Skeletal System:
Human Physiology in Space

Presented by:
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Oklahoma State University
NASA Johnson Space Center
Houston, TX
Subject Areas

Grade Level:
9-12

Subject Areas:
Life Science
Math
Teachers, what subject do you teach?

A. Physics
B. Chemistry
C. Biology
D. Earth Science
E. General Science
Have you used NASA lessons in your classroom?

✔ Yes
✖ No
What are you hoping to get out of today’s web seminar?

Share your ideas in the chat box.
Have you heard of NASA Explorer Schools?

✔ Yes
✖ No
Overview of Session

1. What this lesson teaches, where to find lesson
2. Introduction/prep to Skeletal System: Human Physiology in Space (Earth and Space Physiology)
3. Suggestions for teaching concepts and presenting lessons:
   - How to introduce the lesson, background
   - Performing the experiment
   - Analyzing/reporting results, discussion
4. Extensions and resources for implementing
5. Sharing - your questions and your ideas
Where do I get the lesson?

1) NASA Explorer Schools Virtual Campus
   http://explorerschools.nasa.gov

2) NSBRI
   http://www.nsbri.org/EDUCATION-and-TRAINING/Teaching-Resources/High-School/
Virtual Campus

SKELETAL SYSTEM: HUMAN PHYSIOLOGY IN SPACE

Featured Lesson(s)
Examining the Effects of Spaceflight on the Skeletal System

Essential Question
How does bone formation and calcium metabolism change in microgravity?

Description
The two activities in this lesson focus on the effects of spaceflight on human physiology.

The first activity, Predicting Height From the Length of Limb Bones, demonstrates how bone growth characteristics in our limbs are related to our overall skeletal structure, particularly our height. In the second lesson, The Influence of Applied Forces on Different Materials, students compare the strength characteristics of various materials.

From providing the most nutritional food to managing the many environmental dangers in space such as radiation and bone loss, scientists and engineers work to predict, analyze and build effective countermeasures to the effect of microgravity on human physiology so astronauts can live and work in space and return safely to Earth.

Additional Resources

Lesson Information

Subjects Covered: • Science • Mathematics

Topics Covered: • Science: Life Science • Mathematics: Measurement and Data

Activity Type: Hands-on Activity

Grade Level: 9-12

Instructional Objective: Determine how bone growth characteristics in our limbs are related to our overall skeletal structure. Predict how various materials will respond to external forces and compare the materials' strength characteristics.

Time to Complete the Activity: Two 50-60-minute class periods

Materials Needed:

National Content Standards:
Video 1 of 7: Introduction

This video segment introduces the lessons. It describes the subject area, grade level, standards and learning objectives.
High School

NSBRI has educational resources designed for use in high school classrooms. These materials cover the following topics:

- Human Physiology
- Neurobiology, vestibular function, and spatial orientation
- Sleep and circadian rhythm

Three free curriculum guides are available. Two of the guides offer problem-based instruction about neurovestibular function and sleep and circadian rhythms. A third guide, *The Brain in Space*, provides an opportunity for classrooms to conduct experiments that are relevant to the research conducted in space.

Teachers and students can learn about how the human body adapts to microgravity with the online textbook *Human Physiology in Space*. Another spaceflight-based resource is the *Butterflies in Space Teacher's Guide* that allows teachers and students to replicate an experiment conducted in space.

Also, students can learn about specific NSBRI projects through a series of podcasts and then do activities related to the projects' research areas.
Life Science

- Behavior of organisms
- Interdependence of organisms
- Science as a human endeavor
- Abilities necessary to do scientific inquiry
National Standards

Math

- Measurement – Apply appropriate techniques, tools, and formulas to determine measurements
- Measurement – Understand measurable attributes of objects and the units, systems, and processes of measurement
- Problem Solving – Apply and adapt a variety of appropriate strategies to solve problems
- Geometry – Apply appropriate techniques, tools, and formulas to determine measurements
Learning Objectives

1. How muscle and bone loss contribute to reduced fitness of astronauts when they return to Earth.

2. How bone formation and calcium metabolism change in microgravity.
Life Science @ NASA

- Explain science with science!
- Building blocks for doing some of the coolest jobs at NASA
- Involved in every mission
- Vital to safe, successful mission results
Check for Understanding

1. What does this lesson teach/objectives?
2. Where can you find the educator guide/lesson?

✔ = Yes, I can answer these questions!

