Body fat does not influence venous bubble formation after air dives: nitrogen load models and experiments

Nico A. M. Schellart n.a.schellart@amc.uva.nl.

Biomed Eng & Physics, **A**cad. **M**edical **C**enter, Univ. of Amsterdam

Study questions

A. Is it theoretically possible that body fat (BF) affects VGB?

B. Shows a Doppler experiment an influence of BF with subjects with a wide range of body fat **but with about the same age, VO_{2max} and gender**?

Theoretical study

Fat tissue has a 5 x higher solubility than watery tissues.

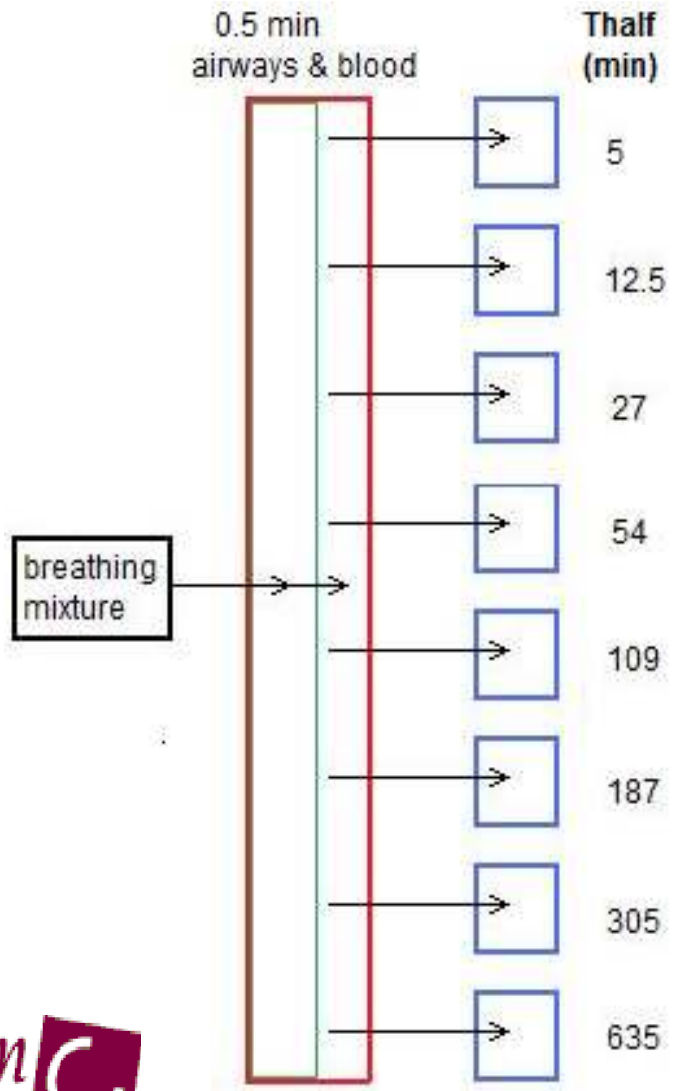
This is the basis of the classical hypothetical explanation why obese divers have more bubbles.

True or not true?

Approach

- Estimate VGB difference after surfacing of
  a lean (14% BF) and **thick** (28%) diver
- by calculating N_2 loads and tensions.

Design: extend Haldanian model with a blood compartment preceding the Haldanian //compartments.



However, connecting //compartments affects $PN_{2\ blood}$.

Modelling with an electric analogue.

Time invariant linear system analysis

9th order linear diff eq, Laplace transformed to 9th-order algebraic equation analytically solved with Mathematica.

