Aerospace Medicine and Rehabilitation Strategies

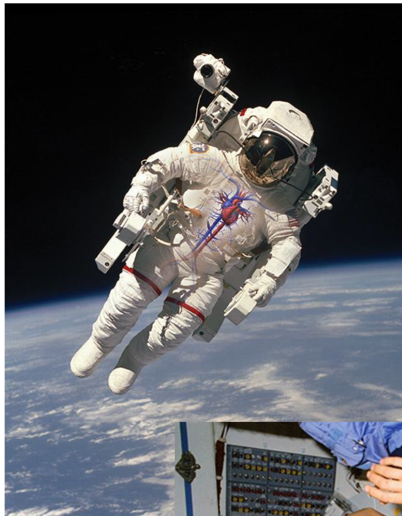
Francesca Gimigliano, MD, PhD
Professor of Physical and Rehabilitation Medicine
Coordinator of the National Ph.D. Program in Public Administration and Innovation for Disability and Social Inclusion
Department of Mental and Physical Health and Preventive Medicine, University of Campania "Luigi Vanvitelli"
Cochrane Rehabilitation, Functioning and Disability, Unit Chair
World Rehabilitation Alliance, member of the External Relations Workstream
International Society of Physical and Rehabilitation Medicine, Past-President

Università degli Studi della Campania Luigi Vanvitelli
Cochrane Rehabilitation, Functioning, and Disability
WRA WHO hosted network
World Rehabilitation Alliance
ISPRM International Society of Physical and Rehabilitation Medicine

Space Medicine

Space medicine can be defined as *the practice of all aspects of* ***preventative medicine*** *including screening, health care delivery, and* ***maintaining human performance in the extreme environment of space*** *and* ***preserving the long-term health of space travellers***

Board certification since 1953 (Aerospace Medicine)



Pool SL, Davis JR. Space medicine roots: a historical perspective for the current direction. Aviat Space Environ Med 2007

Space Medicine: Key Challenges

Environmental Extremes:
- Microgravity, radiation, vacuum
- Temperature swings, contaminants

Physiological Responses:
- Muscle & bone loss
- Cardiovascular, immune, neurovestibular effects

Psychological Factors:
- Isolation, confinement
- Limited communication & privacy

Pool SL, Davis JR. Space medicine roots: a historical perspective for the current direction. Aviat Space Environ Med 2007

Università degli Studi della Campania Luigi Vanvitelli
Cochrane Rehabilitation, Functioning, and Disability
WRA World Rehabilitation Alliance
ISPRM International Society of Physical and Rehabilitation Medicine

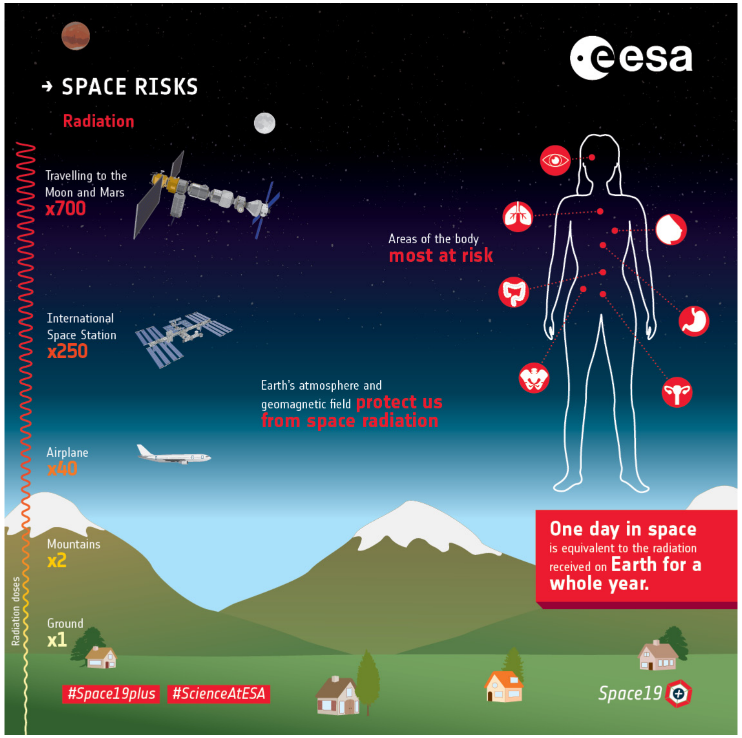
Effects of space flights on the human body

The main factors that change the functioning of the human organism in space are:

- Microgravity → conditions with minimal gravitational acceleration
- Exposure to cosmic radiation → galactic cosmic rays and solar particle events.