✖ = No, I need further clarification.
Questions?
3 – Things you learned from tonight’s topic about human physiology in space

2 – Things you find interesting about the topic

1 – Thing you have a question about the topic
Engagement

- Connect your classroom to background
- Introduce video or NASA Now video to students
- Generate discussion, gather/record questions
  - Essential student buy in
Prior Knowledge

• Earth Physiology
  - Bone development, structure
  - Bone function
How is the human body affected while living in space?
Support for the body here on Earth is supplied by the bones.
Bone Classification

- **Long**: arm and leg bones
- **Short**: wrists and ankles
- **Flat**: ribs and bones of skull
- **Irregular**: vertebrae along spine
Bone Development & Structure
Build the Background
Space Physiology

- Eyes become main way to sense motion
- Otoliths in inner ear respond differently to motion
- Changed sensory input confuses brain, causing occasional disorientation
- Fluid redistribution causes head congestion and puffy face
- Loss of blood plasma creates temporary anemia on return to Earth
- Higher radiation doses may increase cancer risk
- Weight-bearing bones and muscles deteriorate
- Kidney filtration rate increases; bone loss may cause kidney stones
- Fluid redistribution shrinks legs
- Touch and pressure sensors register no downward force
Gravitational Characteristics

- Earth 1G
- Mars 0.38G
- Space ~0G

1 Earth Body Weight (BW)
Tell me what you know.

How is the human body affected while living in space?

First American spacewalk

First educator on a spacewalk
How does microgravity affect the muscles?
How does microgravity affect our bones?
Tell me what you know.

How is the human body affected while living in space?

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You are a NASA space physiologist.

1) You must predict how various materials will respond to a variety of external forces.
2) Design an experiment that will test those hypotheses.
3) Share the results.
New Concepts

- Space Physiology
- Student Investigations
- Space Flight Investigations
Earth vs. Space?

• Atmosphere
• Radiation
• Gravity
Humans in Space?

• Environmental Challenges
• Body Changes
• Human Survival
• Atmosphere
1. Predicting Height from the Length of Limb Bones
2. The Influence of Applied Forces on Different Materials
Examples of Compressional Forces
Bone Function

- **Foot Bones**
  - calcaneus
  - talus
  - metatarsals
  - phalanges

- **Spinal Column**
  - cervical vertebrae (6)
  - thoracic vertebrae (12)
  - lumbar vertebrae (5)
  - sacral vertebrae (5)
  - coccygeal vertebrae (1)
Ossification

- epiphysis
- epiphyseal (growth) plate
- periosteum
- medullary canal
- compact bone
- compact bone cross section
- Haversian
Space Flight – Bone Loss

Diagram showing bone changes in space.

Graphs illustrating the change in height (mm) of different crewmembers over time (preflight, inflight, postflight).
Living in Space
“...we are human guinea pigs for a wide variety of medical experiments. The weightlessness of space offers a biochemical challenge to our bodies, which develop a host of fascinating maladies such as bone decalcification, cataracts, retina swelling, eye focus shifts, smooth muscle atrophy, fluid imbalance, gross weight loss, cardiovascular degeneration, and more. In spite of these maladies, humans can thrive in space...” - Letters to Earth, Expedition 31

Astronaut Don Pettit
Questions?
Investigation #1

Predicting Height from the Length of Limb Bones
Materials

- Tape measures
- Graph paper
- Rulers
- Stopwatch
- Journals to record results
<table>
<thead>
<tr>
<th>Fourth Month</th>
<th>Most primary ossification centers have appeared in the diaphyses of bone</th>
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<tbody>
<tr>
<td>Birth to 5 years</td>
<td>Secondary ossification center appear in the equipment</td>
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<tr>
<td>5-12 years in females or 5-14 years in males</td>
<td>Ossification is spreading rapidly from the ossification center and various bones are becoming ossified</td>
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<tr>
<td>17-20 years</td>
<td>Bone of upper limbs and scapulae becoming completely ossified</td>
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<td>18-23 years</td>
<td>Bone of the lower limbs become completely ossified</td>
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<td>23 to 25 years</td>
<td>Bone of the sternum, clavicles, and vertebrae become completely ossified</td>
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<tr>
<td>By 25 years</td>
<td>Nearly all bones are completely ossified</td>
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</table>
Step 1