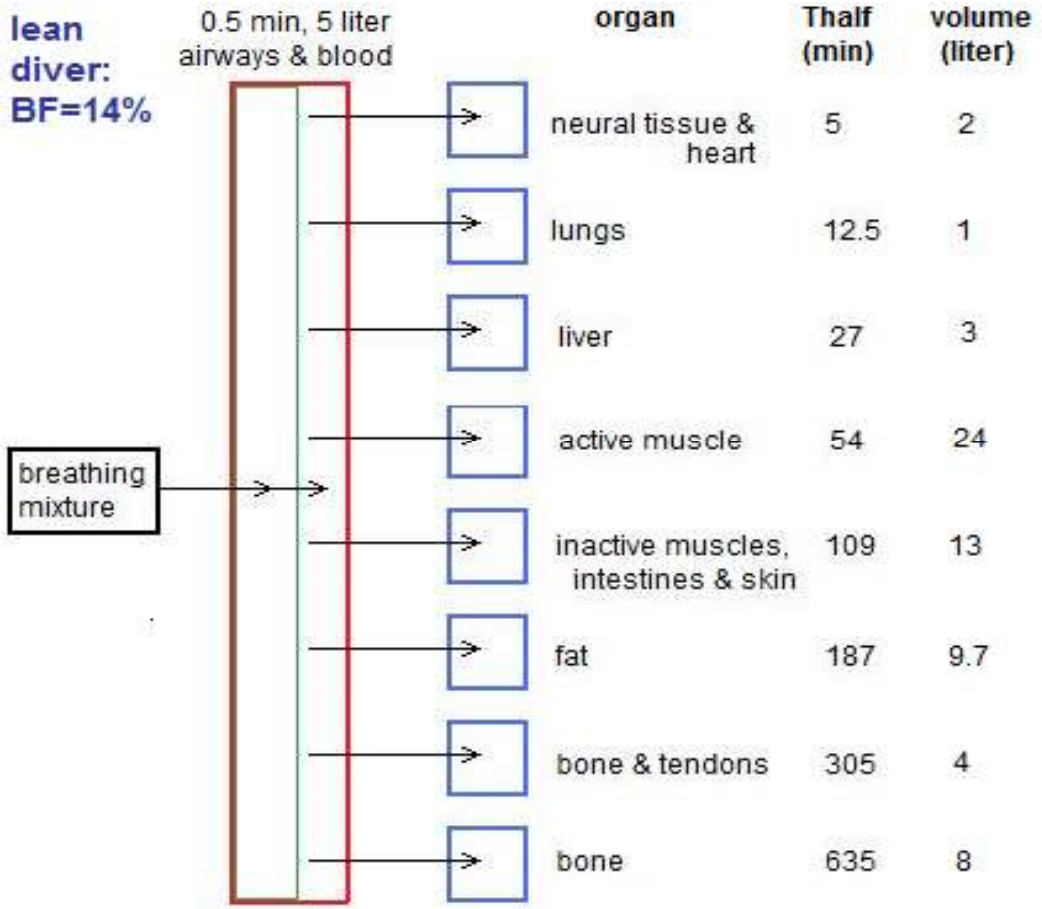
Problem 1: the analogue has compartments with same volume.

Solution: Introduce as many as identical comp's for any of the 9 proportional to its volume.

> 30 compartments results: Mathematica jams.

Problem 2: numerical values of R's and C's unknown.

Solution: abandon the analytic approach (electric analogue) and use a numerical **approximation**.



Numerical approach

Principle

Each time interval (1 min):

