PREDICTING ACUTE CARDIOVASCULAR AND OCULAR CHANGES DUE TO CHANGES IN THE GRAVITATIONAL VECTOR

A. Diaz-Artiles[1], R.S. Whittle[2], L. Stapleton[3], B.J. Dunbar[4]
Department of Aerospace Engineering, Texas A&M University, College Station TX 77843
[1]adartiles@tamu.edu, [2]rswhittle@tamu.edu, [3]lindsaystapleton@tamu.edu, [4]bjdunbar@tamu.edu

BACKGROUND

Exposure to weightlessness results in the removal of hydrostatic pressure gradients and a permanent headward fluid shift, causing a redistribution of blood. Additionally, in space postural changes don't occur and thus, astronauts are not exposed to daily fluid shifts (between supine and upright postures) as we are on Earth. This has currently unknown consequences, but it might be related to a series of neuro-ocular and functional changes developed in some astronauts during both short and long-duration spaceflight, collectively known as Spaceflight Associated Neuro-Ocular Syndrome (SANS). While the exact etiology of SANS is currently unknown, chronic fluid redistribution affecting intravascular, interstitial, and cerebrospinal fluids and pressures is widely hypothesized to be a contributing factor. Additionally, recently demonstrated stagnant and retrograde blood flow and venous thrombosis in the left internal jugular vein during spaceflight could also be associated with sustained headward blood and tissue fluid shift [1]. Based on the current knowledge and hypotheses, countermeasures focused on producing hydrostatic gradients or reducing the microgravity-induced fluid shift, such as lower body negative pressure (LBNP) or centrifugation, become particularly interesting. However, at present, it is not possible to estimate the overall physiological response (both acute or long term) of a particular "dose" of LBNP or centrifugation, and more specifically and relevant to our purposes, the response in the upper body and in the eye.

APPROACH

The objective of this research effort is **to generate acute gravitational dose-response curves of cardiovascular (CV) and ocular variables due to changes in the gravitational vector.** We propose to use both experimental and computational approaches to leverage the advantages of each one of these research methodologies.

Human Experiments: We will conduct the following set of three human experiments, on the same 12 subjects, to generate the desired dose-response curves experimentally:

- **Experiment 1: Tilt table**. Subjects will be exposed to multiple tilt angles covering the 360° spectrum in both prone and supine configurations. CV and ocular measures will be collected and used to generate gravitational dose-response curves as a function of tilt angle.
- **Experiment 2: LBNP.** Subjects will be exposed to multiple levels of negative and positive pressure (from +50 mmHg to -50 mmHg). Similarly, CV and ocular measures will be collected and used to generate gravitational dose-response curves as a function of external pressure.
- **Experiment 3: Centrifugation.** Subjects will be exposed to multiple levels of artificial gravity on the human short-radius NASA centrifuge that is relocated to Texas A&M University. CV and ocular measures will be collected and used to generate gravitational dose-response curves as a function of g-level.

Dependent measures include noninvasive continuous hemodynamics (Finapres NOVA), non-invasive cardiac output and breath-by-breath metabolic data (Innocor), intraocular pressure (Icare tonometer), internal pressures, flows, and size characteristics of vessels such as internal jugular vein (IJV), inferior vena cava (IVC), and common carotid artery (VScan Ultrasound and Vein Press), and blood volume (Bloodtec – optimized CO-rebreathing).

Modeling Effort: We also propose to develop a numerical model capable of predicting the expected acute CV and ocular changes in those conditions. We will leverage our past cardiovascular modeling efforts on full body fluid regulation under orthostatic stress [2] and we will develop additional features to better capture the fluid responses in the upper body, head, and eye. The model will be validated with the experimental data generated during the experiments, and then will be used to simulate additional conditions where data collection is difficult, expensive, or infeasible.

Results from this investigation will inform current and future countermeasure development and in-flight prescriptions.

This research effort is supported by the NASA Human Research Program, Grant number 80NSSC20K1521.

REFERENCES

[1] K. Marshall-Goebel *et al.*, "Assessment of Jugular Venous Blood Flow Stasis and Thrombosis During Spaceflight," *JAMA Netw. open*, vol. 2, no. 11, p. e1915011, 2019.
[2] A. Diaz-Artiles, T. Heldt, and L. R. Young, "Computational Model of Cardiovascular Response to Centrifugation and Lower-body Cycling Exercise," *J. Appl. Physiol.*, vol. 127, pp. 1453–1468, 2019.