HYDROSTATIC AND PHYSIOLOGIC CONTRIBUTIONS TO INTRAOCULAR PRESSURE CHANGE DURING POSTURAL CHANGE

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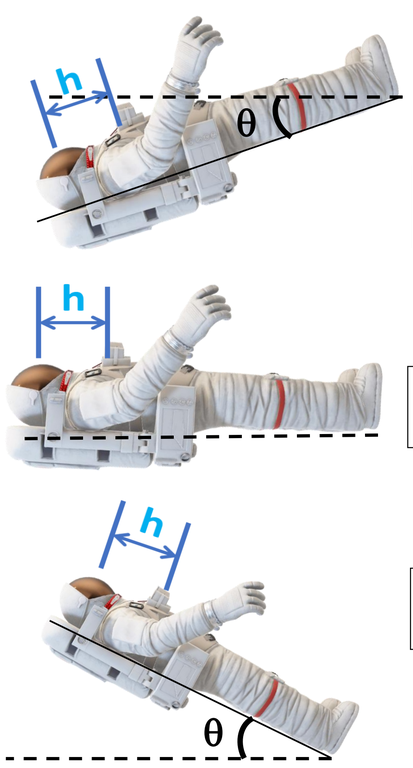
Introduction

- Terrestrial studies (1G) have observed that intraocular pressure (IOP) is dependent on tilt angle (θ) of the body.
- Tilting the body at a small downward angle is used as a ground based analog for studying the effects of cephalad fluid shifts in hypogravity (<1G; i.e. spaceflight) which may be relevant to ocular changes related to SANS.
- We completed a meta-analysis of 36 independent datasets from 30 published articles, representing 821 subjects, to identify the effect of postural change on IOP.
- Results from the fitted curve were compared to simulated predictions generated by a lumped parameter model of the eye[1] to identify hydrostatic effects vs physiologic regulatory effects that determine actual IOP.

Methods



Schematic of body position as a function of tilt angle θ. Height (h) is the distance between the aortic root and the eyes along the body axis.

The nondimensional hydrostatic pressure,

$p_h = \sin\theta$

is normalized by dividing the dimensional hydrostatic pressure by ρgh, where ρ is fluid density and g is gravity.

- Key meta-analysis study inclusion criteria:
  - Only topical anesthesia allowed prior to IOP measures.
  - Experiments required to allow sufficient IOP equilibration time (> 5 minutes between the change in posture and obtaining IOP measures).
  - Measurements must be taken while subject is at the specified tilt angle.
- 28 experimental studies were used for curve fitting while 8 were reserved for validation studies.
- A function finder (www.zunzun.com) determined that an exponential function fit the data best.
- Curve Fits, including experimental uncertainty, were performed with MATLAB built in functions.

References

[1] ES Nelson et al., J Appl Physiol 123(2):352–363 (2017).

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Results

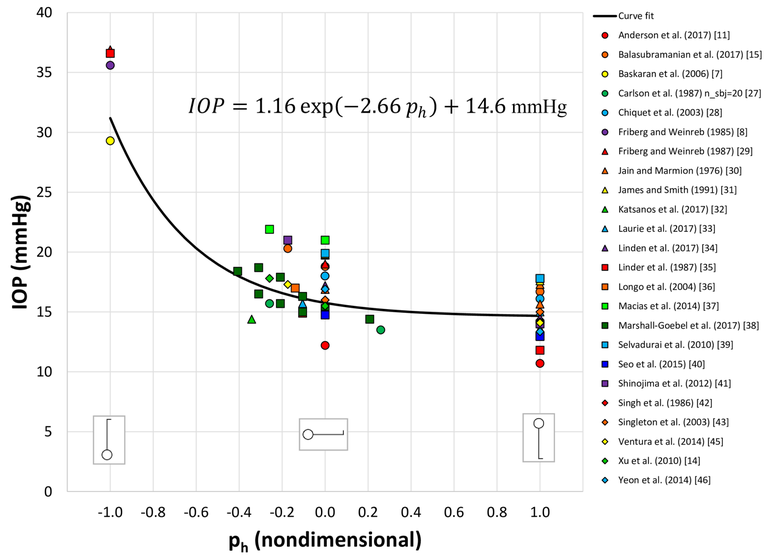

Figure 1: Identifying the experimentally derived curve fit. Markers indicate experimental measurements from 28 studies on 657 subjects (≥949 eyes). Solid line is the curve fit, as defined by the equation shown. When multiple values of IOP were available at a specific p_h, the curve fit weighted the data by the ratio of the number of subjects in the study to the total number of subjects at that p_h.

