BioEd℠

THE SCIENCE OF

MUSCLES AND BONES

Center of Gravity

by

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RESOURCES

For online presentations of each activity and downloadable slide sets for classroom use, visit http://www.bioedonline.org or http://www.k8science.org.

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TEAMING WITH BENEFITS

by Jeffrey P. Sutton, M.D., Ph.D., Director, National Space Biomedical Research Institute (NSBRI)

Dr. Jeffrey P. Sutton

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astronauts are significant. Finding answers to these health concerns is at the heart of the National Space Biomedical Research Institute's program. In turn, the Institute's research is helping to enhance medical care on Earth.

The NSBRI, a unique partnership between NASA and the academic and industrial communities, is advancing biomedical research with the goal of ensuring a safe and productive long-term human presence in space. By developing new approaches and countermeasures to prevent, minimize and reverse critical risks to health, the Institute plays an essential, enabling role for NASA. The NSBRI bridges the research, technological and clinical expertise of the biomedical community with the scientific, engineering and operational expertise of NASA.

With nearly 60 science, technology and education projects, the NSBRI engages investigators at leading institutions across the nation to conduct goal-directed, peer-reviewed research in a team approach. Key working relationships have been established with end users, including astronauts and flight surgeons at Johnson Space Center, NASA scientists and engineers, other federal agencies, industry and international partners. The value of these collaborations and revolutionary research advances that result from them is enormous and unprecedented, with substantial benefits for both the space program and the American people.

Through our strategic plan, the NSBRI takes a leadership role in countermeasure development and space life sciences education. The results-oriented research and development program is integrated and implemented using focused teams, with scientific and management directives that are innovative and dynamic. An active Board of Directors, External Advisory Council, Board of Scientific Counselors, User Panel, Industry Forum and academic Consortium help guide the Institute in achieving its goals and objectives.

It will become necessary to perform more investigations in the unique environment of space. The vision of using extended exposure to microgravity as a laboratory for discovery and exploration builds upon the legacy of NASA and our quest to push the frontier of human understanding about nature and ourselves.

The NSBRI is maturing in an era of unparalleled scientific and technological advancement and opportunity. We are excited by the challenges confronting us, and by our collective ability to enhance human health and well-being in space, and on Earth. ◆

NSBRI RESEARCH AREAS

CARDIOVASCULAR PROBLEMS

The amount of blood in the body is reduced when astronauts are in microgravity. The heart grows smaller and weaker, which makes astronauts feel dizzy and weak when they return to Earth. Heart failure and diabetes, experienced by many people on Earth, lead to similar problems.

HUMAN FACTORS AND PERFORMANCE

Many factors can impact an astronaut's ability to work well in space or on the lunar surface. NSBRI is studying ways to improve daily living and keep crewmembers healthy, productive and safe during exploration missions. Efforts focus on reducing performance errors, improving nutrition, examining ways to improve sleep and scheduling of work shifts, and studying how specific types of lighting in the craft and habitat can improve alertness and performance.

MUSCLE AND BONE LOSS

When muscles and bones do not have to work against gravity, they weaken and begin to waste away. Special exercises and other strategies to help astronauts' bones and muscles stay strong in space also may help older and bedridden people, who experience similar problems on Earth, as well as people whose work requires intense physical exertion, like firefighters and construction workers.

NEUROBEHAVIORAL AND STRESS FACTORS

To ensure astronaut readiness for spaceflight, preflight prevention programs are being developed to avoid as many risks as possible to individual and group behavioral health during flight and post flight. People on Earth can benefit from relevant assessment tests, monitoring and intervention.

RADIATION EFFECTS AND CANCER

Exploration missions will expose astronauts to greater levels and more varied types of radiation. Radiation exposure can lead to many health problems, including acute effects such as nausea, vomiting, fatigue, skin injury and changes to white blood cell counts and the immune system. Longer-term effects include damage to the eyes, gastrointestinal system, lungs and central nervous system, and increased cancer risk. Learning how to keep astronauts safe from radiation may improve cancer treatments for people on Earth.

SENSORIMOTOR AND BALANCE ISSUES

During their first days in space, astronauts can become dizzy and nauseous. Eventually they adjust, but once they return to Earth, they have a hard time walking and standing upright. Finding ways to counteract these effects could benefit millions of Americans with balance disorders.

SMART MEDICAL SYSTEMS AND TECHNOLOGY

Since astronauts on long-duration missions will not be able to return quickly to Earth, new methods of remote medical diagnosis and treatment are necessary. These systems must be small, low-power, noninvasive and versatile. Portable medical care systems that monitor, diagnose and treat major illness and trauma during flight will have immediate benefits to medical care on Earth.

