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Physiological Systems

Slide 1 - Can you think of a situation in which it would be possible for you to balance your friend on just your fingertip? What if you were an astronaut in space? This picture shows just one of the things that is possible during space travel. Unlike on Earth where we experience a strong gravitational force, in space the gravitational force is greatly reduced, and we refer to it as microgravity. - Millie Hughes-Fulford (milliehf@spacedu.com)

Slide 2 - When men and women first traveled in space, little was known about how the environment of space would affect them. We now know much more, but there is still a great deal to learn. Because of this, in June of 1991, NASA launched flight STS 40 the first medical mission flight. The crew of this flight spent 9 days in space conducting life science experiments on themselves and other organisms. Flight STS 40 is shown here lifting off. - Millie Hughes-Fulford (milliehf@spacedu.com)

Slide 3 - The microgravity environment in space can affect the body in three major ways. First, there are changes in the blood system. Second, there is a shift in body fluids toward the head. Third, there is a reduction in the weight bearing forces on the body. Marc E. Tischler (tischler@u.arizona.edu)

Slide 4 - Because of these effects, various systems of the body can be affected by spaceflight. These would include: the vestibular/CNS, the cardiovascular system, the renal/fluid system, bone, muscle, and hematology (blood).- Unknown

Slide 5 - Some of the body's systems adapt to the environment of space quicker than others. This figure represents how quickly each system adapts to microgravity. The bottom line is the 1g setpoint, or normal gravity level on Earth for each system. The middle line is called the 0g setpoint, or the level each system obtains once it adapts to microgravity in space. The setpoints for 1g and 0g are different, and so it takes some time to adapt. The top line is called the clinical horizon and it is the point that problems in performance can occur. As you can see, the neurovestibular system is the first to change. This system is responsible for assessing what direction the body is moving. When this system is not functioning properly, motion sickness can occur. You can see at first, there is a high peak for this system, indicating clinical problems. However, after a few days, this peak disappears, and the system adapts to space travel and has a stable value at the 0g setpoint. You can see it takes the other systems, such as the muscular system, longer to adapt. On the figure, the muscular system is represented in part by the line labeled "lean body mass". Lean body mass refers to the mass of the body which is not composed of fat. You can see on the figure that lean body mass eventually reaches a stable value at Og although it does take some time. In addition, the value at Og is less than that at 1g, indicating a loss in lean body mass with space flight. Some systems, such as bone, don't adapt to spaceflight. The bone system never reaches a stable value at 0g gravity, but instead continues to climb towards the clinical horizon. Marc E. Tischler (tischler@u.arizona.edu)

Slide 6 - As stated, the first system to adapt to space flight is the neurovestibular. This is composed of the brain and the vestibular apparatus which is shown here. The vestibular apparatus is located in the middle ear, and is used to sense movement of the head. It has three canals which are filled with fluid and in this fluid are calcium crystals. When motion occurs, these crystals move and bump into sensory hair cells which send a signal to the brain. The brain then interprets this signal to determine the direction of movement. Because there is no gravity in space , the calcium crystals do not move in a manner similar to that on Earth. Therefore, confusing messages are sent to the brain and this can cause a feeling of motion sickness. When it occurs in space, it is called Space Adaptation Syndrome (SAS) or Space Motion Sickness. - Unknown

Slide 7 - People have been very interested in what causes Space Adaptation Syndrome since almost 60% of the astronauts suffer from this during the early stages of a flight. Therefore, several experiments have been designed to study head movements both on Earth and in space to see how they are related to SAS. For example, this slide shows one of the astronauts in a rotating chair. The chair is rotated about 20 rpm and the person is required each time a metronome goes off to touch her head to a pad and back up, then touch the pad and back-up. - M. Hughes-Fulford (milliehf@spacedu.com)

Slide 8 - This is similar set-up in space, with the person wearing head gear to measure his responses. It is hoped that such data will help show the relationship between head movements and SAS. M. Hughes-Fulford (milliehf@spacedu.com)

Slide 9- Eye movements have also been associated with SAS. Here an astronaut is shown wearing contact lenses which have spokes drawn on them. While wearing the lenses, the astronaut places his or her head into a chamber which has a screen of rotating dots, as is shown here - M. Hughes-Fulford (milliehf@spacedu.com)

(Slide 10). Inside the dome there is a camera to measure eye movements. M. HughesFulford (milliehf@spacedu.com)

