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We Deliver

Why on Earth Should We Study the Health Issues of the Space Environment?

Patrice O. Yarbough, PhD
Sr. Scientist, NASA JSC ISSMP
Flight Analogs Bed Rest Studies

Spring 2019--UHCL Physics and Space Science Seminar Series
STEM Building, March 4, 2019

Human Health Related Space Research

Ground Based Studies

What are the health risks of humans living in microgravity and partial gravity?

- ~0 g of space
- 1/6th g of the moon
- 3/8th g of Mars

Space Environment--Microgravity

- Nothing to breathe
- No air pressure
- No protection from solar radiation
- Nothing to transmit sound waves
- No fluid to transfer heat to/from the body

Changes in the muscular, skeletal, digestive, and lymphatic systems

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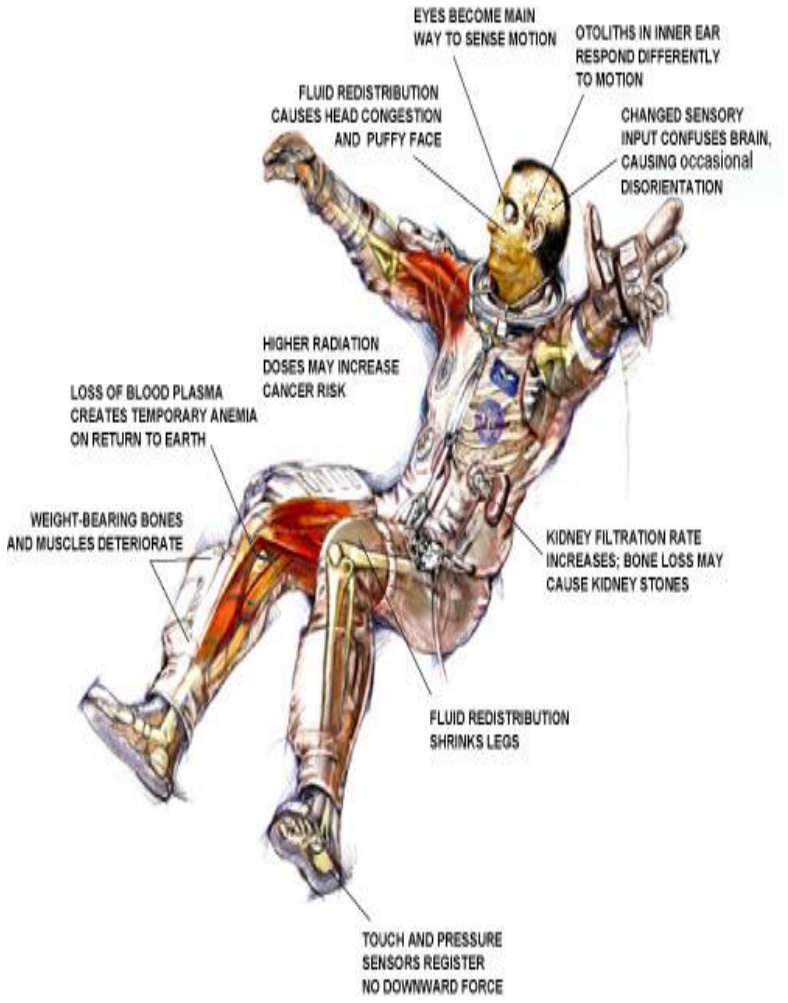
What's Different About Being in Space?



Human Adaptations

- Changed sensory input causes disorientation
- Kidney filtration rate increases; bone loss may cause kidney stones
- Fluid redistribution shrinks legs
- Touch and pressure sensors register no downward force
- Weight bearing bones and muscle deteriorate
- Fluid redistribution causes head congestion

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NASA Human Spaceflight Research

Create an environment that produces affects on the human body similar to those experienced in spaceflight

- Physiological
- Cognitive/behavioral

Use a ground-based analog for studies of:

- Human adaptation
- Confinement, mission stressors

Integrate studies on a non-interference basis and run together as one study

- Allows for selection of best candidate countermeasures before using them in flight
- Saves time and money; ground-based studies are faster

Spaceflight Analog: Bed Rest

Bed Rest conditions place the subject in a horizontal position with the head 6 degrees lower than the feet

- Bed rest is a ground analog used by the NASA Human Research Program as a model for studying physiological changes that occur during spaceflight *under controlled conditions*
- Provides a platform for comparison between bed rest and space flight
- Provides a mechanism for testing countermeasures prior to being used in flight

What Happens During Bed Rest?

