Integrated Resistance and Aerobic Exercise Mitigates Multi-System Deconditioning: Results from the NASA 70 Day Bed Rest Study

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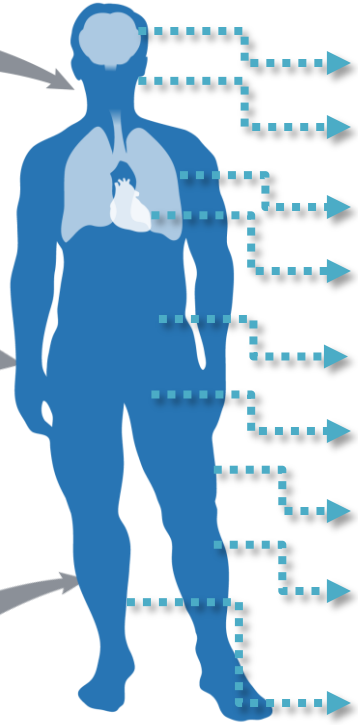
No Disclosures

Spaceflight: A "Multiple-Hit"

Baseline risk factors
Obesity, hypertension, age

'Direct' injury
Microgravity

'Indirect' Injury
Secondary to microgravity (deconditioning)

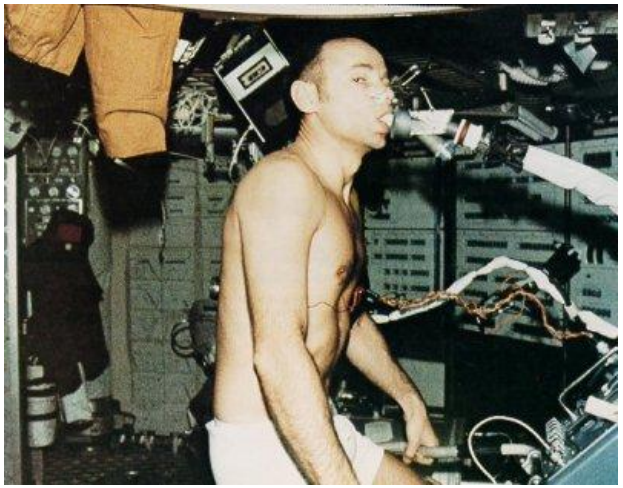


- Cognitive Impairments
- Sleep Deficiency
- Immune Dysfunction
- Cardiovascular Dysfunction
- Anemia
- Gastrointestinal Events
- Exercise Intolerance
- Skeletal Muscle Dysfunction
- Bone Demineralization

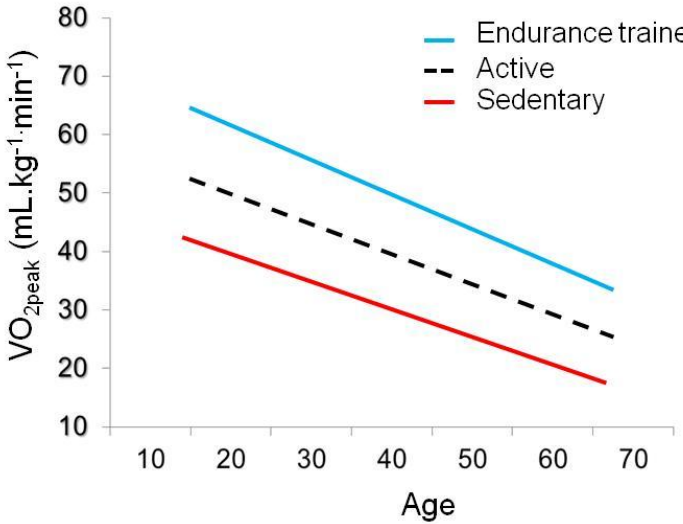
Multisystem Deconditioning

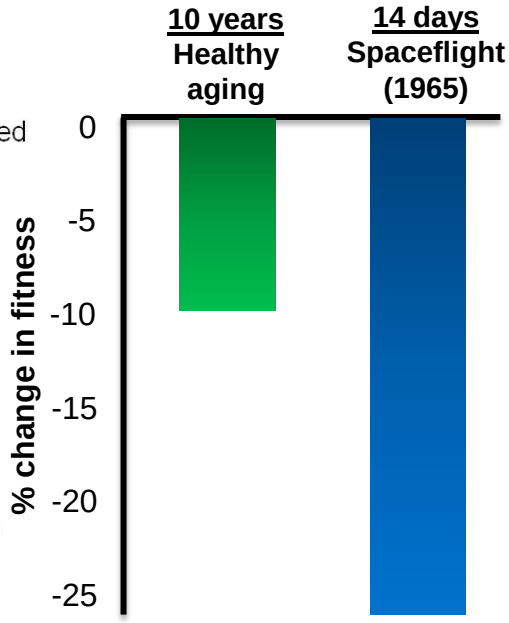
Symptom limited cardiopulmonary exercise test

Cardiorespiratory fitness (VO_{2peak} – $mL \cdot kg^{\cdot -1} min^{-1}$)