Slide 11 - The results of the Space Adaptation Syndrome studies done on the NASA medical mission flight are shown here. There appears to be no predictors for SAS, meaning there has been nothing observed which clearly indicates who will suffer from SAS and who will not. Another finding was that there are problems with the vestibular apparatus after landing, which may last for a week after landing. There is also a loss in the ability to perceive one's position in the environment (spatial orientation), as well as a loss in muscle stamina. - M. Hughes-Fulford (milliehf@spacedu.com)

Slide 12 - Another effect of travel in a microgravity environment is that the fluid distribution in the body is changed. Since the human body is almost 60% water, changing the distribution of this fluid can greatly affect the functioning of the body's organs. Usually the effects of spaceflight on the fluid systems of the body begin to occur after the first week or so of spaceflight. This shows the fluid shift that occurs with spaceflight. On Earth, fluid is distributed more to the legs because of gravity. With the microgravity environment of space, there is no gravity pulling the fluid downward, therefore the fluid is shifted towards the head. (Follow slide) - M.E. Tischler (tischler@u.arizona.edu)

Slide 13 - This is a different way to depict the fluid shifts that occurs with space travel. Note that upon reentry, fluid levels are reduced in every body compartment. - Unknown

Slide 14 - Here an astronaut is seen using what is called a Thornton sock. This sock has a lot of circumference bands up and down the legs and by marking the sock every day and measuring circumferences, the volume of the leg can be determined. The shift in fluid towards the head causes large losses in leg volume and this is sometimes called chicken leg syndrome. - M.Hughes-Fulford (milliehf@spacedu.com)

Slide 15 - Along with fluid shift, the cardiovascular system is also affected with spaceflight. The CV system is composed of the heart and blood vessels. - M.E. Tischler (tischler@u.arizona.edu)

Slide 16- Because of the fluid shifts associated with space flight, the heart can be affected, as it pumps blood through the circulatory system. This represents some of the changes observed in the cardiovascular system during flight STS 40.

1.fluid shift
2. decrease heart size
3. decrease exercise capacity
4. orthostatic hypotension - a decrease in blood pressure with changes in position, for example, when you stand up quickly, there is a decrease in blood pressure in the head, which can lead to feelings of dizziness - M. Hughes-Fulford (milliehf@spacedu.com)

Slide 17 - One way astronauts try to improve their cardiovascular function in space is the same way we do on Earth - they exercise!!! Here you can see an astronaut bicycling while in space. She is hooked up to various machines which monitor her metabolic, breathing, and heart rates. Although astronauts do exercise while in space, this does not seem to compensate for all the changes in the CV system as the astronauts still experience some loss of exercise endurance during spaceflight. - M. Hughes-Fulford (milliehf@spacedu.com)

Slide 18 - The body's ability to monitor blood pressure changes is also affected by spaceflight. In the neck, there are receptors called barrow receptors which help keep blood pressure levels from going too high or low. During one experiment, the astronauts wear a neck collar that can perceive changes in blood pressure. By day 7 of the flight, this collar showed that the astronauts had lost their barrow receptor responsiveness. M. Hughes-Fulford (milliehf@spacedu.com)

Slide 19 - As discussed earlier, two other organs affected by low gravity environments are the bones and muscles. In a microgravity environment, there is no weight to put stress on the bones, therefore they begin to lose their strength. In addition, muscles in the body, as shown here, are used to generate forces against the gravitational pull of the Earth. Without the stress of gravity, these muscles are not used as much, and thus can begin to atrophy during spaceflight. - M.E. Tischler (tischler@u.arizona.edu)

Slide 20 - For normal bone health and strength, calcium is essential. Without adequate calcium, bones become weaker and more brittle. It has been shown that during spaceflight, there is a loss of calcium from the bones. This figures shows some of the body organs that are used to maintain calcium balance, such as the kidneys and intestines. - M.E. Tischler (tischler@u.arizona.edu)

Slide 21- One way the microgravity environment of space has been studied here on earth has been to suspend the hindlimbs of animals, such as rats. By doing so, this simulates the effects of weightlessness on the suspended limbs. This table shows the similar physiological changes which occur during space flight and hind limb suspension. You can see that hind limb suspension is a good model for space flight as many of the responses are similar. Another model scientists often use is bed rest in humans. When humans are resting in bed, there is a reduced stress placed upon their bodies, as they are not walking upright and completing various movements as one normally would. This reduction in stress is similar to that experienced by astronauts during space flight. Human bed rest is also shown on the table, and compares favorably with space flight. Dan Bikle