Physiological De-Conditioning

- Weight bearing muscles and bones of the lower body are “unloaded”
- Muscle mass decrease, body fat increase, decrease in muscle strength and endurance
- Decreases in bone density in the hip and pelvis
- Decreased mobility
- Fluids shift toward the upper body and head; blood volume decreases
- Cardio-vascular de-conditioning
- Alterations in the immune system
- Altered cognitive functions

History of Bed Rest as a Flight Analog

6º Head Down Tilt

Early 1970s: cosmonauts return from longer duration missions

- Difficulty sleeping due to sensation of slipping off the end of the bed
- Foot of the bed was raised to compensate, then gradually lowered to horizontal
- Soviets tested a variety of tilt angles; 6º of head down tilt (HDT) optimized comfort

6º HDT bed rest is an accepted model for studying physiological affects of spaceflight on bone, muscle & cardiovascular systems.

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JSC-NASA Flight Analogs Program

- Plan experiments to answer questions of relevance to the Human Research Program
  - Ground -based analogs to test countermeasures prior to use in spaceflight
- Maintain compliance with the JSC and UTMB IRBs during conduct of the study
  - Conduct informed consent briefings
  - Assess adverse events with PI attending physician

Team Acknowledgements

- Our ultimate goal is to develop the best technologies for long-duration *human* space exploration.
- Our team is comprised of scientists and engineers, from the NASA civil service workforce and NASA contractors.
  - Campaign Scientists
  - Operations Planners
  - Data Engineers
  - Facility Engineers
  - Experiment Support Scientists
  - Subject Screening Coordinators

NASA Flight Analogs Research Unit (FARU)

UTMB

Children's Hospital

Flight Analogs Research Unit

Structure of Bed Rest Studies

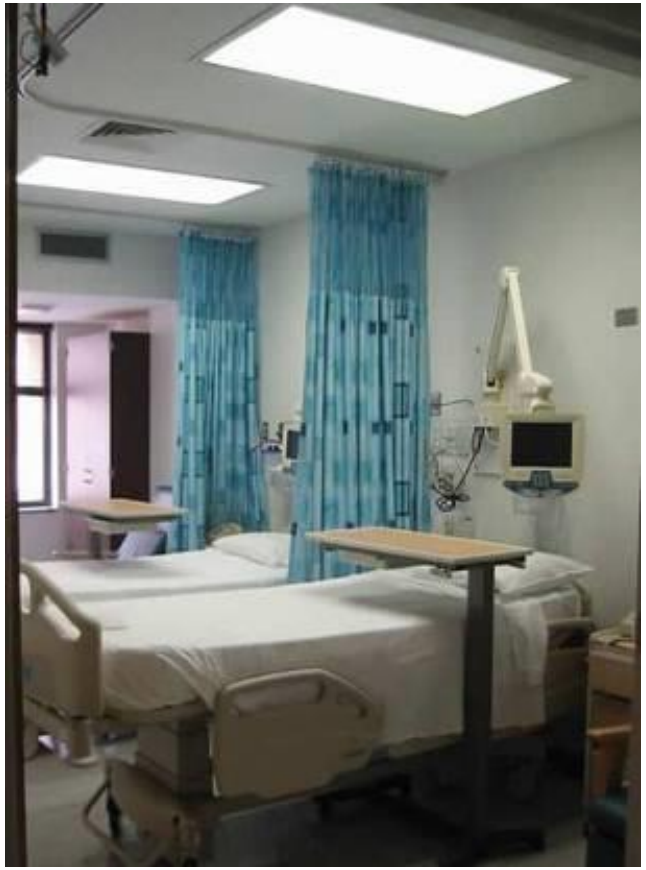
- Studies are integrated into **study complements** on a non-interference basis.
- **Standard conditions** provide a controlled set of variables that are kept consistent across all complements.
- **Standard measures** are a battery of tests integrated with all complements.

Purpose of Standard Measures

- Characterize human responses to head down tilt bed rest.
- Assess candidate countermeasures in a multidisciplinary manner to determine outcomes on non-targeted systems.
- Provide a basis for comparison between bed rest and spaceflight.

Standard Conditions

- 6º HDT bed rest
- Room Temp: 70-74º F
- Study duration ~87 days
  - 13 days pre-bed rest
  - 60 days in bed
  - 14 days post bed rest (recovery)
- Sleep/Wake cycle
  - Wake at 0600 hrs
  - Lights out at 2200 hrs



Standard Conditions-2

- Monitored 24 hrs/day
  - Subject monitors
  - Cameras
- Daily vital signs
  - Blood pressure
  - Heart rate
  - Body temperature
  - Respiratory rate
  - Body weight (bed scale)
- Fluid intake/output is measured
- Psychological support provided

Standard Conditions-3

- Stretching twice each day
- Physiotherapy (massage therapy)
  - every other day during bed rest
  - daily for 1st week post bed rest
- No exercise permitted