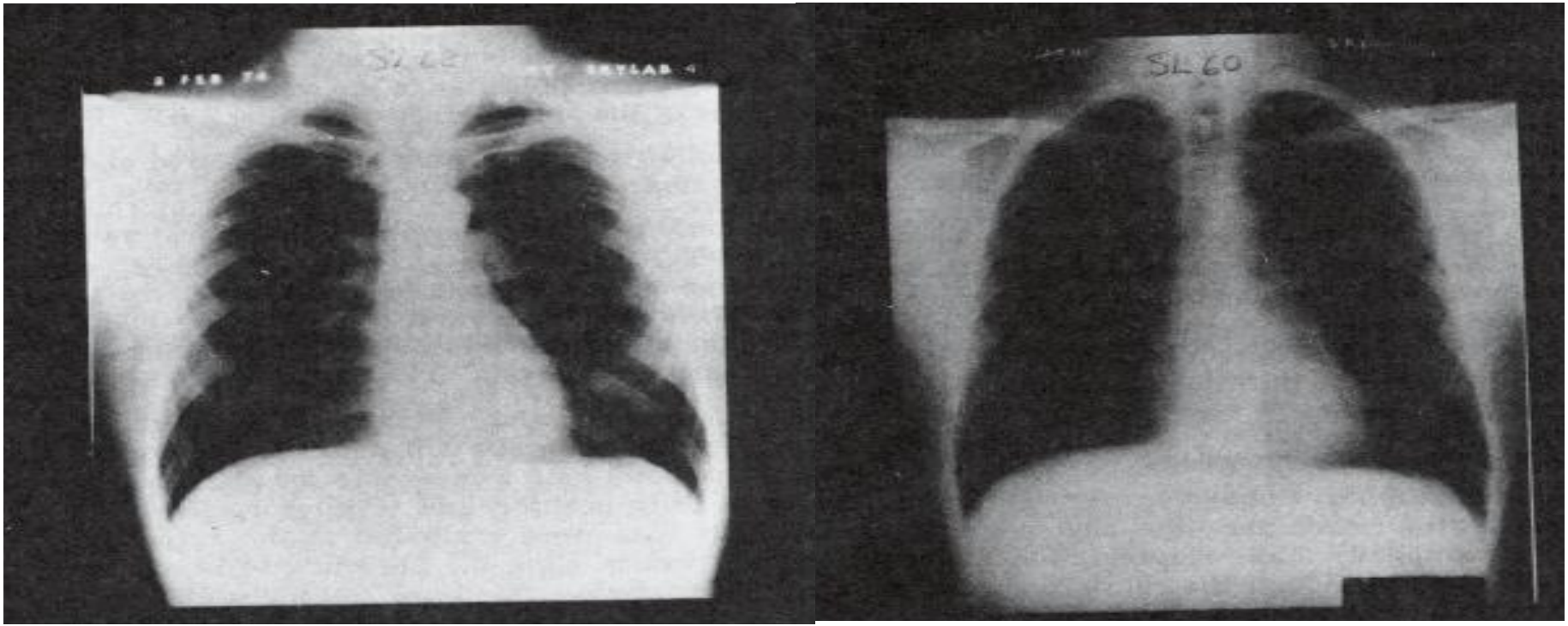


Cardiopulmonary exercise test

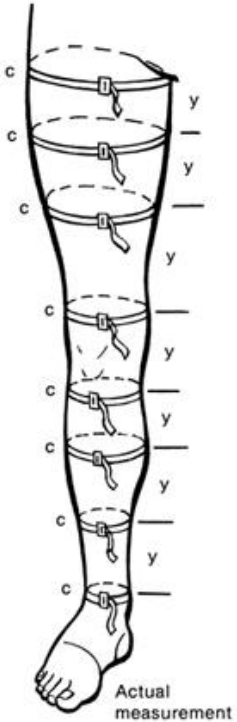


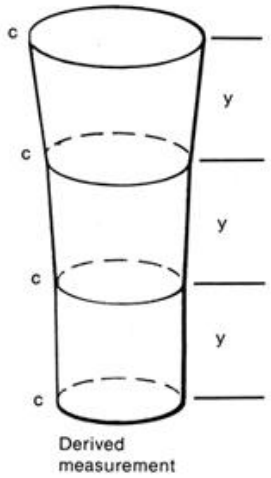


Cardiac Atrophy



Muscle Atrophy

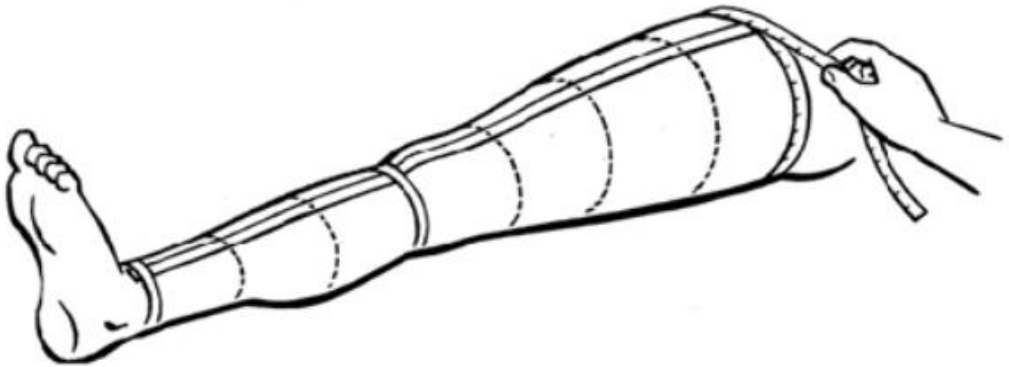




Circumference = 2π radius

$$\text{Vol} = \pi y \left(\frac{R_1^2 + R_1 R_2 + R_2^2}{3} \right)$$

$$\text{where } R = \frac{\text{circumference}}{2\pi}$$



How to Prevent / Treat Multisystem Deconditioning?

EXERCISE

Pulmonary diffusion
- no change

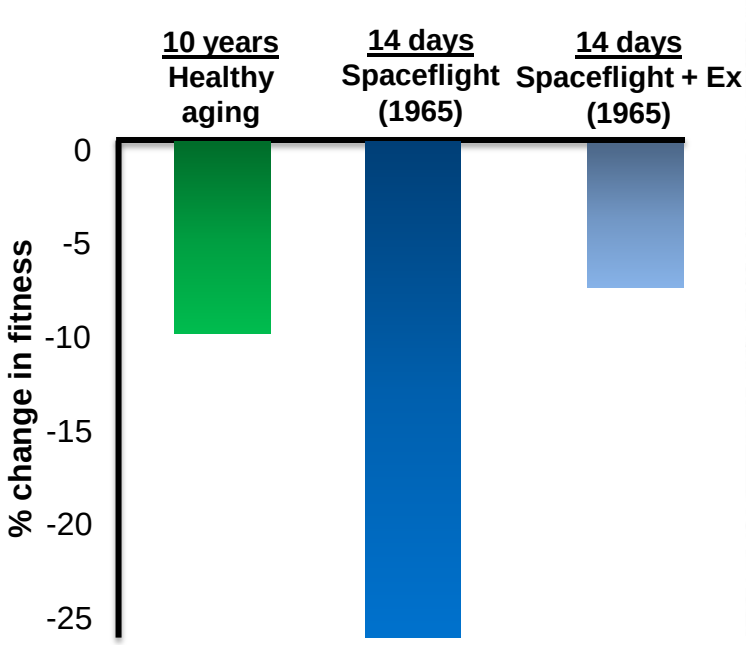
Cardiac function
- stroke volume↑
- heart rate↓
- cardiac output↑