Shielding against galactic cosmic rays is very difficult.

One day in space is equivalent to the radiation of one year on Earth.



Tomsia M. et all Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024 Feb
https://www.nasa.gov/learning-resources/for-kids-and-students/what-is-microgravity-grades-5-8/
https://www.esa.int/ESA_Multimedia/Images/2019/05/Space_risks_Radiation

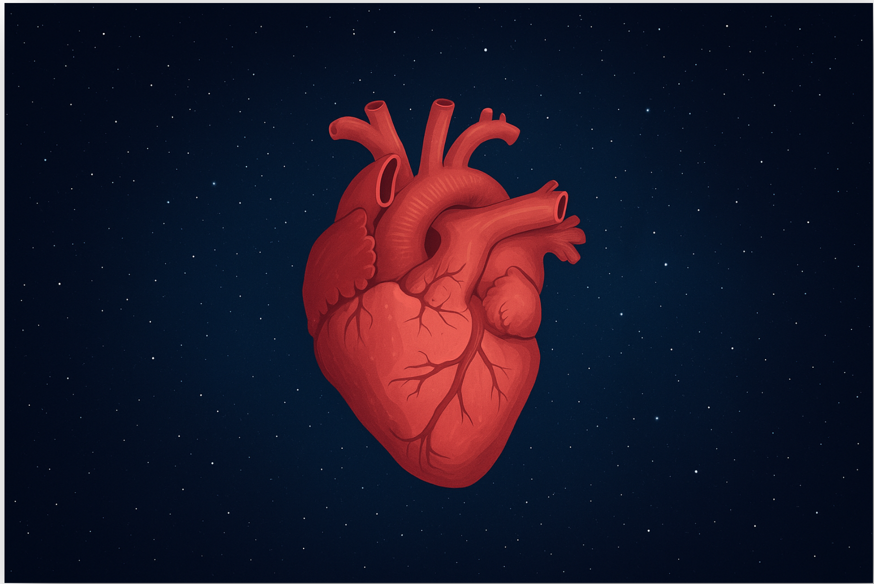
Cardiovascular system

In space:

- Reduced exercise tolerance and physical fitness
- Decreased heart rate, blood pressure, and pulse pressure

Coming back:

- Orthostatic intolerance and altered heart electrical rhythm



Tomsia M et al. Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024 Feb

Romero, E., and Francisco, D. (2020). The NASA human system risk mitigation process for space exploration. Acta Astronaut.

Respiratory system

Mars atmosphere: 95% CO_2, low pressure (636 Pa), weak gravity (3.71 m/s^2)

Main risks to lungs:

- Radiation exposure → tissue damage, inflammation, cancer risk
- Low gravity → fluid buildup, reduced lung capacity
- Pressure changes → decompression sickness (DCS), prevented by oxygen pre-breathe & campout protocols
- Dust inhalation → airway inflammation, long-term exposure risks

Research gaps:

- Limited data for missions >6 months
- Essential to study for future Mars missions

Tomsia M. et all Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024 Feb

Digestive system

- Microgravity, cosmic radiation, and stress affect digestive organs and gut microbiota.
- Liver may develop early non-alcoholic fatty disease or radiation-induced damage.
- Microgravity disrupts blood flow and gut motility; stress impacts secretion.
- Cosmic radiation increases risk of gastrointestinal cancer and inflammation.

- Proper diet with fiber, probiotics, and prebiotics may help maintain gut health.

- Future research: adapt food production, improve nutrition, and develop countermeasures.