For current, in-depth information on NSBRI's cutting-edge research and innovative technologies, visit www.nsbri.org.

OVERVIEW

Students learn about center of gravity and how the body adjusts to the force of gravity to remain balanced.

ACTIVITY

CENTER OF GRAVITY

Gravity places a heavy load on the human body. Only through coordinated muscle movement is the body able to counteract the downward pull of gravity and remain upright. Muscles in the back, legs, ankles and feet are used most. The nervous system tells these muscles which changes to make to help the body maintain posture and balance during movement.

To balance itself, the body makes tiny adjustments to maintain its center of gravity over the feet. The center of gravity is an imaginary point within the body at which there is balance and from where the weight on all sides is equal. Fortunately, the minor muscle adjustments necessary to maintain balance and posture are made automatically.

TIME

10 minutes setup; 60 minutes to conduct activity

MATERIALS

Part 1

Each team of 2 students will need:

- Masking tape
- Meter stick
- 3 weights (standard weight items, such as heavy coins, washers, etc.)
- Copy of "Balancing Act" page

Part 2

Each team of 2 students will need:

- Light-weight chair
- Copies of "Balancing You!" page

SCIENCE, HEALTH & MATH SKILLS

GRADES 5–8

- Predicting
- Observing
- Gathering and recording data
- Drawing conclusions

CONCEPTS

- Gravity pulls down on all objects on Earth, including the bodies of organisms.
- Muscles work against gravity.
- Center of gravity is the point around which all the weight of an object is equally distributed.

SETUP & MANAGEMENT

Place meter sticks, weights and masking tape in a central location. Have students work in pairs.

PROCEDURE

Part 1: Balance, Weight and Stability

1. Ask students, *Do you usually fall over when you are walking, riding a bicycle or standing on a bus? Why?* Encourage students to think about how the body coordinates balance. Ask, *Do you need muscles to keep your balance? Would your skeletal system alone be able to keep you upright in a moving vehicle?* Explain to students that they will investigate balance and stability using different amounts of weight and meter sticks, and that they will be learning how living things use muscles and body position to maintain balance.
2. Tell each Materials Manager to collect weights, masking tape and a meter stick for her/his group.
3. Instruct one student in each group to hold the meter stick horizontally by supporting it with one index finger at each end. Have the student move his/her fingers slowly toward each other, keeping the stick balanced until the fingers meet. Explain that the point

Free Fall

Objects falling with an acceleration equal to that caused by gravity alone experience "free fall," or weightlessness. The acceleration required to achieve free fall is 9.8 meters per second squared or 1 g at the Earth's surface. Free fall is the lightness that you feel on some amusement park rides. Astronauts orbiting the Earth also experience weightlessness for the same reason.

Under these conditions, many movements can be accomplished with minimal effort. However, after long space flights, astronauts may demonstrate changes in their posture upon return to Earth. These changes are believed to be related to adaptation by the body to microgravity conditions.

Muscle Controllers

The brain and nervous system coordinate muscle movements necessary to maintain balance.

The Base

To keep from toppling over, an object's center of gravity must stay above the area outlined by the object's base. This is why you will fall over if you lean too far forward. Once your center of gravity is beyond the limits of the base defined by your feet, you lose your balance and stability. This is why people will stand with their feet farther apart (and thus widen their "base") to keep their balance in a moving bus or train.

Extension

The body constantly makes adjustments to compensate for the pull of gravity. Some of these adjustments are large, as when we pick up a chair, but many of the adjustments are very subtle. The muscles make minor adjustments constantly to maintain balance and posture. Have students work in pairs and observe the movements made by their partners as they perform certain tasks. The tasks can be: moving from standing on two feet to standing on one foot, walking heel-to-toe, squatting or standing on tip toes.

where the fingers meet is the balance point for the stick. In other words, the balance point is the place where the weight on each side is equal and the object is balanced. Have the students in each team record the balance point for their meter stick.

4. Next have students tape one weight on the 30-cm mark of the meter stick. Ask students to predict where the new balance point will be and to record their predictions. Have them determine the new balance point of the meter stick as before and record it.
5. Have students add another weight to the one already on the meter stick and repeat the process. They should repeat the experiment one more time with three weights on the meter stick.
6. Direct students' attention to their data sheets and ask, What happened to the balance point of the meter stick as more weight was added? [the balance point moved toward the added weight] What would have happened if you had not moved your finger to find a new balance point? [meter stick would have fallen] Help students understand that, in order to stay balanced, the weight of each end of the meter stick had to be equal. The only way to achieve this when more weight is added is to move the balance point.