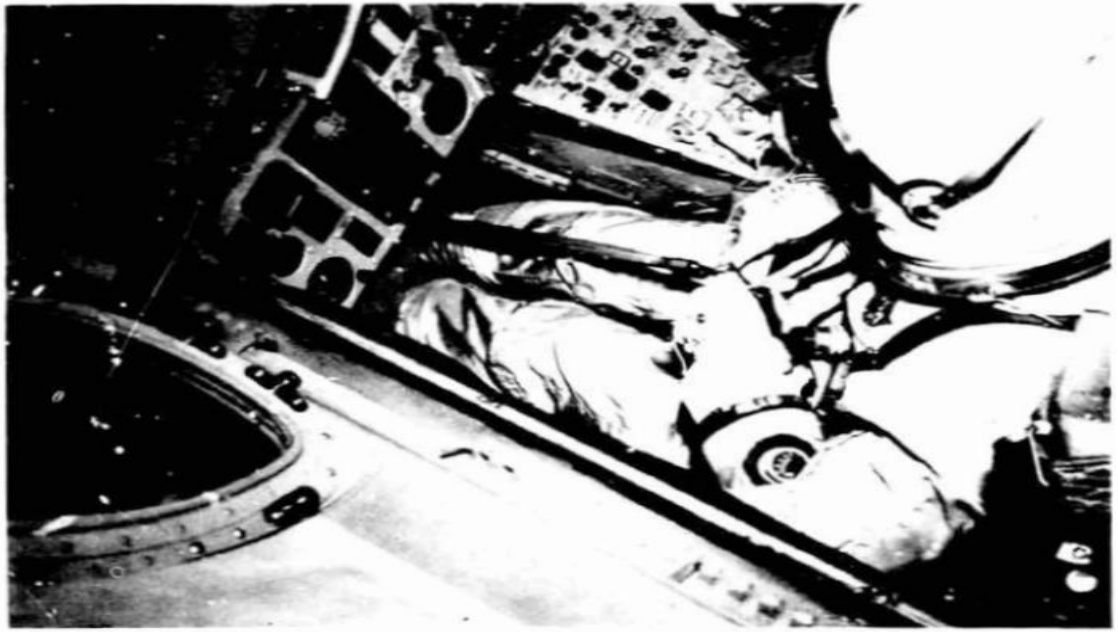
Arterial/endothelial function
- nitric oxide↑
- angiogenic factors↑

Skeletal muscle function
- mitochondrial size&number↑
- capillarization↑

Whole-body cardiovascular performance
- Cardiac
- Blood / peripheral resistance
- Muscle oxidative capacity

Early Exercise Countermeasures





Project Gemini: 1964-1966
(4-14 day missions)

“Rather than seeking permission to exercise, you should have to get permission to be sedentary”

Exercise: Mandatory on ISS Missions

Exercise on the ISS: 2001-2009
(~6 month missions)

Exercise: Mandatory on ISS Missions

Exercise scheduled for 2h/day

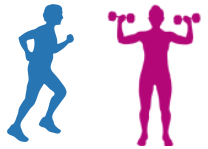
- **Includes set-up time
- ~30-60min/day, 6 days/ week, moderate intensity

Historical Practice

Risk Stratification

Heterogeneous

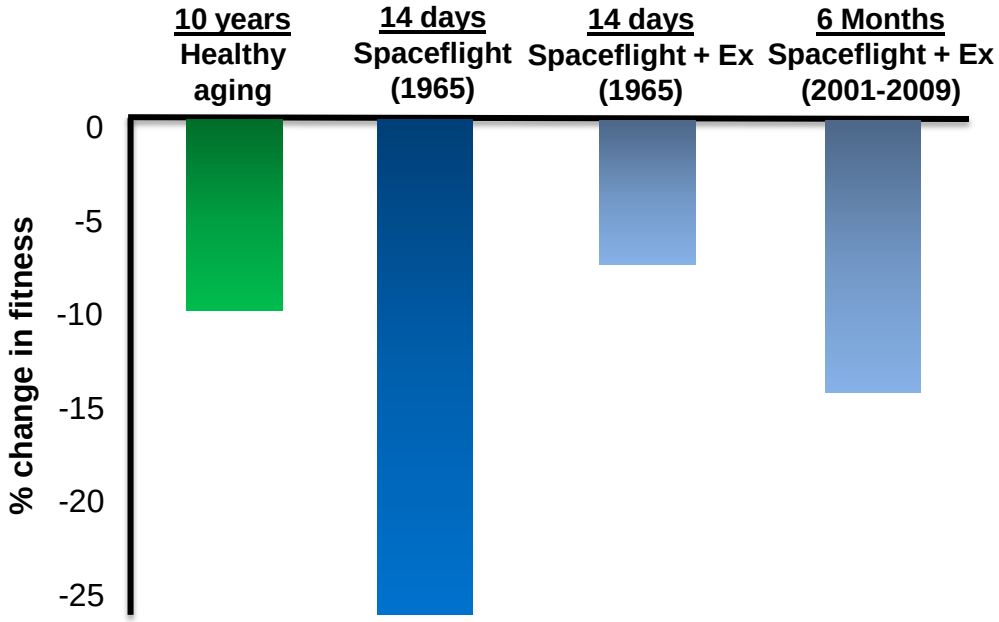
Exercise Rx



One size fits all:
~30-60min/day, 6 days/ week, moderate intensity

Response

ISS Standard Exercise Countermeasures



- *Standard exercise countermeasures still associated with accelerated decline*

Moore et al. *J Appl Physiol*, 2014

Head Down Tilt Bed Rest Study: Spaceflight Analog

Watch Live CBSN coverage of the

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By MICHELLE CASTILLO / CBS NEWS / September 22, 2

Need some time feet? NASA pay volunteers $18 for 70 days

Go to Bed for NA

by NANCY ATKINSON on NOV

Nasa is paying a man £11,000 to stay in bed for 70 days

Jimmy Nsubuga for Metro.co.uk Tuesday 4 Nov 2014 5:03 pm

97

Would you lay in bed for 70 days for £11,000? (model used in picture) (Picture: Getty Images)

udy: volunteers will be
nth for lying in bed

SCIENCE

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BED FOR THE SAKE OF

SPACE, NASA PAYS TEST SUBJECTS TO LIE

10 Weeks of Head Down Tilt Bed Rest

‘Astronaut-like cohort’

RANDOMIZE

ARM A
Diet
(n=9)

ARM B
Diet + traditional exercise
(n=9)