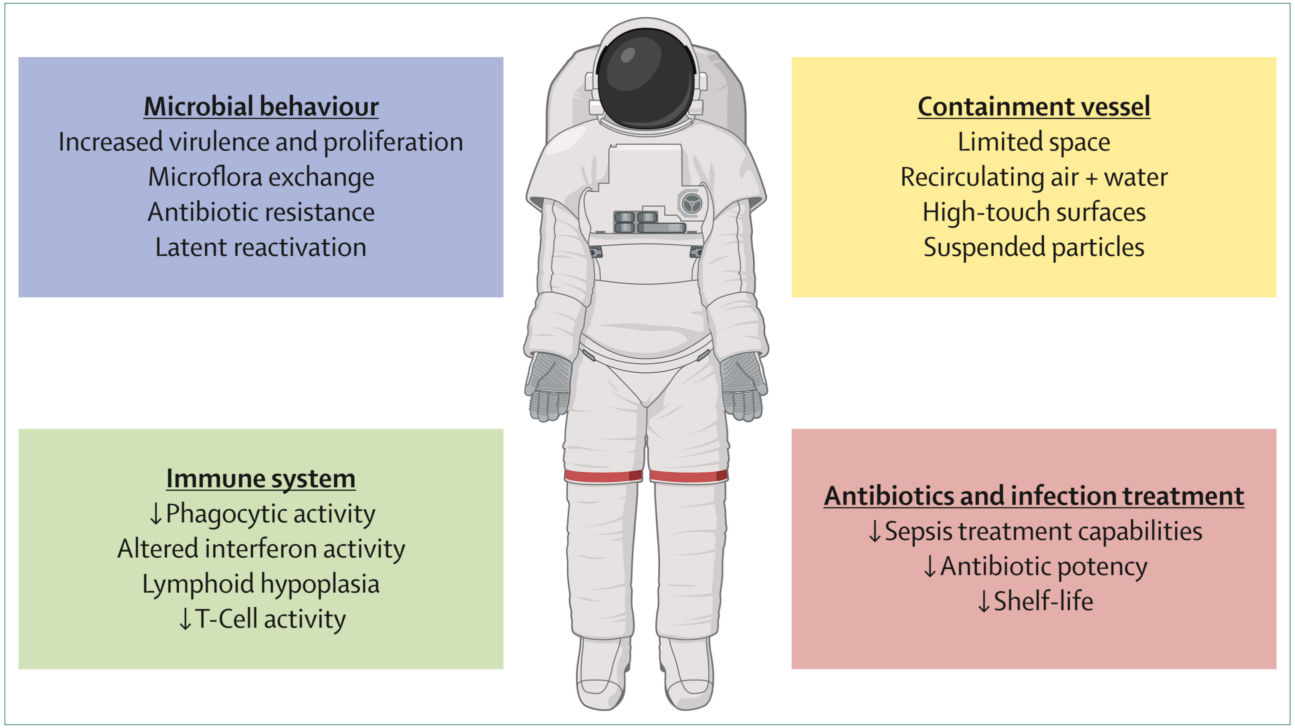
Tomsia M. et all Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024 Feb

Università degli Studi della Campania Luigi Vanvitelli
Cochrane Rehabilitation, Functioning, and Disability
WRA WHO hosted network
World Rehabilitation Alliance
ISPRM International Society of Physical and Rehabilitation Medicine

Immune system

- Decreased number of immune cells, increased inflammation, and decreased ability to fight off infections
- Herpes virus reactivation common; vaccines (e.g., VZV) can help prevent outbreaks.
- Gene expression shifts: less DNA repair and cell protection; more oxidative damage.
- Space radiation increases DNA damage, mutations, and cancer risk (lung, colon, leukemia).

- Future research: better radiation protection and immune support for long missions.