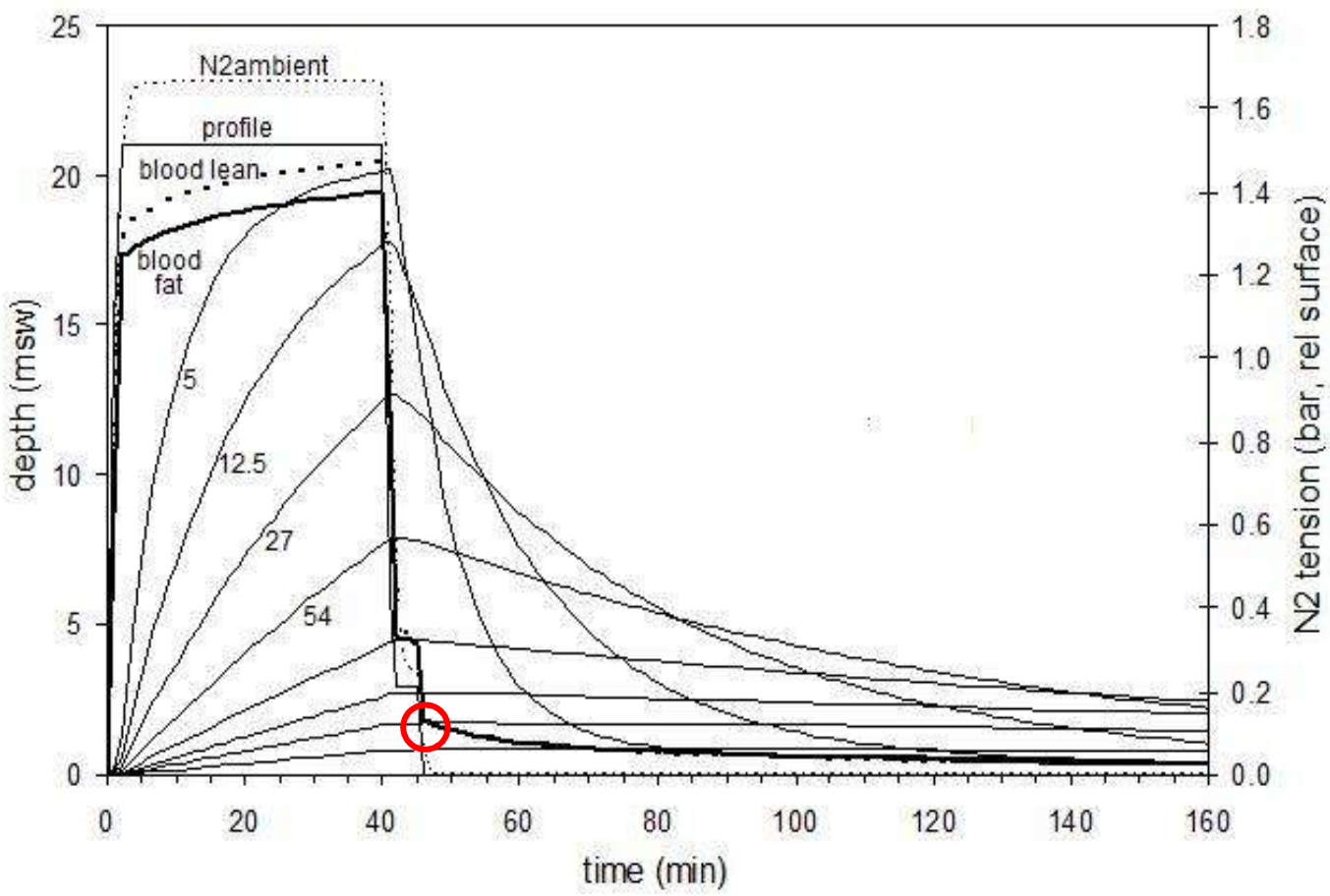
1 Calculate summed change of N_2-loads // compartments.

