MATH AND SCIENCE @ WORK

AP* BIOLOGY Student Edition

MICROGRAVITY EFFECTS ON HUMAN PHYSIOLOGY: CIRCULATORY SYSTEM

Background

Since its conception in 1981, NASA has used the space shuttle for human transport, the construction of the International Space Station (ISS), and to research the effects of space on the human body. One of the keys to the success of the Space Shuttle Program is the Space Shuttle Mission Control Center (MCC). The Space Shuttle MCC at NASA Johnson Space Center uses some of the most sophisticated technology and communication equipment in the world to monitor and control the space shuttle flights.

Within the Space Shuttle MCC, teams of highly qualified engineers, scientists, doctors, and technicians, known as flight controllers, monitor the systems and activities aboard the space shuttle. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support preflight, ascent, flight, and re-entry of the space shuttle and the crew. The flight controllers provide the knowledge and expertise needed to support normal operations and any unexpected events.

One of the flight control positions in the MCC is the Surgeon. Surgeons have an extensive role in the crews' health and well-being during training, pre-flight, mission, and post-landing. Each astronaut is selected and trained for a very specific skill set. Their inability to perform due to health reasons can be very costly to the mission and hazardous to the whole crew. Therefore, flight surgeons work very closely with astronauts throughout their training and monitor their health from the MCC during flight.

Figure 1: Astronaut Edward T. Lu exercises on the Treadmill Vibration Isolation System (TVIS) on the International Space Station (ISS).

Figure 2: Catherine (Cady) Coleman is performing a remotely guided echocardiogram on a test subject utilizing the Integrated Cardiovascular protocols.

Shifting from an environment with gravity to one of microgravity causes changes in an astronaut's body. Structural and functional changes of the cardiovascular system in microgravity are known medical issues associated with human space flight. Even though short-duration flights pose no major problems with post-flight functional and structural recovery, understanding these physiological changes are of great importance when planning for challenging extravehicular activities and longer duration missions.

Problem

In spaceflight, shortly after reaching orbit, astronauts experience much lower gravity than on Earth. This is known as microgravity. Therefore, the average physical exertion of astronauts on board the space shuttle and the ISS is reduced compared to pre-flight, with the exception of challenging extravehicular activities such as a space walk. An astronaut's circulatory system, which is accustomed to working against gravity, receives a different set of signals and stimuli in microgravity and adapts to the new environment. The heart does not need to work as hard to send blood to the upper body as it does when it working against gravity. This causes blood volume to increase in the upper body.

Table 1 demonstrates a comparison of percent changes obtained from pre-flight and post-flight taken on 17 male astronauts, with an age range of 34-48 years. Thirteen subjects had flown on short-duration flights of 4-17 days versus four subjects that had flown long-term missions of 129-144 days.

Table 1: Percent Changes from Pre-Flight to Landing of Echocardiographic Parameters (Mean ± SE)**

	Short-duration ***n* = 13** **Δ % (Mean ± SE)**	**Long-duration** ***n* = 4** **Δ % (Mean ± SE)**
Systolic Blood Pressure (mm Hg)	6.69 ± 2.47	8.93 ± 3.12
Diastolic Blood Pressure (mm Hg)	6.64 ± 4.12	16.60 ± 3.90
Stroke Volume[+] (mL)	- 5.00 ± 0.03	- 17.40 ± 0.05
Cardiac Output * (L/min)	- 2.30 ± 0.07	- 12.20 ± 0.09

[+]*Stroke volume is the amount of blood that is pumped by the left ventricle in one contraction.*

**Cardiac Output is the stroke volume multiplied by the heart rate.*

****** Martin, David S., South, Donna A., Wood, Margie L., Bungo, Michael W., Meck, Janice V. Comparison of Echocardiographic Changes After Short- and Long-Duration Spaceflight. *Aviation, Space, and Environmental Medicine*. June 2002; 73-6: 532-536.

A. Describe arterial pressure changes during a single heart beat of a fit human on Earth.

B. Consider the data in Table 1 and explain how the circulatory system of a fit astronaut is affected by the muscle atrophy and fluid shift (from lower to upper body) as a result of microgravity. Explain why this could be a serious issue on long-duration flights.

Note: In Table 1, blood pressure is not presented in the usual format of systolic/diastolic. Each data set in Table 1 is presented as the percent change of the values measured before and immediately after flight.

C. To stay healthy and productive in space and after astronauts return to earth, they follow certain procedures, strategies, medications, exercise routines, etc. known as countermeasures. What are some potential countermeasures the Surgeon might suggest to help minimize the effects of microgravity on the circulatory system, specifically for long-duration flights or on board the ISS?

D. How might these microgravity studies and results be applied to the treatment or prevention of circulatory diseases on Earth?