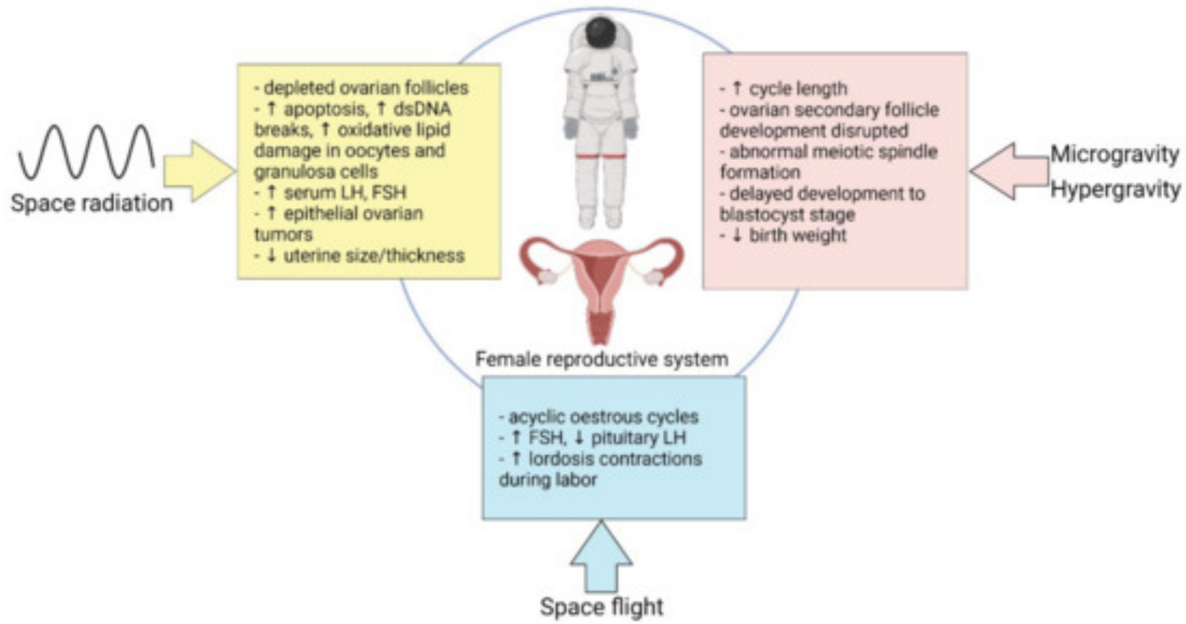


Tomsia M. et all Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024 Feb
Cowen D, et al. Infections in long-duration space missions. Lancet Microbe. 2024 Sep;5(9):100875.

Reproductive systems

- Space radiation damages sperm/eggs and reduces fertility; testosterone drops.
- Female astronauts face ovarian reserve decline and menstrual suppression risks.
- Embryos can develop in space but show genetic and epigenetic damage.

- Future research: protect fertility, study hormonal regulation, and reduce radiation effects.



Tomsia M. et all Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024 Feb
Drago-Ferrante R, et al. Extraterrestrial Gynecology: Could Spaceflight Increase the Risk of Developing Cancer in Female Astronauts? An Updated Review. Int J Mol Sci. 2022 Jul 5;23(13):7465.

Nervous system

Microgravity disrupts balance and orientation → dizziness, disorientation, motion sickness

Spaceflight-Associated Neuro-Ocular Syndrome (SANS): vision problems from fluid shift & increased pressure

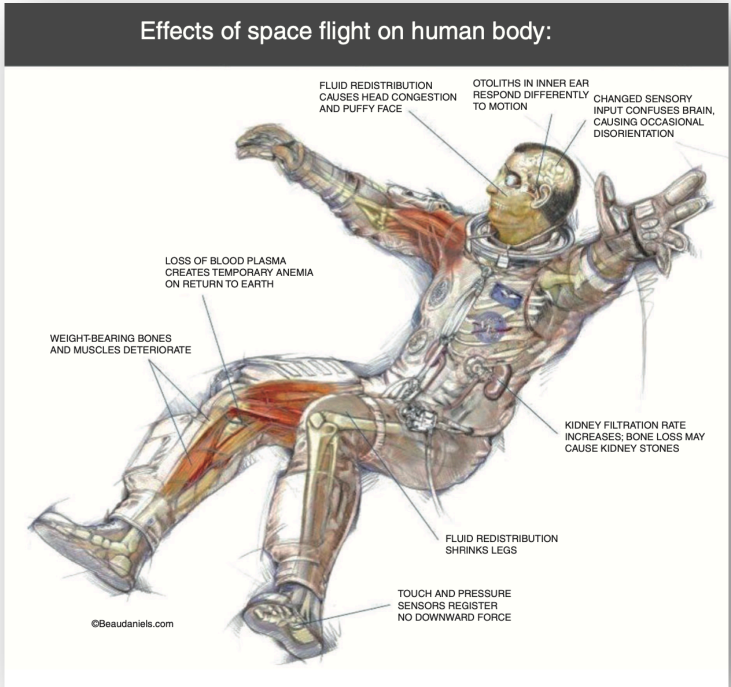
Long-term missions cause brain changes:

- Reduced gray matter, ventricle dilation, brain shift
- Affects memory, movement, and coordination
- Cosmic radiation → brain cell damage, aging, cancer risk