Standard Diet

- Diet based on NASA spaceflight nutritional requirements
- Caloric intake 35.7 kcal/kg body weight (2500 calories/70 kg subject)
- Fluid intake 28.5 ml/kg body weight (2000 ml/70 kg subject)
- Carbohydrate:Fat:Protein ratio 55:30:15
- No caffeine, cocoa, chocolate, tea or herbal beverages
- All food must be consumed
- Caloric intake adjusted to weight within 5%

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Clinical Labs

Clinical Laboratory Assessment

- Blood and urine studies to monitor subject health
  - BR-10, BR 28, BR+0, +5

Immune Status

- General immune status
- Viral specific immunity
- Latent Viral Reactivation
- Physiological stress
  - BR-10, BR28, BR+0, +5

Nutrition

- Nutritional analysis
- Markers of bone resorption and formation
- Circulating bone and calcium regulatory factors
- Antioxidants and oxidative damage
  - BR-10, -3, BR28, BR+0, +5

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Bone Assessment

- Dual Energy X-Ray Absorptiometry (DXA) – Bone Density
  - BR-13, BR+2, +180, +365
- Quantitative Computerized Tomography (QCT) – hip and lumbar spine bone mass and structure
  - BR-4, BR+4, +180, +365

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Physical Fitness

- Isokinetic Testing – muscle strength/endurance
  - BR-11, -6, BR+2, +12
- Cycle Ergometry – maximum aerobic capacity
  - BR-12, -7, BR+0, +11

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Functional Neurological Assessment

- Posturography testing – standing posture
  - BR-10, -5, BR+0, +1, +2, +4
- T-Reflex – spinal monosynaptic stretch reflex
  - BR-10, -4, -1, BR 5, 20, 60, BR+0, +3, +5

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Cardiovascular Function

- Operational Tilt Test – orthostatic tolerance
  - BR-5, BR+0, +3
- Carbon monoxide rebreathing - plasma volume
  - BR-5, BR 3, 21, 31, BR+0, +3
- Echocardiography – cardiac function assessment
  - BR-5, BR 7, 21, 31, BR+0, +3, +13

Countermeasures & Functional Testing in HDT Study

Investigators: Ploutz-Synder and Bloomberg

1. Determine the effects of bed rest on functional performance.
2. Determine the rate of recovery of functional performance post bed rest.
3. Determine how post bed rest changes (in sensorimotor, cardiovascular and muscle physiology) impact functional performance.
4. Evaluate the effectiveness of the iRAT exercise countermeasure for the maintenance of cardiovascular, muscle and bone health.

Integrated Resistance and Aerobic Training (IRAT)

	Day 1 (min)	Day 2 (min)	Day 3 (min)	Day 4 (min)	Day 5 (min)	Day 6 (min)	Day 7 (min)
Resistance	35-60		35-60		35-60		0
Aerobic Interval		32		15		35	0
Aerobic Continuous	30		30		30		0

IRAT is based on findings that exercise intensity is the most important factor determining training effectiveness.

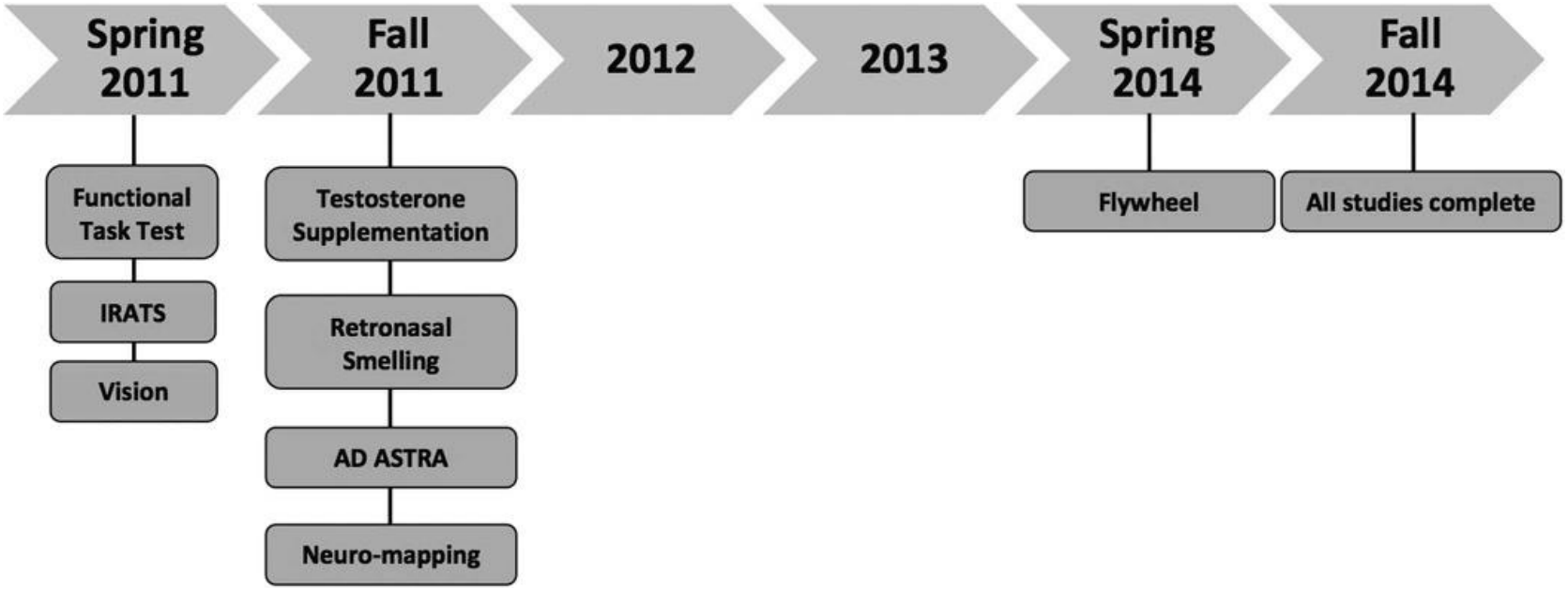
- Program uses periodic resistance exercise 3 days /week.
  - Squats, lifts, leg/knee extensions, heel raises
- Aerobic exercise is done on vertical treadmill and cycle.
  - Protocol consists of 3 days/week high intensity interval exercise alternating with 3 days/week continuous exercise
- On resistance training days, continuous moderate intensity aerobic exercise is performed.