ARM C
Diet + exercise + testosterone
(n=8)

ARM D
Diet + flywheel exercise
(n=8)

10 weeks

10 Weeks of Bed Rest: Spaceflight Analog

- Subjects monitored 24 hours/day
- Toileting and showering performed in the head down tilt position
- Standard wake/sleep schedule
- 3 meals/day controlled diet with adjusted energy intake
  - 55% CHO, 30% fat, 15% protein
- Monitoring of fluid intake/output
- Resting metabolic rate measured every 2 weeks
- Exercise energy expenditure measured every week
- Individualized exercise prescriptions based on peak tests
- Each exercise session conducted by two exercise physiologists

Bed Rest Resistance Exercise

ISS

Bed Rest

Bed Rest Aerobic Exercise

ISS

Bed Rest

Bed Rest Flywheel Aerobic and Resistance Exercise

Future Missions

Bed Rest

Resistance

Aerobic

SPRINT Exercise Schedule

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

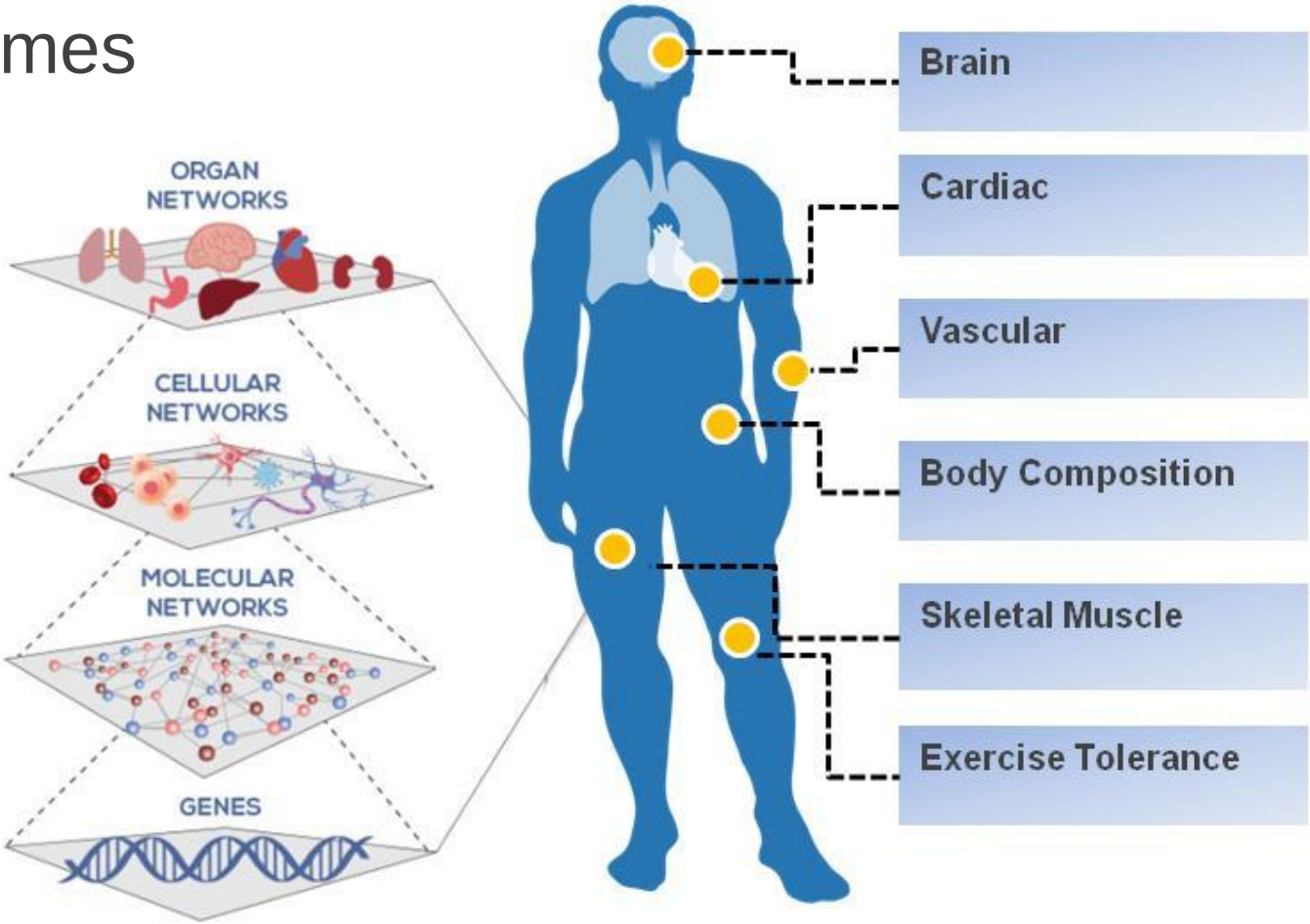
Aerobic Intervals:

- 4x4-min @ 85% max
- 6x2-min @ 70%, 80%, 90%, 100%, 90%, 80% max
- 8x30-sec @100% max, 15 sec rest