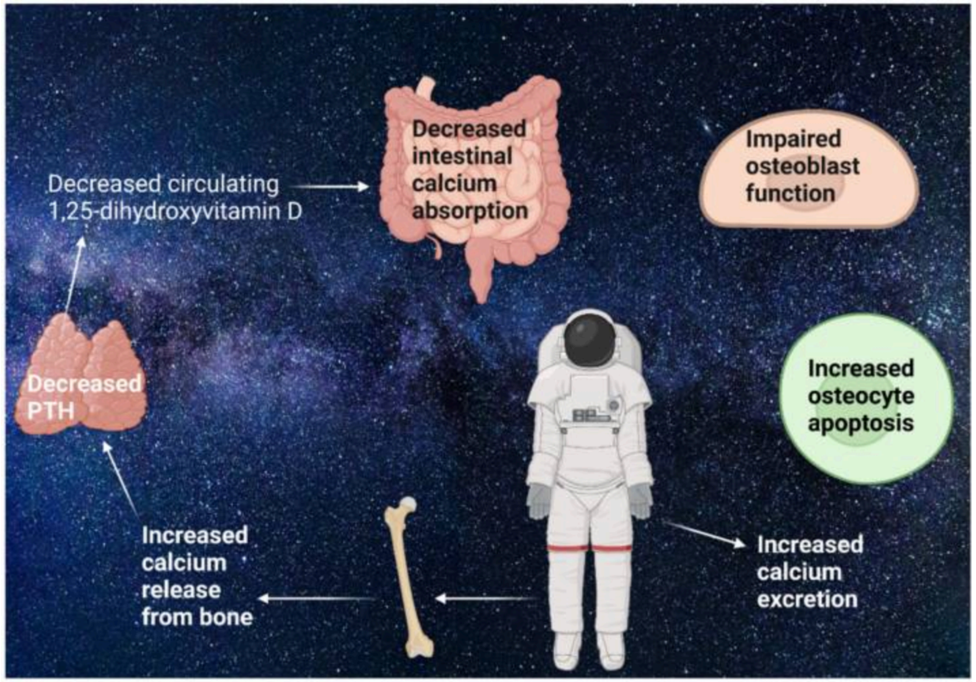
Psychological challenges:

- Stress, isolation, sleep issues, mood changes
- Need for psychological screening & support

Future astronaut selection: focus on neuropsychological and genetic resilience



Effects on musculoskeletal system



Microgravity → bone density & muscle strength loss, up to 20% BMD loss on long missions with slow recovery after return to Earth

Mechanisms: Microgravity disrupts Ca^{2+} balance & bone hormones and reduces osteoblast activity, increases bone resorption

Space Adaptation Back Pain (SABP) from spinal elongation

Possible long-term effects: cartilage thinning, osteoarthritis

Countermeasures: 2+ hrs/day aerobic + resistance training, vitamin D, balanced diet

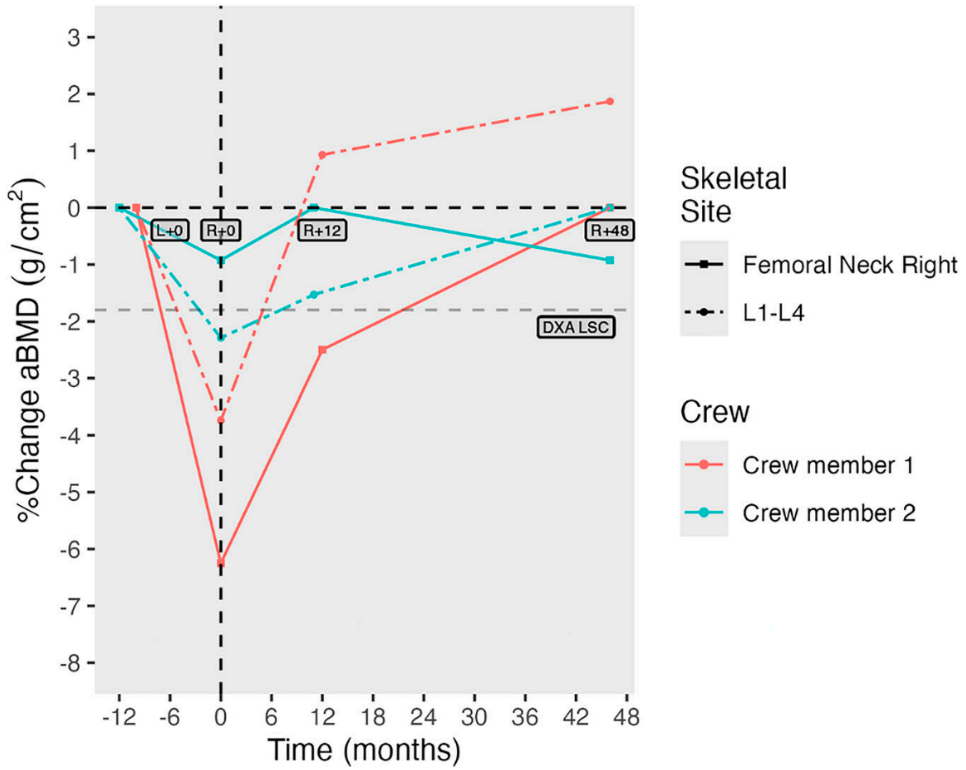
Current limits:

- Exercise & bisphosphonates help, but incomplete solution
- Need more research on anabolic muscle treatments

Grimm D, et al. The impact of microgravity on bone in humans. Bone. 2016 Jun
Juhl OJ 4° et al. Update on the effects of microgravity on the musculoskeletal system. NPJ Microgravity. 2021
Baran R, et al. Microgravity-Related Changes in Bone Density and Treatment Options: A Systematic Review. Int J Mol Sci. 2022
Man J, et al. The effects of microgravity on bone structure and function. NPJ Microgravity. 2022
Tomsia Met al. Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024

The duration of spaceflight effects

Assessments: HR-pQCT and DXA performed pre-flight and up to 48 months post-flight on two crew members.
Immediate Effects:
Both: Substantial tibial bone loss upon return.
One: Additional radius loss observed.
4-Year Recovery:
•Crew Member 1: Full skeletal recovery.
•Crew Member 2: Persistent trabecular deficits, offset by cortical thickening.
Implications:
•Highlights need for individualized countermeasures.
•Supports long-term bone monitoring post-mission.
•Provides insights into bone adaptation during unloading and reloading.



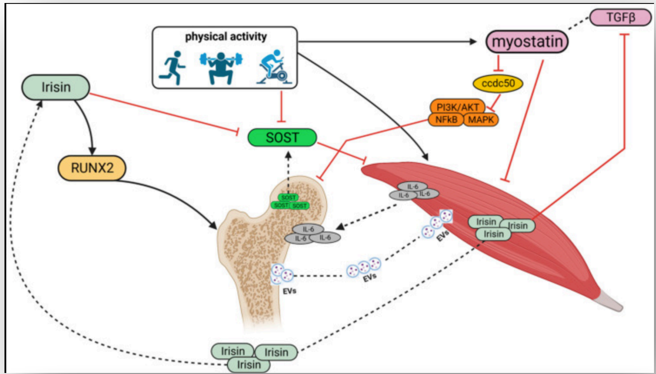
Matheson BE, Walle M, Liphardt AM, Hulme PA, Heer M, Zwart SR, Sibonga JD, Smith SM, Gabel L, Boyd SK. Recovery of bone microarchitecture and density four years after spaceflight: two case studies. NPJ Microgravity. 2025 Jul 28;11(1):47. doi: 10.1038/s41526-025-00511-x. PMID: 40721429; PMCID: PMC12304210.

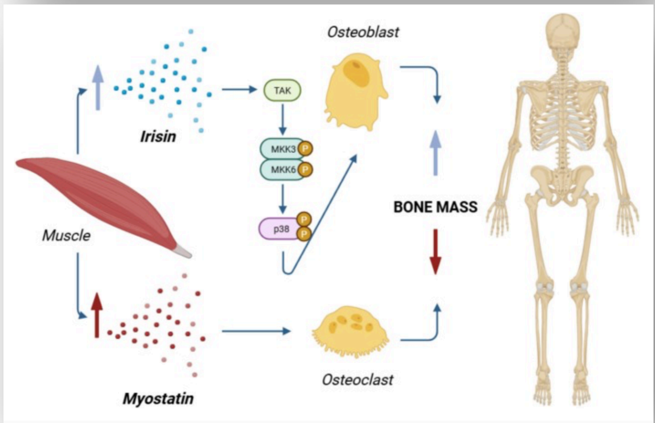
Università degli Studi della Campania *Luigi Vanvitelli*
Cochrane Rehabilitation, Functioning, and Disability
WRA WHO hosted network
World Rehabilitation Alliance
ISPRM International Society of Physical and Rehabilitation Medicine

Effects of physical activity on musculoskeletal system

Irisin is secreted by skeletal muscle cells in response to **physical activity** which

- increases muscle mass and even hypertrophy of muscle fibres
- stimulates osteoblast differentiation





Dalle Carbonare L, et al. Crosstalk between Bone and Muscles during Physical Activity. Cells. 2023

Jaśkiewicz Ł, et al. Effect of myokines on bone tissue metabolism: a systematic review. Bone. 2025

NASA SPRINT exercise program efficacy for vastus lateralis & soleus skeletal muscle health during 70 days of simulated microgravity

Key Findings

BR (bedrest only):
- Surprisingly, the typical bedrest-induced decrements invastus lateralis myofiber size and power were either blunted (MHC I) or eliminated (MHC IIa).
- No change (P>0.05) in %MHC distribution and blunted quadriceps atrophy.