Bed Rest Campaign 11: 70 Days Head Down Tilt

70 Day Bed Rest Study, 6 Integrated Studies

1. **Physiological Factors Contributing to Post-Flight Changes in Functional Performance (Bloomberg)**
2. **Integrated Resistance and Aerobic Training (Ploutz-Snyder)**
3. **Testosterone Supplementation as a Countermeasure Against Musculoskeletal Losses During Space Exploration (Urban)**
4. **Effects of Retronasal Smelling, Variety and Choice on Appetite and Satiety (Hunter)**
5. **Automated Detection of Attitudes and States Through Transaction Recordings Analysis (Miller)**
6. **Bed Rest as a Spaceflight Analog to Study Neuro-Cognitive Changes (Seidler)**

Timeline for Studies in the Bed Rest Complement



Study Outcomes

Overview of the NASA 70-day Bed Rest Study

Cromwell, RL., JM. Scott, M Downs, PO Yarbough, SB Zanello, and L Ploutz-Snyder in Medicine & Science in Sports & Exercise, 2018, pgs 1901-1919.

24 subjects were randomly assigned to:

- ***Non-exercising control group***
- ***iRAT exercise group***
- ***Exercise plus testosterone supplementation***

1. *Long-duration head-down tilt bed rest provided a suitable platform for examining physiologic effects of spaceflight and testing countermeasures in a ground-based model.*
2. *Integrating studies into a complement is an effective way to support multiple investigations while minimizing the number of subjects to answer many research questions.*
3. *Research benefits included the ability for investigators to share outcome measures across investigations to broaden interpretation for each individual investigation.*

PI Study Outcomes

- **IRAT program shows promise; exercisers maintain knee strength and aerobic endurance**
- **Ocular monitoring weekly; no clinically relevant visual changes observed during bed rest**

International Bed Rest Studies

At envihab, the international bed rest facility in Cologne, worldwide experts from NASA, ESA, DLR work together:

- Share resources among space agencies for cost effective solutions to study implementation
- Use international standard measures
- 6° head-down tilt bed rest with 0.5% CO2 exposure during the bed rest phase

Coming Soon: *Physiological and Behavioral Responses in Humans to Intermittent Artificial Gravity during 60-Days of Head-down Tilted Bed Rest*

Artificial Gravity Bedrest--envihab

60-day study, 6 degrees head down tilt (HDT)

- Control group: no centrifugation
- Centrifugation on a short arm radius centrifuge
  - Continuous AG group: Daily continuous centrifugation for 30 minutes
  - Interval AG group: Daily centrifugation of 6 x 5 minute intervals
- Medical monitoring
- International Standard Measures
  - Sensory-motor, muscle, bone, nutrition
  - Cardiovascular, immunology, psychology

Future of Space Medicine Research

- Human Element is the most complex element of the mission design
- Moon, Mars, and other missions will pose physiological and psychological challenges to crew members

For continued manned spaceflight, ground-based and specialized flight research (ie. bed rest studies) will be needed to study the physiological changes that occur during spaceflight under controlled conditions.