2 Correct $PN_{2\ blood}$ for sum (Henry)

3 Calculate new $PN_{2\ blood}$ with $PN_{2\ ambient}$.

4 Calculate new $PN_{2\ //comp}$

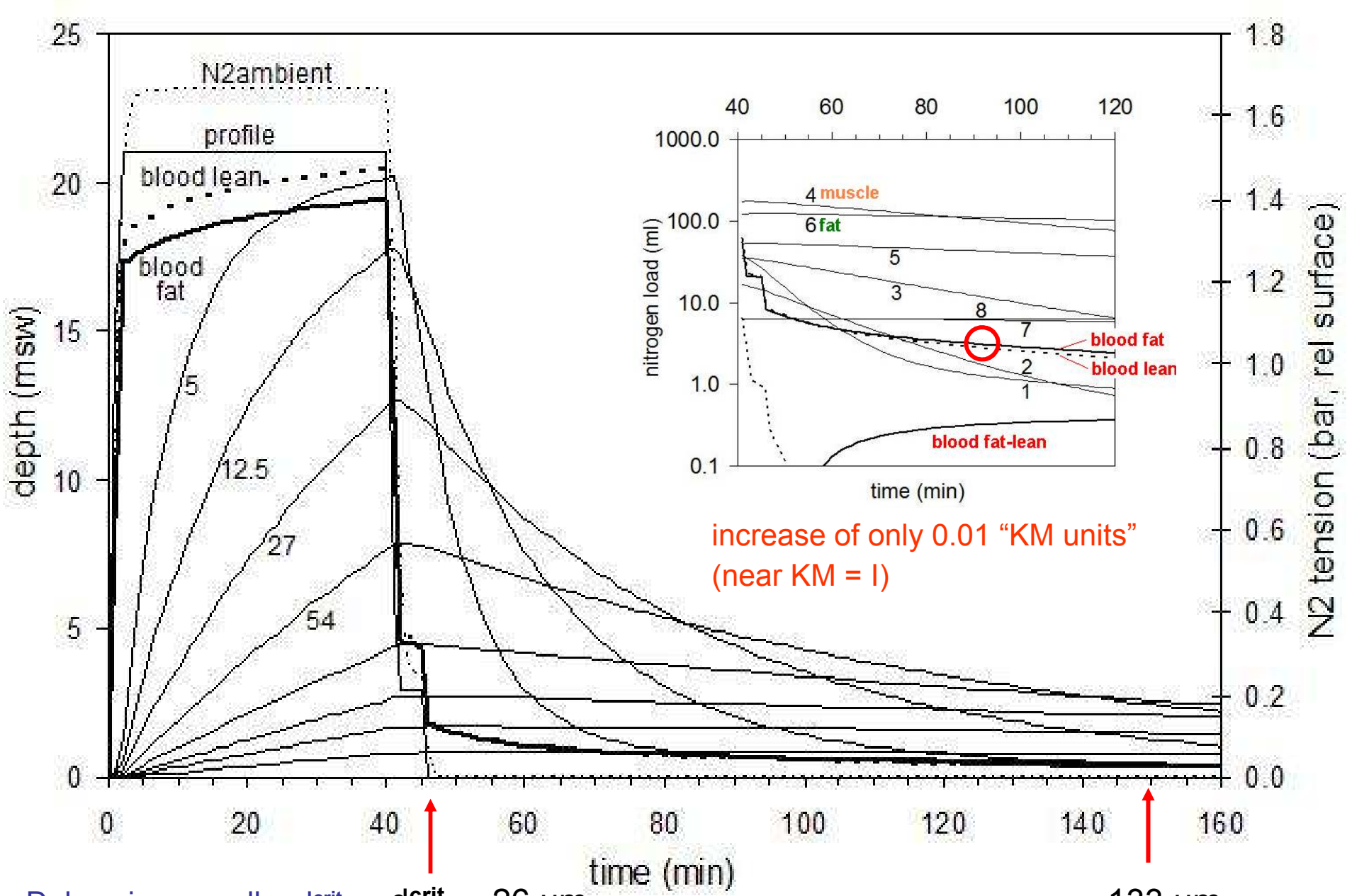
Repeat 1-4, etc.



Compartments have delayed release; $PN_{2\ blood}$ is asymptote.

$PN_{2\ blood} = 1.65(1 - 0.77x2^{-t/0.22} - 0.06x2^{-t/5.3} - 0.17x2^{-t/59})$ (approx)

$PN_{2\ //comp}$ = convolution of $PN_{2\ blood}$ with $2^{-t/Thalf//comp}\ /T_{half//comp}$



Delay gives smaller d^{crit}. d^{crit} = 26 µm 133 µm

Robustness: **Substantial changes in** halftimes, compartment volumes, profile (also saturation), halftimes after surfacing….. do not/hardly affects outcomes.

