GRAVITATIONAL DOSE-RESPONSE CURVES DURING TILT, LBNP, AND CENTRIFUGATION

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ABSTRACT

The objective of this ground-based research effort is to generate acute gravitational dose-response curves of cardiovascular (CV) and ocular variables when exposed to different types of orthostatic stress. We propose to use both experimental and computational approaches to leverage the advantages of each one of these research methodologies. Our study consists of three different ground experiments where the same 12 male subjects (26.8 ± 2.9 years) are exposed to the following interventions: 1) Experiment 1: different tilt angles (from 45° head-up tilt (HUT) to 45° head-down tilt (HDT), in both supine and prone position); 2) Experiment 2: different LBNP pressure levels (from 0 mmHg to –50 mmHg, in both supine and –15° HDT); and 3) Experiment 3: different centrifugation levels (from 0g to 2g at the center of mass).

Objective measures related to human performance and cardiovascular regulation are collected in all three experiments. These data include continuous CV variables and autonomic responses (Finapres NOVA), non-invasive cardiac output (Innocor, Innovision), intraocular pressure (I-care tonometer), metabolic data (Innocor), blood volume (Blood Tec), Internal Jugular Vein pressure (IJVP, Vein Press), and cross-sectional areas (CSA) of the IJV (left and right side) and the Common Carotid Arteries (CCA, left and right side) (Ultrasound VScan Extend). When possible, measurements are continuously monitored during the pre- (baseline), during-, and post-experimental testing (e.g., Finapres); otherwise, measurements are collected after an appropriate time of exposure to the intervention to ensure steady state (typically 5 min). During baseline, all data are also collected in upright seated position.

To date, we have successfully completed the first two experiments (i.e., tilt and LBNP). Preliminary analysis indicates that most variables are strongly dependent on the gravitational/fluid shift conditions. For example, during experiment 1 (i.e., tilt), IJV CSA increased from 16.8 ± 1.7 mm^2 (mean ± SE) in 45° HUT to 178.3 ± 10.8 mm^2 in 45° HDT. Similarly, IJVP increased from 11.3 ± 1.3 mmHg in 45° HUT to 57.2 ± 2.6 mmHg in 45° HDT (see Figure 1 left). (Note: experiment 1 is further described in an accompanying abstract by Whittle et al.). During experiment 2 (i.e., LBNP) in supine position, IJVP decreased from 20.4 ± 1.8 mmHg at 0 mmHg of LBNP to 13.1 ± 1.1 mmHg at –50 mmHg of LBNP. Similarly, when subjects were positioned at 15° HDT during LBNP, IJVP decreased from 27.7 ± 2.0 mmHg at 0 mmHg of LBNP to 18.9 ± 1.7 mmHg at –50 mmHg of LBNP (see Figure 1 right). Based on all the experimental data, we are also generating gravitational dose-response curves for all variables studied to establish comprehensive baselines for future research and countermeasure development.

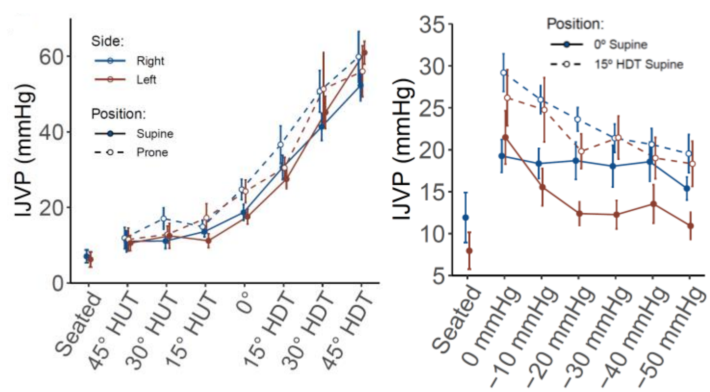

Figure 1: IJVP during tilt (left) and LBNP (right) interventions. Data presented as mean ± SE (n=12).

We are also investigating gravitational dose responses using modeling approaches. We are using a "full-body" lumped-parameter model [1] to simulate the same experimental interventions previously described (i.e., tilt, LBNP, and centrifugation) to characterize and quantify differences in CV responses between the three interventions, both at the local (i.e., compartment) and global level. Future modeling efforts also include the integration of the "full body" model with other models more focused on the upper body circulation and the eye to develop a unique, more powerful and versatile model to study SANS, the cranial venous system during different fluid shifts mechanisms, and the effects of potential countermeasures

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REFERENCES

[1] R. S. Whittle and A. Diaz-Artiles, "Modeling individual differences in cardiovascular response to gravitational stress using a sensitivity analysis," *J. Appl. Physiol.*, vol. 130, pp. 1983–2001, 2021.