BRE (bedrest with resistance & aerobic exercise):
- MHC I (vastus lateralis and soleus) and IIa (vastus lateralis) contractile performance was maintained (P>0.05) or increased (P<0.05)
- Vastus lateralis hybrid fiber percentage was reduced (P<0.05) and energy metabolism enzymes & capillarization were generally maintained (P>0.05), while not all of these positive responses were observed in the soleus.
- Exercise offset 100% of quadriceps and ~ ⅔ of soleus whole muscle mass loss.

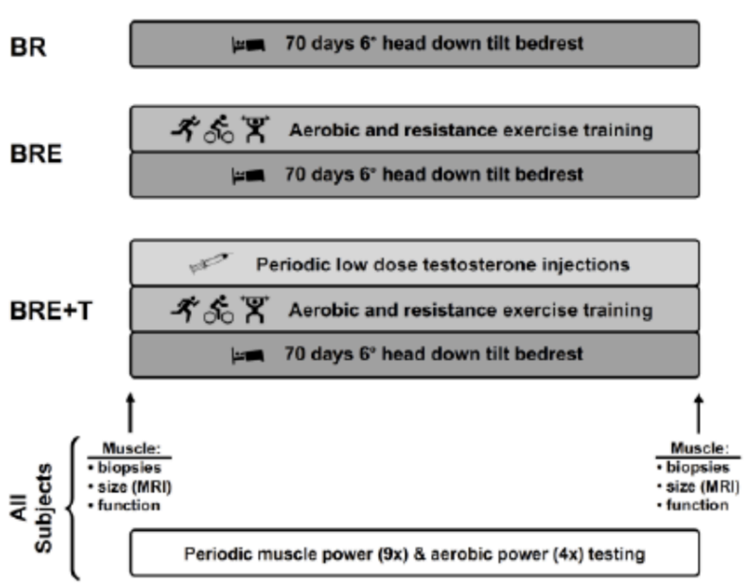
BRE+T (bedrest with exercise + testosterone):
- Testosterone did not provide any benefit over exercise alone for either muscle, and for some myocellular parameters appeared detrimental.

Summary Points

The extremely low exercise dose of the periodic testing likely provided a partial exercise countermeasure for the quadriceps in the bedrest group

The SPRINT exercise program appears to be viable for the quadriceps; however, refinement is needed to completely protect triceps surae myocellular and whole muscle health for astronauts on long-duration spaceflights.

Study Protocol



Protocol schematic of the 70 day simulated microgravity study for subjects in bedrest only (BR), bedrest with resistance and aerobic exercise (BRE), and bedrest with resistance and aerobic exercise + testosterone (BRE+T).

Trappe TA, et al. NASA SPRINT exercise program efficacy for vastus lateralis and soleus skeletal muscle health during 70 days of simulated microgravity. J Appl Physiol (1985). 2024 May 1;136(5):1015-1039.

NASA/SP–20250000273

Astronaut physiological deconditioning and exercise prescription countermeasures in spaceflight

Sarah D. Taoufik, Office of the Chief Health and Medical Officer, JES Tech, Houston, Texas
Kristin M. Coffey, Office of the Chief Health and Medical Officer, KBR Systems, Houston, Texas
David R. Francisco, Office of the Chief Health and Medical Officer, NASA, Houston, Texas

January 2025

«NASA scientists have developed an exercise prescription for astronauts during their missions to the ISS to mitigate decrements to their cardiovascular system, musculoskeletal system, and bone density. In addition, exercise in-flight improves overall crew health and performance, maximizes reconditioning post-flight, and prevents injury.»

«The schedule consists of a recommended 2.5 hours a day/6 days a week of exercise with 30-60 minutes of resistive training and average 27 minutes of metabolic/aerobic training.»