Slide 22 - Much of what we know of the effects of weightlessness on bone metabolism have been learned from studies involving hindlimb suspension. Some of the results of one such study are shown here. The figure shows the comparison of calcium in bone that is normally used (controls) versus suspended bone . The figure on the left shows the results of the tibia bone, which is a lower leg bone. During hind limb suspension, this bone is suspended so no stress is placed upon it. You can see a decrease in milligrams of calcium in bone which was suspended (open figures) compared with the control bone which was not suspended (closed figures). Therefore, it appears suspension of bone may cause calcium losses similar to that seen with weightlessness. D. Bikle

Slide 23- Isolated bone cells can also be used to study the effects of weightlessness. These bone cells experienced simulated space flight. They were then studied to determine the effects of such treatment. It was seen that bone cells subjected to simulated space flight did not secrete collagen, which is a component of bone, in a manner similar to control cells. - Unknown

Slide 24 - Although bone formation appears to be lessened with weightlessness, it seems that once bones are normally used again they being to reform the lost bone. These are the results of another hindlimb suspension experiment. Bones were at first suspended and then were used normally (seen as "reloaded" on the figure). Once bones were used normally, the rate of bone formation steadily increased. - D. Bikle

Slide 25 - Muscle loss can also be a big problem in space. This slide shows a Russian Mir astronaut after he had been in space for a year. He was one of the most athletic astronauts and yet was unable to walk immediately upon his return to Earth. - M.E. Tischler (tischler@u.arizona.edu)

Slide 26 - These are the results from flight STS 40 concerning the loss of muscle in space. There was a 15-40% reduction in the strength of the calf muscle. There was also a 10-15% atrophy in all other muscle groups. In animals, muscle loss was between 10-30%. Overall, there was no loss of muscle cells, but there was a decrease in muscle cell protein and mRNA. - M. Hughes-Fulford (milliehf@spacedu.com)

Slide 27 - Another body system that can be affected by spaceflight is the immune system, which serves to protect the body against infection. During the first spaceflights, it was thought that the astronauts might "catch" something during a flight which would infect people on earth. These astronauts were thus isolated upon their return to Earth, as you see here. Once it was realized there were no risk of infection, the isolation procedure for the astronauts stopped. However, when this was done, the incidence of the astronauts becoming sick increased. Thus it was not the astronauts infecting the people on earth but rather us infecting them. We now know this occurs because with spaceflight, the functions of the immune system are decreased. G. Sonnenfeld

Slide 28- Microgravity is a stress on the immune system. Like many stresses on Earth, such as studying for exams, this stress can lead to a decrease functioning of the immune system and an increased risk of infection. On this figure, "spaceflight stressors" is listed at the top, with an arrow pointing to "microgravity", showing that microgravity is considered to be one stressor. In the square box at the bottom of the figure are representations of the various cell types in the immune system. All these cells play a role in protecting the body from infection. You can see that a stressor such as microgravity can directly affect the functioning of these cells. G. Sonnenfeld

Slide 29- This data was obtained by studying rats on Earth and on space flights. IFN titer is one measurement which represents the functioning of the immune system. The higher the titer, the better the functioning of the immune system. As you can see, there was a large difference between those rats who experienced space flight, and those who remained on Earth (controls). All but one of the flown rats had a titer less than 10. Of the control rats, only three had a values less than 10 and several had values of 25 and above. - G. Sonnenfeld

Slide 30 - One of the primary concerns of space flight and the immune system is that with longer spaceflights, there is a greater risk of infections. G. Sonnenfeld

Slide 31- This re-caps the body systems which are affected by space flight. Upon their return to Earth, many astronauts experience such things as loss of red cell mass, loss of bone mass, loss of muscle mass, loss of exercise capacity, loss of fluids and electrolytes, cardiovascular changes, and vestibular disturbances. It does take some time for each of here systems to return to levels normally seen on earth. M.E. Tishcler

Slide 32 - Hopefully, the knowledge we have gained about spaceflight and the effects of microgravity on the body, along with the knowledge we will continue to gain, can be used to ensure even more successful missions. M. Hughes-Fulford