Doppler experiment

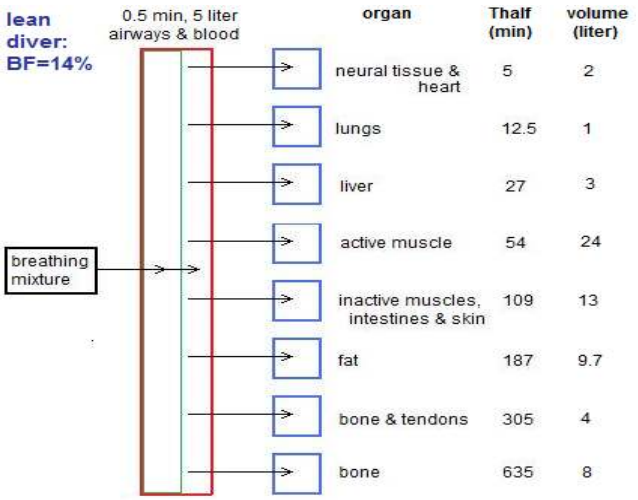
Material and methods

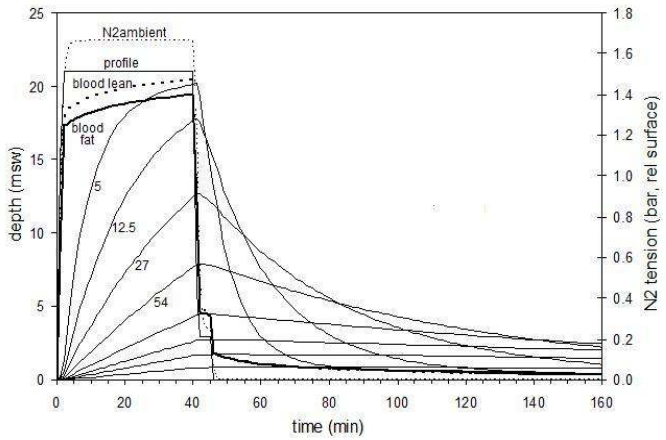
Precordial Doppler (KM) at 40, 80, 120, and 160 min, 40 min/3.1 bar(a) n= 53 male divers, small range in age and VO_{2max} (suppressing multicollinearity).

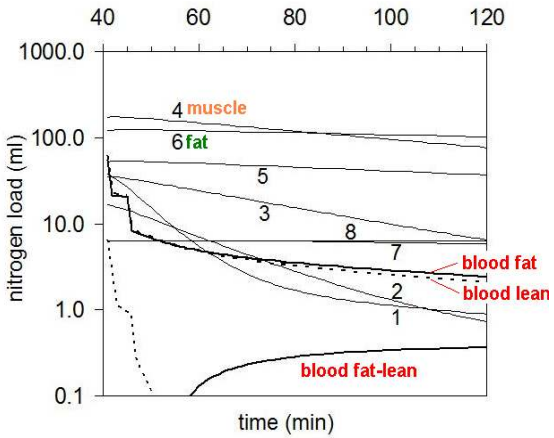
KM scores transformed to: logKISS and to log{#bubbles/cm^2} =logB (from EB scale).

Results

All statistical outcomes of (partial) correlations (Pearson & Spearman) of logB and logKISS with BF were far from significant, **as predicted by the model outcomes**.







CONCLUSIONS

Newness: 1. blood compartment **preceeds** all Haldanian //**compartments;**

2. **//compartments have** also **volume**

1. Series//-N_2-load *model*: much slower uptake and release; very robust.

(2. Grow Doppler bubbles more understandable.)

3. *Model*: BF appears irrelevant for VGB (also caisson work).

4. Again *Doppler data* indicate that BF does not affect VGB.

(Schellart et al., JAP, 2013:114;602-10.)

Thank you for your attention!

Thanks to Frank van Dijk, Rob van Hulst and Tjeerd van Rees Vellinga

Greetings from the Kingdom of the Netherlands