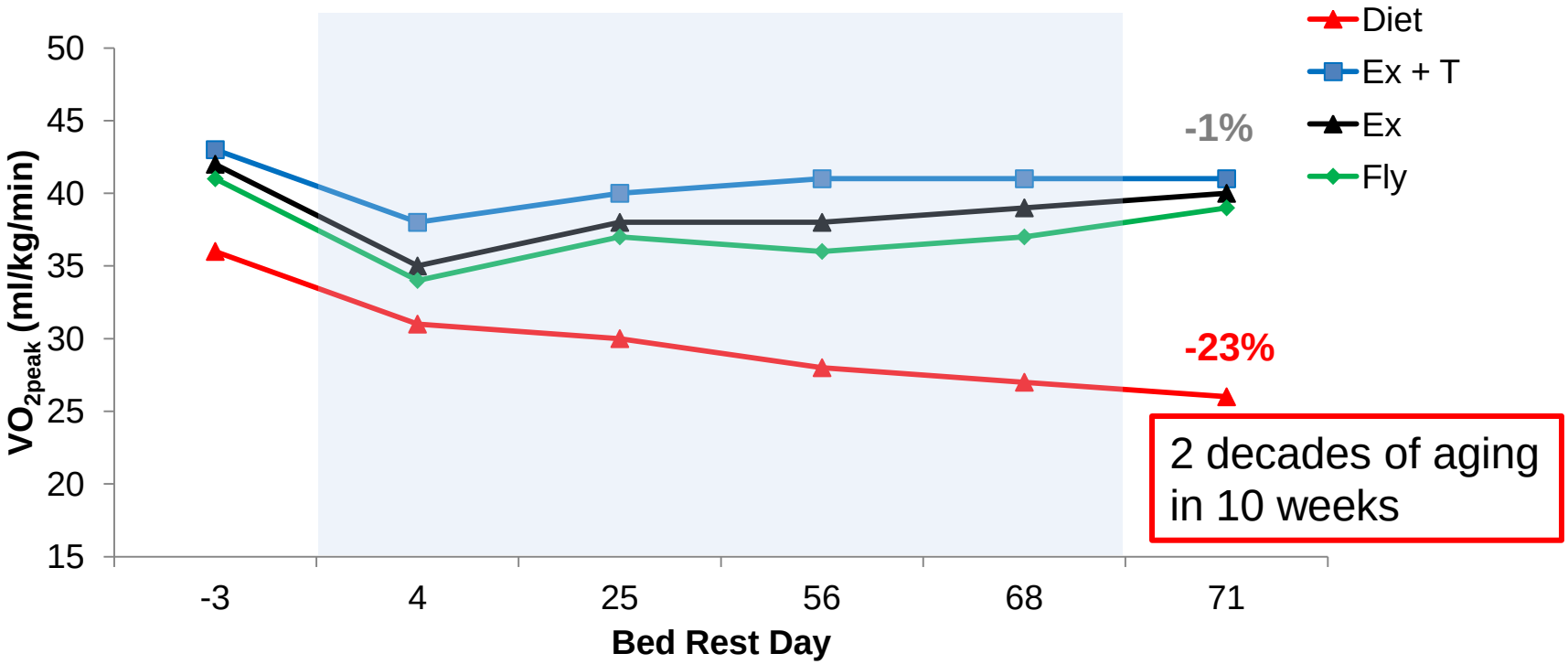
Resistance exercise:

