Exercise is Medicine is Pivotal for Humans to Go to Mars and Return to Earth

Physical Deconditioning with Space Flight

Cardiovascular Deconditioning
Musculoskeletal Wasting

Muscle Wasting

% Change in Muscle Mass

Bed Rest (90 days)  Aging (50 years)  Spaceflight (6 months)

Skeletal Muscle Plasticity

Athletes: ~5 to 10% shift possible
Unloading: ~20 to 30% shift possible - preventible with exercise
Aging: ~20 to 30% shift possible - reversible with exercise
Extreme disuse (SCI): ~60% shift possible - partially reversible with E-Stim
Current Generation Exercise Program

Exercise Astronauts Like Athletes

Human Muscle Function with Space Flight

Whole Muscle → Single Fiber

MRI

Human Muscle Fiber Magnified 400 times

Single Muscle Fiber Performance

Size  Strength  Speed  Power

Single Muscle Fiber Technique

Slow and fast fibers respond differently to exercise and space flight

Meb Keflezighi
Boston Marathon Winner
Mostly Slow Fibers

Colin Jackson
World Champion Sprinter
Mostly Fast Fibers
Single Muscle Fiber Power with Space Flight

Heterogeneity in Skeletal Muscle

Astronaut Health for a Mars Mission

New Astronaut data slide to be made
The Health Benefits of Exercise

Heart Health
Skeletal Muscle Health
Brain Health
Bone Health

Skeletal Muscle as An Endocrine Organ

Skeletal Muscle Contraction Induced IL-6 Release

"It is a most remarkable finding that the knee extensors of the leg are able to produce an increase in plasma IL-6 concentration to reach a level comparable to that obtained during severe infections."

Muscle-Derived IL-6: A Biological Role?

Muscle-derived IL-6 purported to work in a hormone-like fashion, contributing to maintenance of glucose homeostasis during exercise.
Myokines are Pluripotent

Exosome Biology and Exercise

Organ Cross-Talk with Exercise

Functional Genomics and Health

What Are Exosomes?
- Exosomes are small vesicles
- Released from skeletal muscle into circulation with exercise
- Carry cargo (i.e. proteins and myokines) to other tissues
- Novel and powerful communication network
Molecular Transducers with Exercise
Conceptual Framework from Available Data

Exercise Biology Discovery

The Athlome Project Consortium

Molecular Transducers of Physical Activity Consortium (MoTrPAC)

National Institutes of Health
$170 Million (2017-2023)

Largest, most complex and highly coordinated human exercise physiology training study in the history of the field
Goal: Assemble a genetic map of the health benefits of exercise

56 years of Exercise in Space

John Glenn
First Exercise in Space
Bungee Device
2/20/1962

Skylab - 1970's
First Multifaceted Exercise Program

Space Shuttle Era
More Complex Measures
More Organ Systems

<10 Physiological Variables Measured
100's of Physiological Variables Measured
1000's of Physiological Variables Measured

New Frontiers in Space Medicine

NASA Twins Study Research Integration

NASA

Take Home Message

- High degree of plasticity (all organs)
- Skeletal muscle is an endocrine organ
- Exercise triggers biological events lasting from minutes to hours to days
- Exercise stimulates numerous organ systems (pluripotent and multi-system cross-talk)
- Molecular transducers (“-omics”) is an emerging and maturing frontier of discovery

100,000's of Physiological Variables Measured
Exercise is Medicine

Whole body to Gene
✓ Exercise Heterogeneity
✓ Exercise Dose Response
✓ Organ Cross-Talk
✓ Functional Genomics

Health Effects Observed on Earth and in Space

Funding & Collaborators

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ISS and Bed Rest Teams
Hargens Team
Biolo Team
Muscle Team
MEDES Team
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