Zero G and Me: Modeling Cardiovascular Dynamics from Echocardiography and Impedance Cardiography during Parabolic Flight

National Aeronautics and Space Administration

Margaret Dominguez
San Francisco State University, STAR internship
Dr. Patricia Cowings (Mentor)
Pyschophysiology, NASA Ames Research Center
Dr. Bill Toscano
Pyschophysiology, NASA Ames Research Center

Abstract

It has been observed that Astronauts in prolonged Zero-g space flight have issues with cardiovascular deconditioning during transition into 1-g and may experience fainting (orthostatic hypotension). High priority has been given to maintaining Astronaut health, safety, and performance during long duration missions. The purpose of this study is to simultaneously collect echocardiographic data and impedance cardiographic data from test participants in both 1-g and Lunar-g (1/6g) conditions during parabolic flight in a Zero-G aircraft. This data will be used to develop countermeasures to mitigate risks to neurobehavioral functions and to enhance the health, performance, and safety of crews during extended duration spaceflight. It is expected that from the data collected, real-time mathematical models will be created which will be capable of extrapolating relevant cardiovascular dynamics, such as stroke volume, cardiac output, cardiac index, and ventricular ejection time, from impedance cardiography measurements. The real time display of these measurements can help crew members understand what is happening to their body and, through Autogenic Feedback Training Exercise (AFTE), be able to control their cardiac output, helping their transition from Zero-g to planetary-g.

Figure 1

Figure 2

Figure 3

Background

The effect of altered gravity during space flight and planetary transition on human cardiovascular function is of critical importance to the maintenance of astronaut health [1]. Due to the prolonged exposure to zero-g, the cardiovascular system becomes weak due to the lack of gravity the heart has been evolved to pump with. While continued exercise helps crew members stay healthy to a certain point, this cannot resolve the loss of gravity. The Zero-G aircraft, as seen in Figure 2, is designed to stimulate a micro-g experience, allowing this experiment to record the effects on the human body in micro–g environments without planetary transition. This is done by flying 40 parabolas (20 seconds of 2-g followed by 20 seconds of Lunar-g) over the course of a 2 hour flight.

Acknowledgements

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Equipment

Figure 4

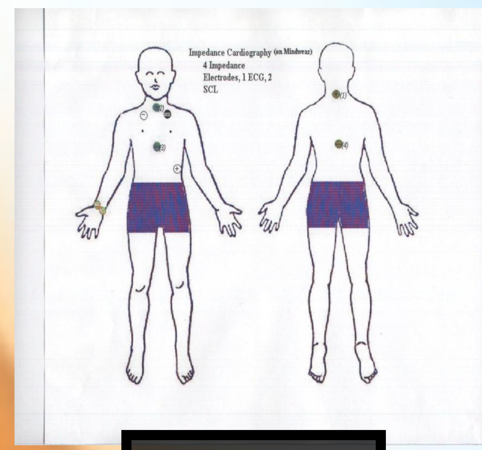

Figure 5

Mindware Impedance Cardiography: This apparatus, displayed in Figure 4, derives and displays real time measures of stroke volume, cardiac output, and total peripheral resistance. This was recorded by placing two pairs of disposable Ag-AgCl electrodes on the lateral sides of the neck and thorax at the level of the lower jaw and the xyphoid process, respectively [2] (See Figure 5). A small amount of electric current runs between the electrodes in correspondence with the amount of fluid in the segment, measuring the amount of blood pumped. The change in the voltage is proportional to electrical resistance and blood flow for each beat of the cardiac cycle [3]. This instrument was used throughout the duration of the flight.

Echocardiography: Also known as the cardiac ultrasound, this instrument was used on each of the participants once during their flight over the course of 5 parabolas. At this time, the subject remained seated while an echo-technician measured the participants cardiac function [4] (See Figure 6).

Figure 6

Figure 7

Zephyr Wristband: The Zephyr apparatus, as seen in Figure 7, wrapped around the participants' wrists and stayed on for the duration of the flight. This instrument measured the Skin Conductance Levels, Temperature, and Activity throughout the duration of the flight.

References

1, 2, 3, 4, 5 Cowings, P.S., Toscano, W.B. et all. "Zero G and Me: Modeling Cardiovascular Dynamics from Echocardiography and Impedance Cardiography during Parabolic Flight"

Procedures

Subjects

Eight men and women volunteered to participate in this experiment. The average age of the subjects was 36 and each participant was required to successfully complete medical and aerospace training. All qualified subjects were briefed on the procedures and risks before boarding the aircraft.

Preflight Procedures

Before beginning their flight, the test participants were assisted in donning their physiological monitoring systems and the principle investigators confirmed that the data were being collected and displayed on their PDA [5]. Their "stand test", or baseline test, was done before entering the aircraft which consists of the participant standing, sitting upright, and supine for three minutes each. The baseline test was conducted in order to record the cardiovascular system in its normal gravity.