- 3 x 5-10 RM
- Leg press, squat, leg curl, calf extension

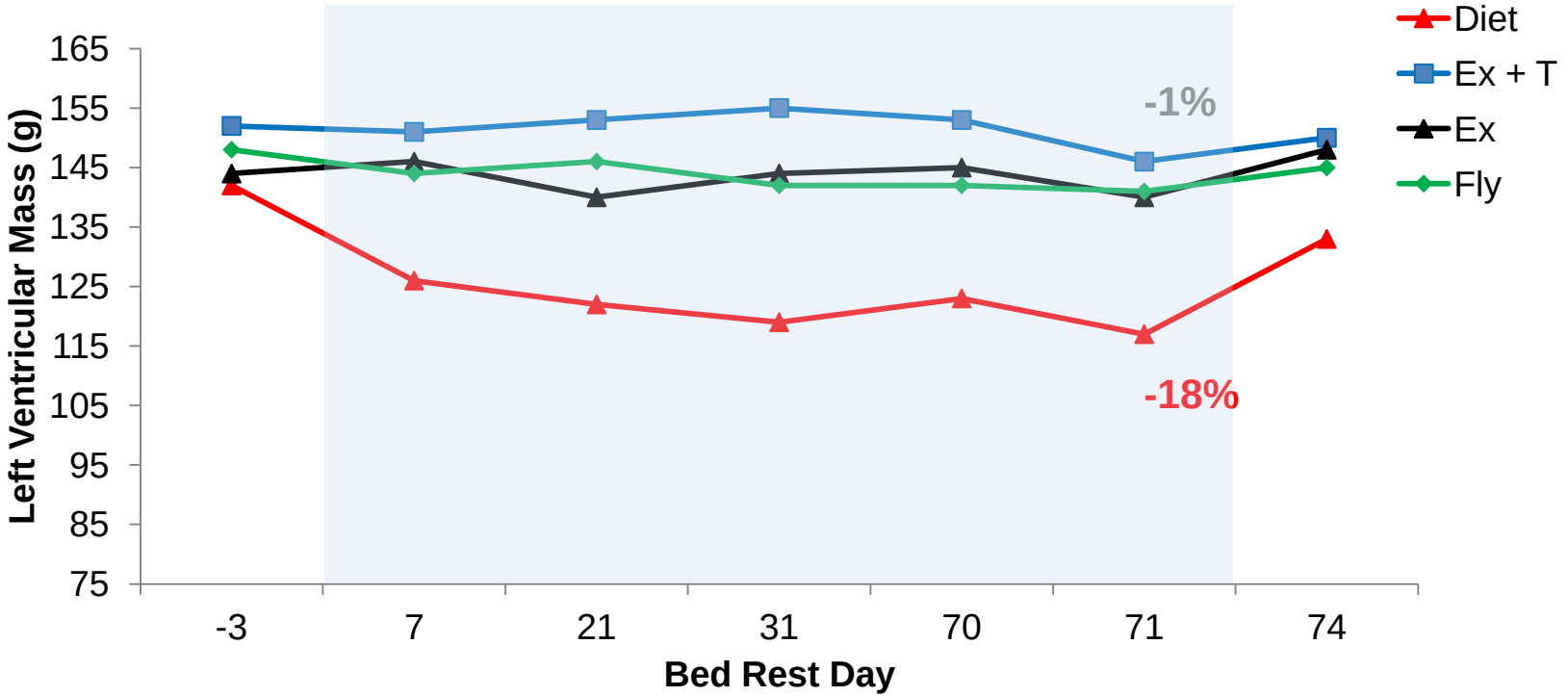
Bed Rest Outcomes



Results: Cardiorespiratory Fitness

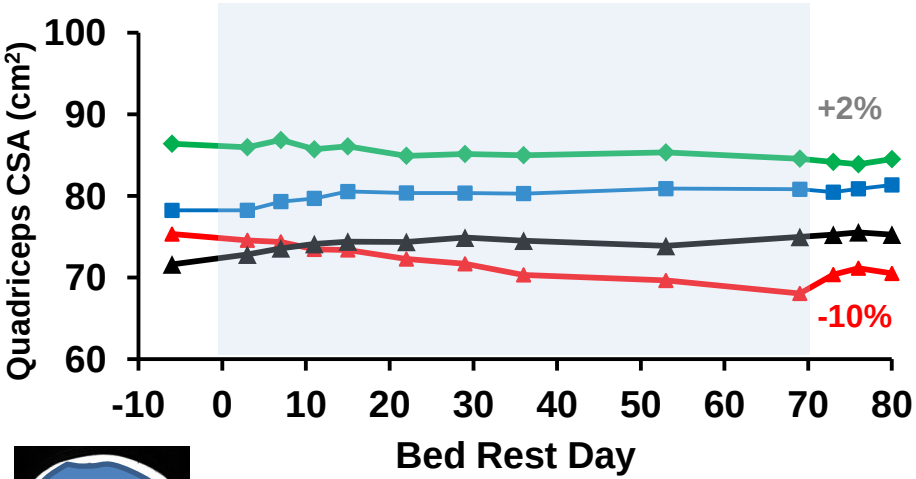


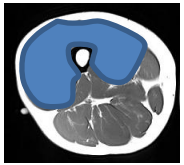
Results: Cardiac Mass



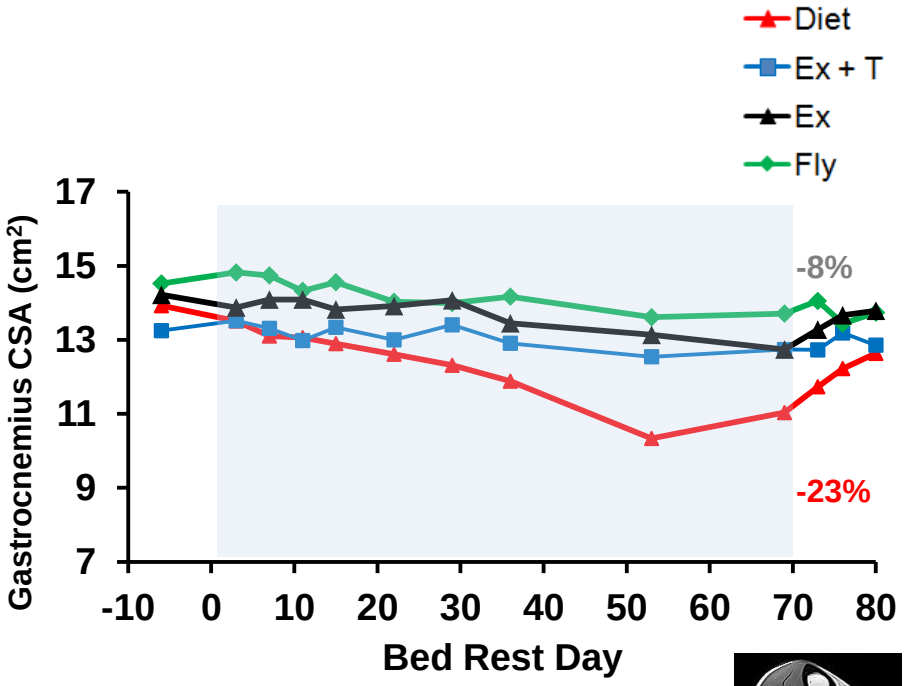
Exercise: no change in cardiac size

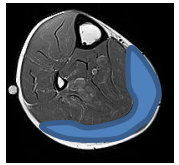
Results: Leg Muscle Mass





Exercise: no change in upper leg size





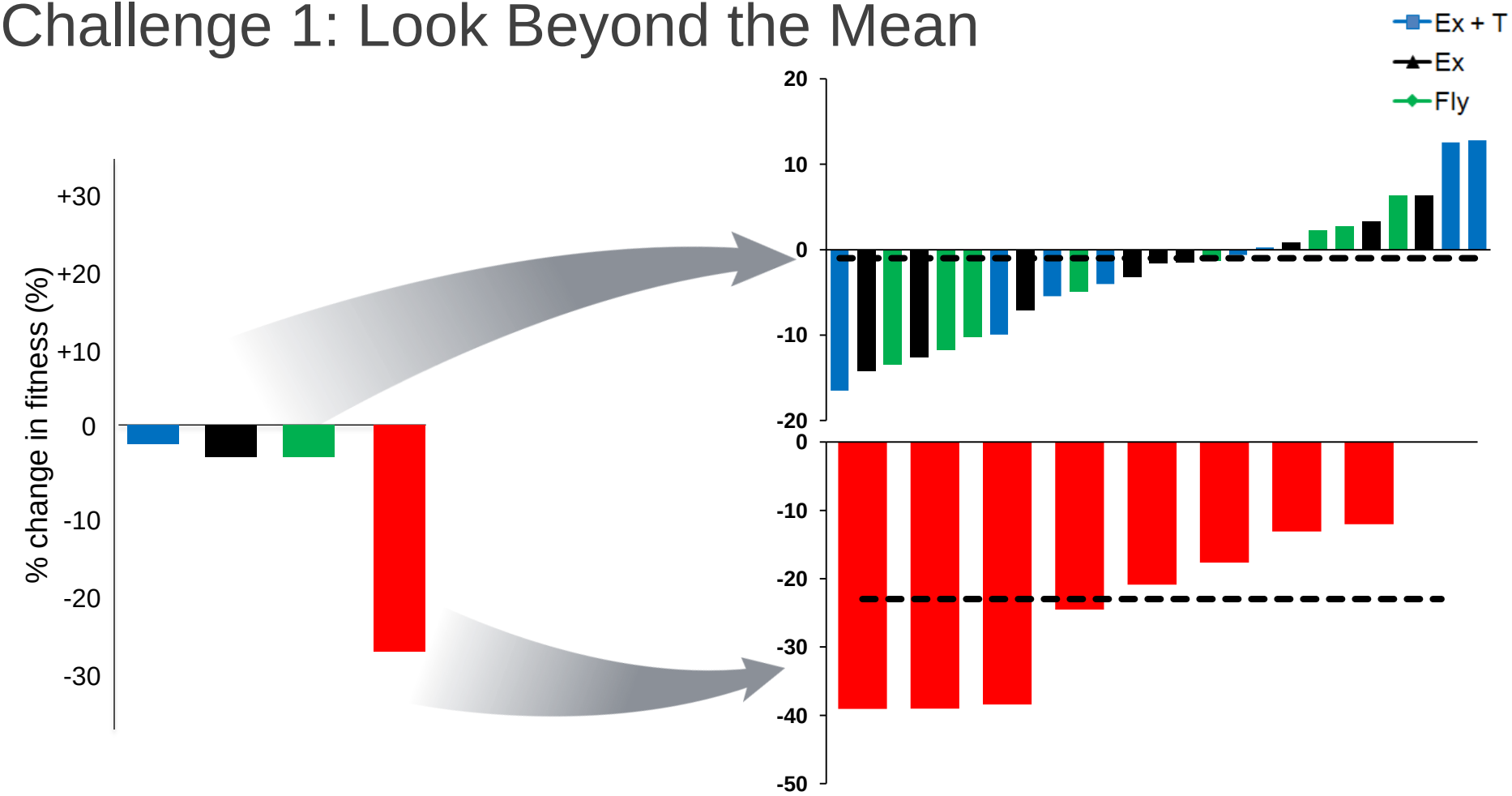
Exercise: abrogated decline in lower leg size

