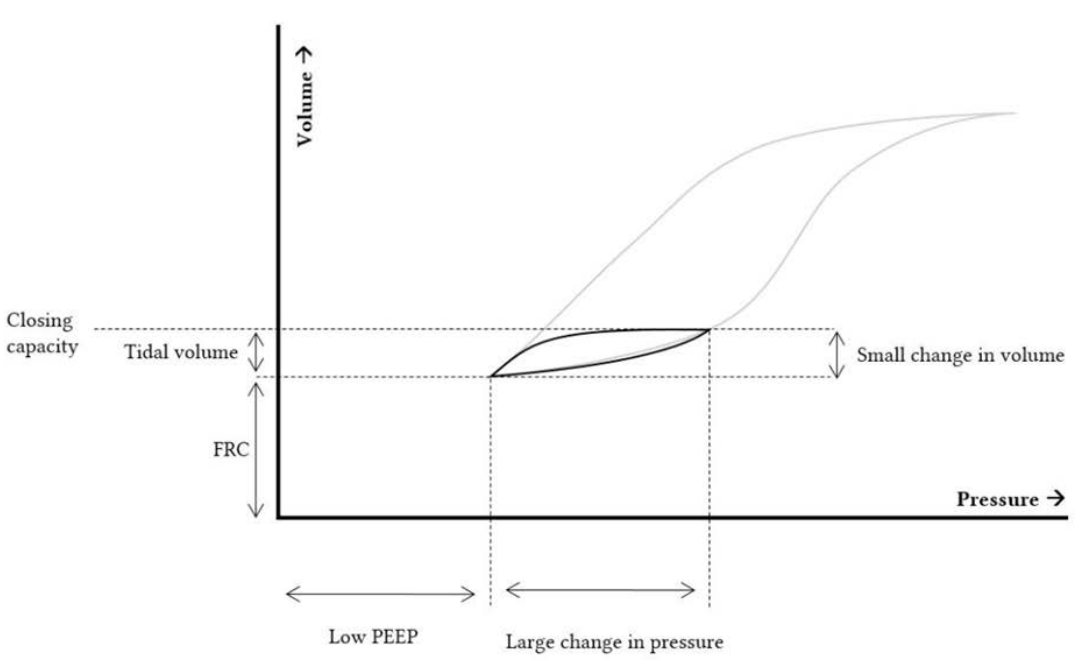
Results

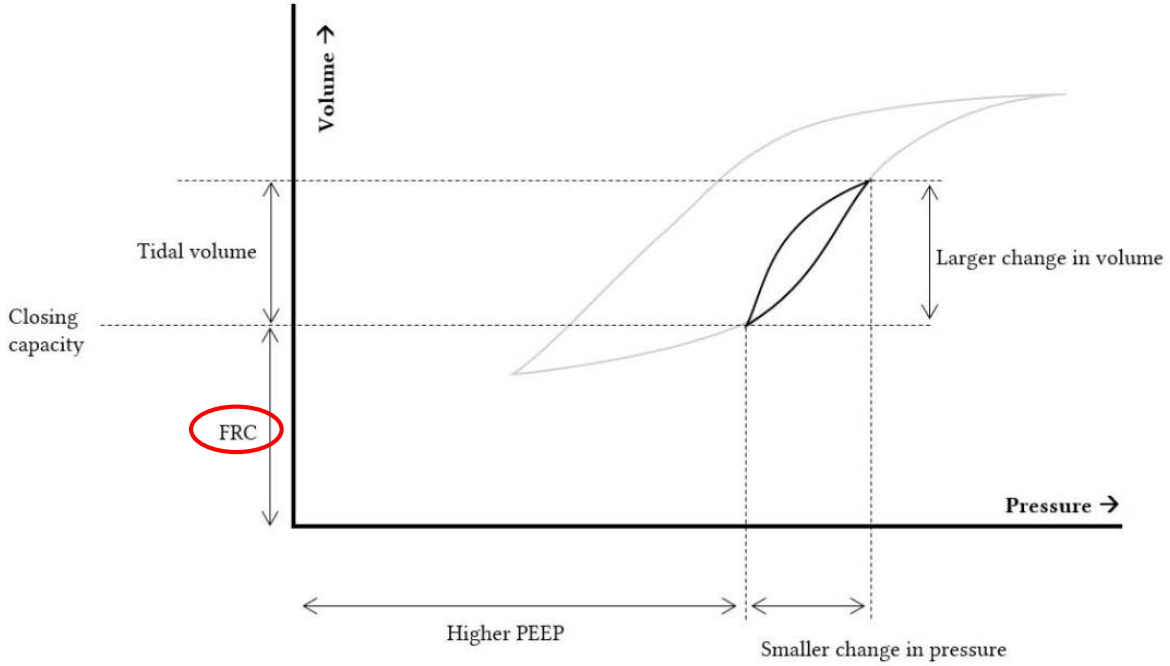
- R5 ↓
- R5-20 (R5-19) ↓
- X5 ↑
- AX ↓

Compliance ↑
Resistance ↓



Explanation





Resistance?

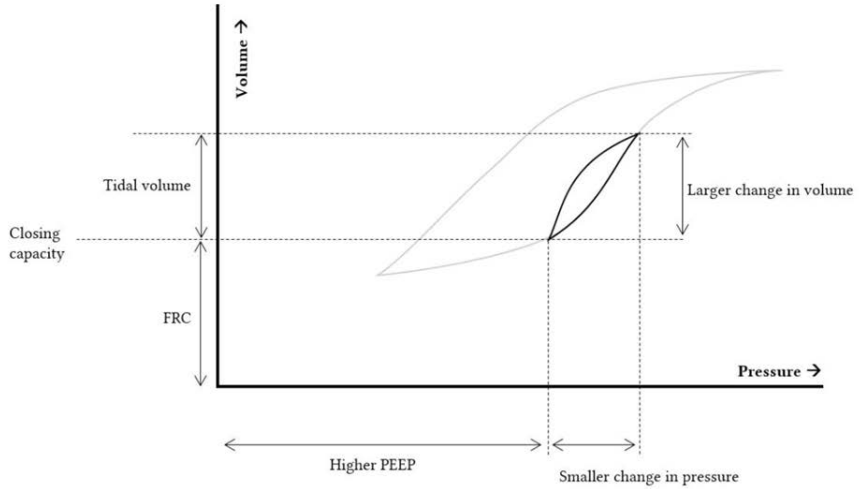
Deranged physiology. Effects of pressure ventilation on pulmonary physiology (2015).

Explanation?

AGSM (Hook-manoeuvre) = insufficient expiration

→ FRC ↑ → ΔP ($P_{alveolar}$ ↑ – $P_{pleural}$) → ΔP↓

C = ΔV / ΔP → C ↑ & VT ↑ & Rrs ↓



C = Compliance
V = Volume
P = Pressure
FRC = Functional residual capacity
VT = Tidal volume

Discussion

- Hook manoeuvre protective?
  - High-G physiological protection training
  - Factor absorption atelectasis

- Sample size?
  - Similar changes in 25/28

- Airwave oscillometry (Tremoflo) vs Spirometry?
  - Pilot selection?

More Research!

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Simon Cornelissen

E-mail: SJWM.Cornelissen@mindef.nl
LinkedIn: https://www.linkedin.com/in/simon-cornelissen-652081142/

Research video: https://www.youtube.com/watch?v=TIJJP0s88WI&t=22s