Inflight Procedures

While inflight, the participant stayed seated during departure and arrival. During all other times on the aircraft, participants were allowed to maneuver about the cabin at will (See Figures 1 and 3), except for the 5 parabola duration of the cardiac ultrasound which required the participant to stay seated. The participants wore the Zephyr wristband and Mindware the entire duration of the flight.

Results and Conclusions

It can be seen from the data shown below that gravity effects the cardiovascular system. The stand test graphs in Figures 8 and 9 show the cardiovascular system in its normal gravity settings, which is useable for the development of a model. Figures 10 and 11 show impedance cardiography can continuously record the effects of parabolic flight on cardiovascular function.

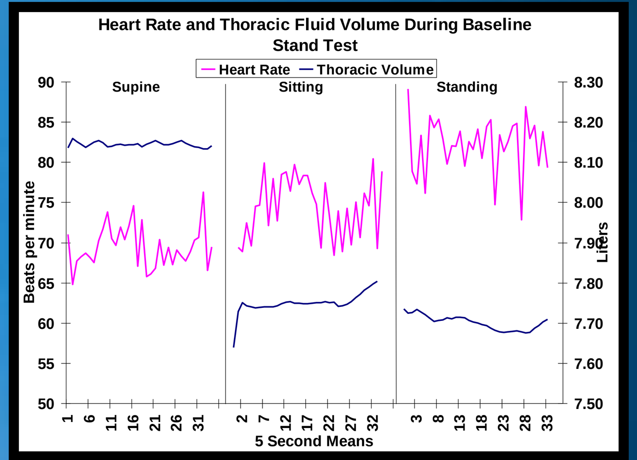

Figure 8

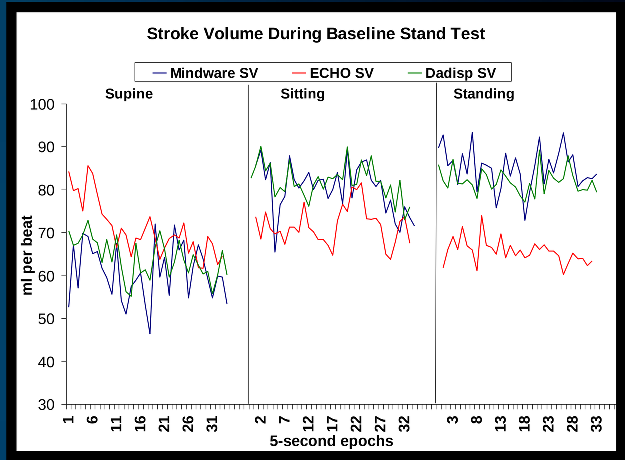

Figure 9

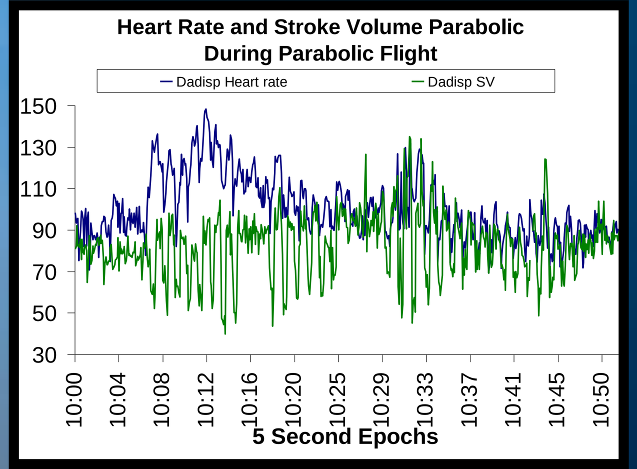

Figure 10

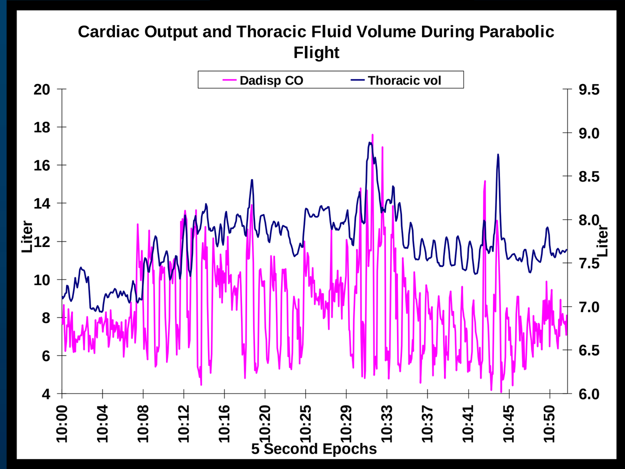

Figure 11