Part 2: Maintaining Balance

1. Ask students to think about whether maintaining their own balance is as simple as moving their fingers on the meter stick. Follow by asking them to think about whether their center of gravity ever changes. Ask, *What do you do to keep yourself from falling when you trip over something? How about when you are standing in a moving train or bus?* Tell students that they will be exploring their own centers of gravity in two different ways.
2. First, have students in each group take turns standing up from a seated position in a chair. They should record the results on their data sheets. Ask, *How easy was it to stand up?* [very easy]
3. Follow by having students try again to stand up from a seated position in a chair. This time, however, have them do so without leaning their back and shoulders forward. Have them record their results.
4. Next, instruct one student to stand with feet shoulder-width apart. Have the second student place a lightweight chair 15 cm in front of the feet of the first student. Instruct the first student to try to pick up the chair and to record his/her results. Then have the other student in each group try it and record his/her results.
5. Tell students to move to the periphery of the room and take turns repeating the process again, but this time with their heels, hips, back and shoulders against the wall and with feet flat on the floor. Again, have them record their results.
6. Discuss the students' results. Ask them to identify the differences between the two trials of each experiment. Ask, *Why do you think it was not possible to stand up when you didn't move your shoulders? Why was it impossible to pick up the chair when you stood against the wall?* Help students understand that in both cases, their body movement was limited.
7. Discuss gravity again. Ask, *Does gravity affect people? Do people have a center of gravity?* The meter stick center of gravity changed as students added more weight. Ask, *Have you been able to observe whether a person's center of gravity changes?* Have students think about where their centers of gravity are when they are sitting in chairs and how their centers shift when they begin to stand up. Their weight shifts from their seats to their feet; thus, their centers of gravity must change also. Have students think about where their centers of gravity are when they lift a chair. The chair adds extra weight to the body, so the body must compensate for that weight by moving the center of gravity. The body changes the center of gravity and achieves balance by moving the hips backward. This is why students were not able to pick up the chairs with their backs against a wall. Have students try these two experiments again, and this time have them watch their partners' body movements. ◆

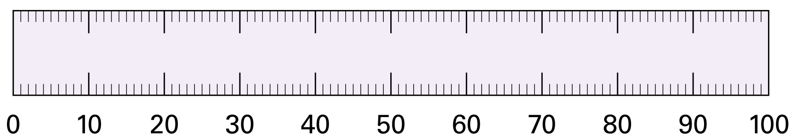
ACTIVITY

BALANCING ACT

You will need a meter stick, 3 weights (coins, washers, etc.) and tape.

1. Hold out your hands with only index fingers extended.
2. Have your partner lay the meter stick across your outstretched fingers.
3. Starting with you fingers at opposite ends of the meter stick, slowly move your fingers together, keeping the meter stick balanced at all times. The point where your fingers meet is the balance point. Note that position on the meter stick and record it on the picture of a meter stick below.

Centimeters (cm)



4. Tape one weight to the meter stick at the 30-cm mark.
5. Find the balance point of the meter stick with the weight on it and record your result in the table below.
6. Tape another weight on top of the first one at the 30-cm mark.
7. Determine the balance point and record your result.
8. Tape the third weight on top of the others at the 30-cm mark.
9. Determine the balance point of the meter stick and record your result.

	0 Weights	1 Weight	2 Weights	3 Weights
Balance Point				

10. What happened to the balance point as you added more weight?

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Activity 7

Balancing You

You will need a light-weight chair and a metric ruler.

Experiment 1: From a sitting position

1. Sit in a chair and try to rise to a standing position. Switch places so your partner can try. Record your results below.
2. Again, sit in a chair and try to rise to a standing position, but this time, do not let your shoulders move forward. Switch places with your partner so he or she can try. Record your results below.

Experiment 1	Results
A. Standing up from a seated position	
B. Standing up from a seated position without shoulder movement.	

Experiment 2: From a standing position

3. While you are standing, have your partner place the chair 15 cm in front of you. Try to pick up the chair. Switch places so your partner can try, and then record your results.
4. Repeat Step 3, but this time, stand with your heels, hips, back and shoulders flat against a wall. Now let your partner try it. Record your results below.

Experiment 2	Results
A. While standing, pick up a chair.	
B. While standing with heels, hips, back and shoulders flat against the wall, pick up a chair.	

5. What happened during the second part of each experiment?

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6. Did you expect this result? Why or why not?

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