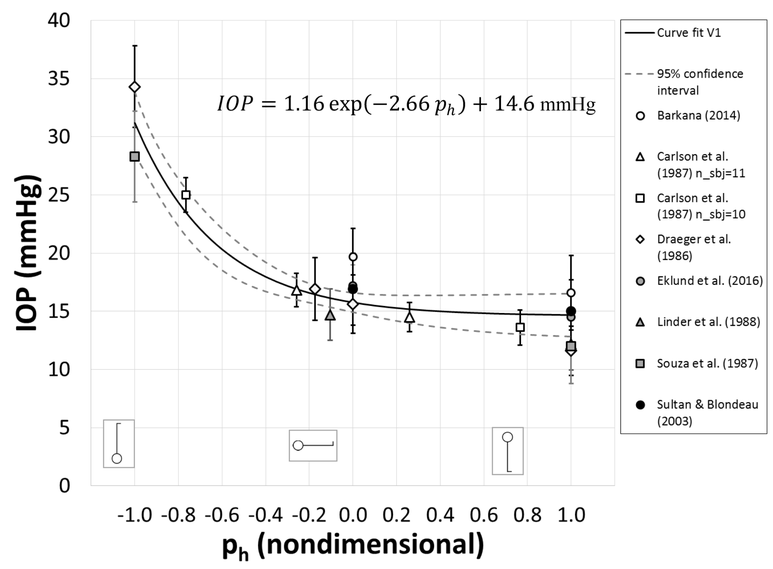

Figure 2: Testing the curve fit vs validation datasets. Experimentally derived curve fit (black line) compared to the validation data (symbols) with their respective standard deviations. 95% confidence interval of the curve fit is denoted by the dashed line.

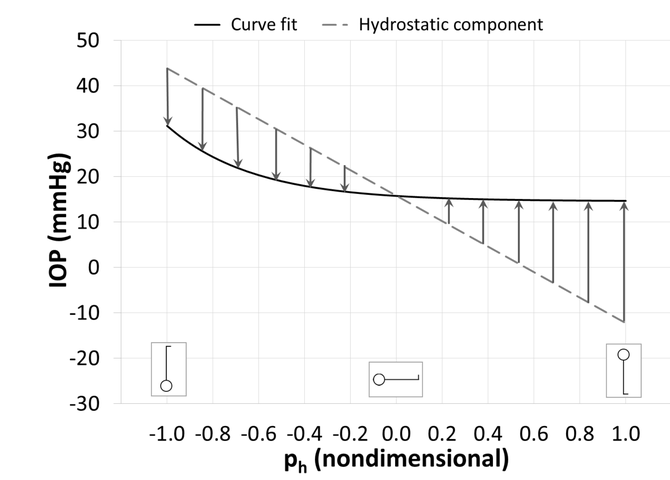

Figure 3: Identifying the body's physiologic influence on IOP at different tilt angles. Observed IOP response (black line) compared to the simulated IOPs assuming a purely hydrostatic response (dashed line). The difference between the two lines represent the body's physiological influences on IOP at each tilt angle (arrows).

Conclusions

- The experimentally derived equation for IOP vs p_h is an excellent fit for the reserved validation data, supporting this exponential function as a "universal" equation for posturally induced change in IOP at 1G.
- The difference between numerical simulations and actual IOPs highlights the effect of physiologic regulatory processes in overriding the idealized hydrostatic pressure effects at different tilt angles.

Acknowledgements

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