Summary I

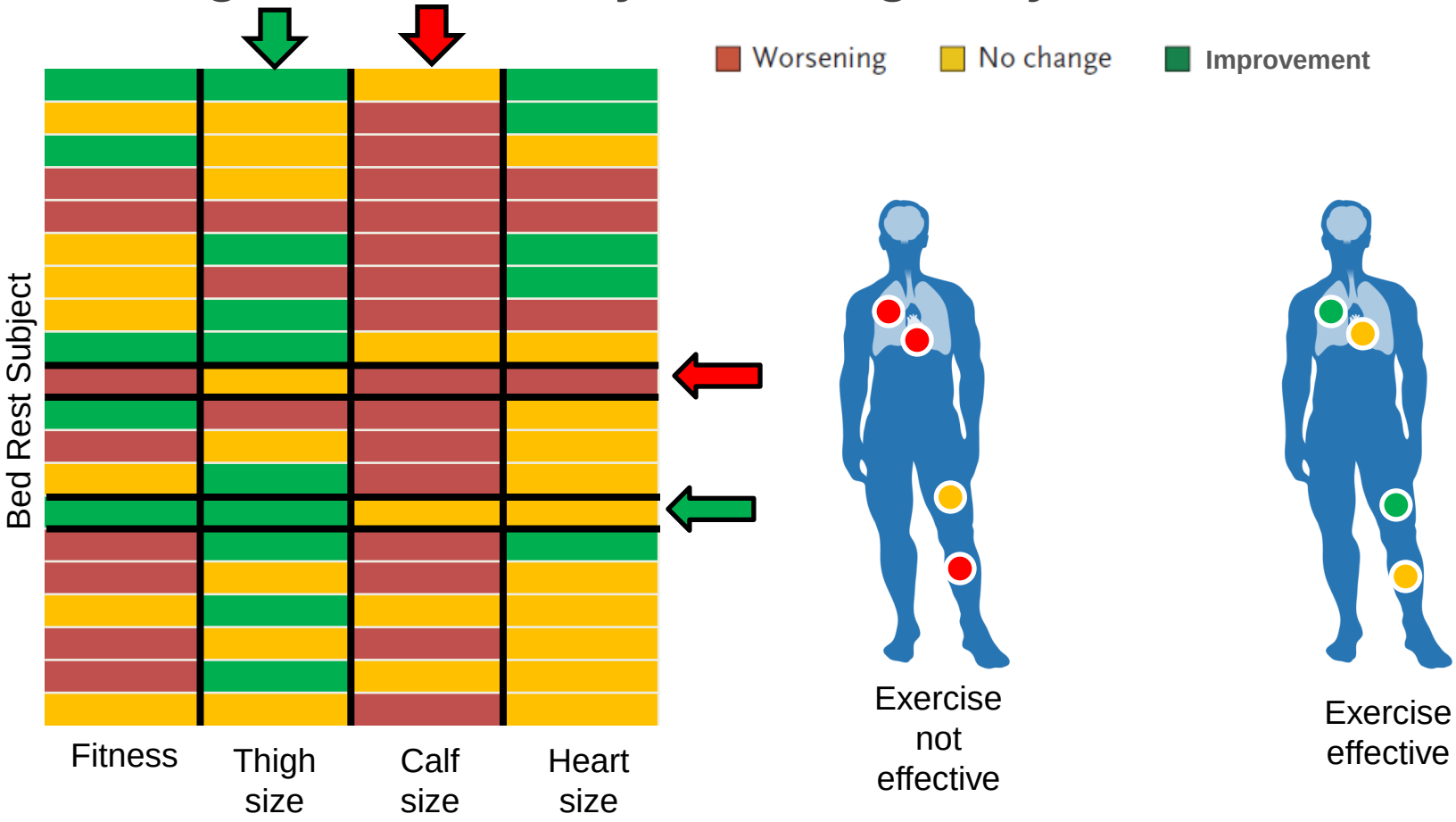
1. SPRINT exercise with traditional exercise equipment alone and with the addition of low dose testosterone supplementation is safe and abrogates multi-system deconditioning
2. SPRINT exercise with FLY effective in mitigating multi-system deconditioning relative to exercise performed on traditional exercise equipment


HUMAN EXPLORATION
NASA's Path to Mars
NASA
EARTH RELIANT
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS
PROVING GROUND
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS
MARS READY
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS
4 Key Challenges
Mastering fundamentals aboard the International Space Station
U.S. companies provide access to low-Earth orbit
Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit

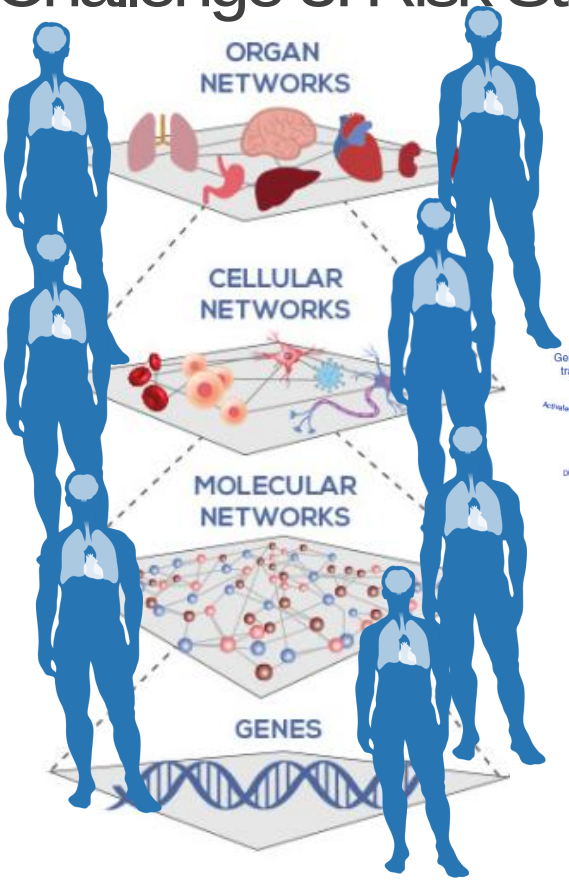
Challenge 1: Look Beyond the Mean

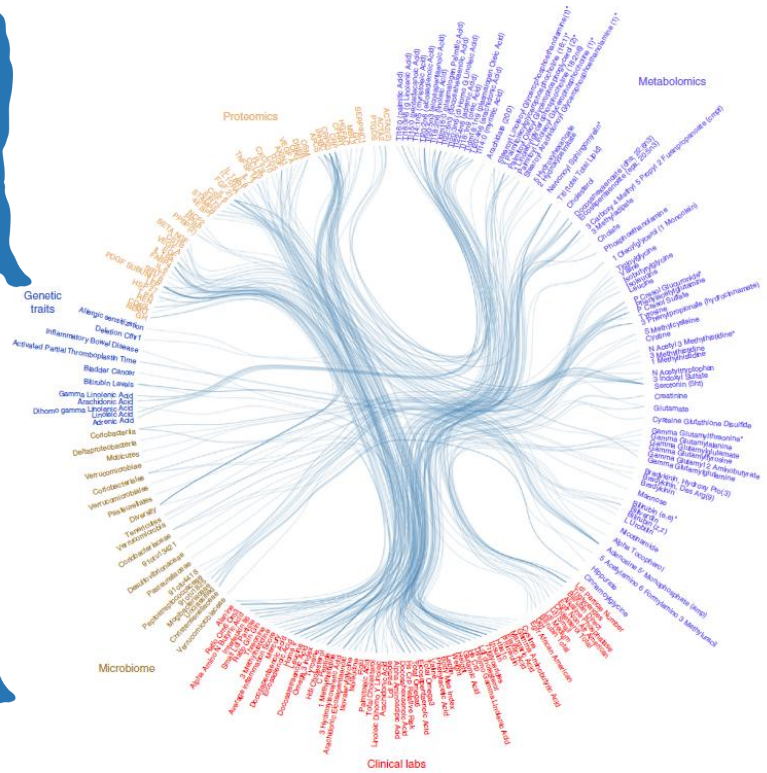


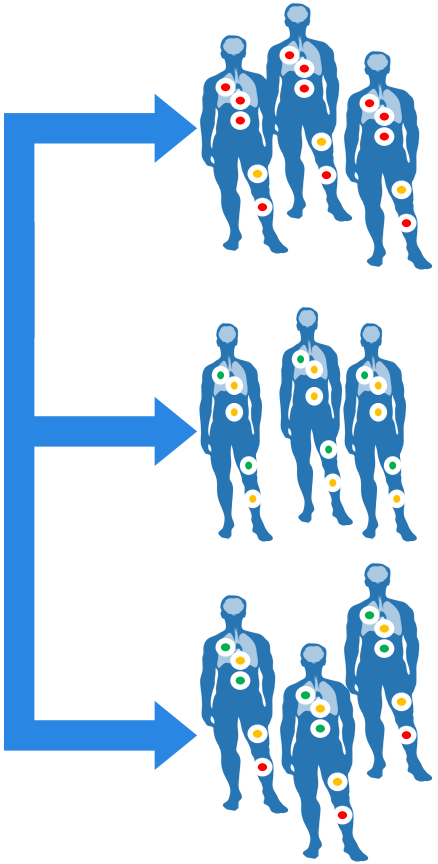
Challenge 2: Look Beyond Single Systems



Challenge 3: Risk Stratification





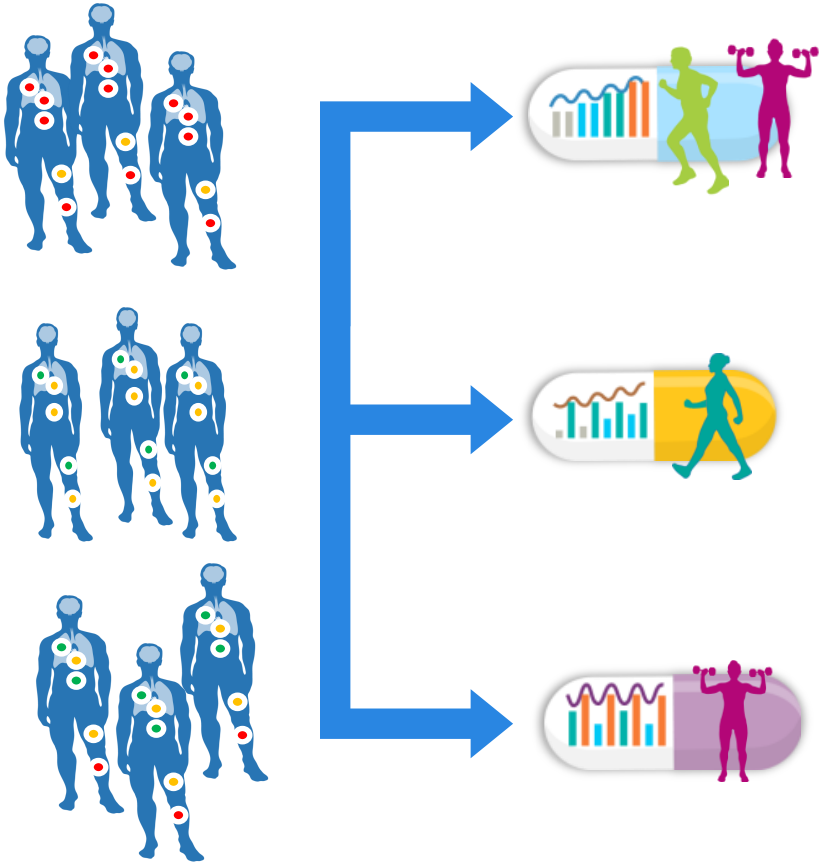


Input

Unsupervised Machine Learning

Output

Challenge 4: Precision Exercise Prescription



Optimize:

1. **Safety**
2. **Efficacy**
3. **Resource utilization**

Summary II

1. One size of exercise does not fit all
2. Critical to understand individual multisystem variability prior to exploration missions

- Look beyond ‘research silo’

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