• Break into groups
• For each person in group – two measurements
  - length of the upper arm limb (humerus)
  - height of each person
• Graph the data!
Step 2

- Data for each person should include two measurements
- Graph data – length of the humerus on x-axis, height on the y-axis
- After graphed, draw straight line along data points, extend to x-axis
- Determine slope of line and equation of the line
Procedure

Step 3

- Complete data, determine equations for lines
- Switch people around in groups
- Measure the length of the humerus for the “new” people in the group
- Determine height – using graphs and using line equations
- Each group will calculate new person’s height!
Procedure

Equation of a line: \( y = \frac{2}{3}x + 2 \)

Equation of a line: \( y = -\frac{5}{3}x + 1 \)
To determine the slope of a line on a graph, divide the number of vertical units by the number of horizontal units, or remember the relationship rise/run (for positive slopes) and fall/run (for negative slopes). The y-intercept is indicated on the graphs.
Discussion

What are the sources of error that might have been responsible for:

- Data point not lining up
- Graph not being accurate enough
- Equation not being accurate enough
What kind of sample population would yield the best set of data points?

How will age of the sample population affect results? How old must they be to determine height from the radius, the tibia, and the femur?
Questions?
Investigation #2

Influence of Applied Forces on Different Materials
• Compress
• Stretch
• Twist
• Bend
Uniform compressional and tensile forces applied to materials that we understand create predictable stresses. On the other hand, torsional forces are much more difficult to control and often create more damage.
Strength of Materials

• Kind of material
• Physical characteristics of material
• Molecular forces holding material together
• Kinds of forces being applied
Materials

- Various materials differing in: kinds of material, cross sectional area, density, geometry
- Various instruments: small hammer, large rubber hammer, mortar and pestle, stretching mechanism
Before Investigation...

- Before applying forces – predict and rate how materials will respond
- Record predictions
- Create a rating system – elasticity, plasticity, fracture point
Procedure

Step 1

• Discuss the materials
• Select materials/items to test: compressional, tensile, and torsional
• Select materials/items that vary in: cross-sectional area, shape, density, and elasticity
• Form a hypothesis
• Test
Table 2. Example table of the physical characteristics of materials.

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<tr>
<th>Demonstration</th>
<th>1</th>
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<th>3</th>
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<th>Test at least 10 materials</th>
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<td>Kind of Material</td>
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<td>Cross-sectional area (large-med-small)</td>
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<td>Shape (regular-irregular)</td>
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<td>Density (high-med-low)</td>
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<td>Elasticity (high-med-low)</td>
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<td>Brittleness (high-med-low)</td>
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<td>Applied Force (compressional, tensile, torsional)</td>
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<tr>
<td>Degree of Applied force (strong-med-light)</td>
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Discussion

- What material was the most elastic? Least elastic?
- What was the most brittle? Least brittle?
- Which material that you tested is comparable to a human bone?
Space Flight Investigations

Animal Enclosure Module

Preflight and post-flight rat growth during the space flight experiment
Changes in Rate and Strength

• Tibia Cross Section: Control
• Tibia Cross Section: Flight
Questions?
Extensions and Resources
Related Activities

http://nsbri.tamu.edu/HumanPhysSpace/indexb.html
Get your students doing real-life science now with NASA!

How Does Parathyroid Hormone Affect Changes in Bone Mass in Microgravity? Grades 8-12
Additional Resources for High School:

Microgravity Effects on Human Physiology: Circulatory System

Microgravity Effects on Human Physiology: Skeletal System

Microgravity Effects on Human Physiology: Immune System
Astronaut Don Pettit’s Blog

http://blogs.nasa.gov/cm/blog/letters/posts/post_1341123599023.html
Elementary & Middle School Resources

NASA Explorer Schools
• Human Body: Space Adaptations

Teaching from Space Office
• A Day in the Life
• Spaced Out Sports
Tell us what you think!

Take the Product Survey
Become eligible for NASA recognition opportunities!

NASA Explorer Schools
“I would make everybody do science four times a week for an hour and half, even if they cry. It’s for their own good.”

J. Kirby, age 10, grade 4
Centerville Elementary School
Thank you for joining us!
Thank you to the sponsor of tonight's Web Seminar:

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You've recently earned:
- Ruby Aggregator
- Add Personal Resources

You're close to earning:
- Ruby Commenter
- Post 9 more comment/questions

**Activity Progress Bar**

- YourActivity Matters!
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