Table 5. Current Spaceflight Exercise Protocol

Type of Exercise	Protocol Guidelines	Equipment
Metabolic/Aerobic	Average 27 minutes of interval or steady-state training. Based on a pre-flight VO_{2peak} of 70-100%. Increased intensity (watts) based on monthly fitness evaluation and changes in VO_{2peak}.	CEVIS & T2 Treadmill
Resistance	Average 30-60 minutes of training. Nominally starting crew at their bodyweight or loads from preflight training sessions and increasing based on comfort and capability. Linear progression of loads for upper body; undulating volume for lower body.	ARED

Università degli Studi della Campania *Luigi Vanvitelli*

Cochrane Rehabilitation, Functioning, and Disability

WRA WHO hosted network

World Rehabilitation Alliance

ISPRM International Society of Physical and Rehabilitation Medicine

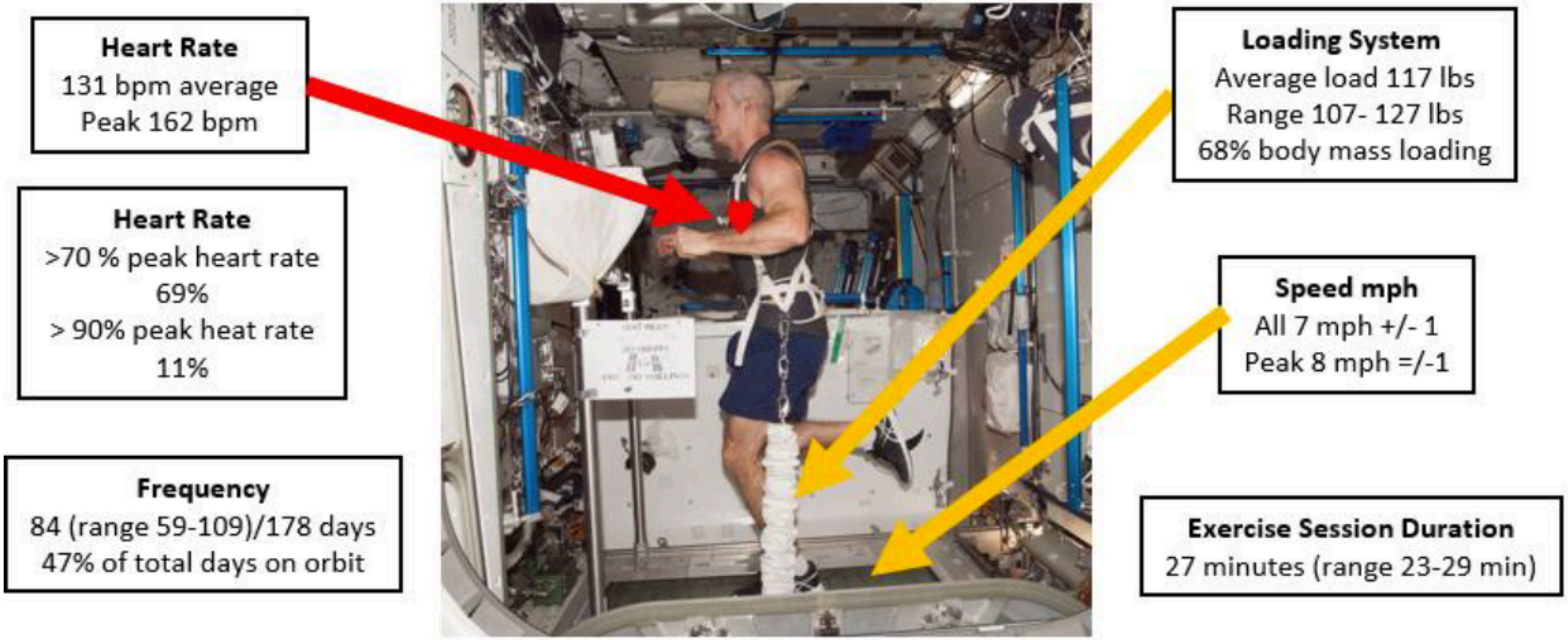


Figure 2. ISS Treadmill – T2

Overview of ISS treadmill capabilities

Figure 3. ISS ARED – Squat

Overview of ARED capabilities

Università degli Studi della Campania *Luigi Vanvitelli*

Cochrane Rehabilitation, Functioning, and Disability

WRA WHO hosted network

World Rehabilitation Alliance

ISPRM International Society of Physical and Rehabilitation Medicine

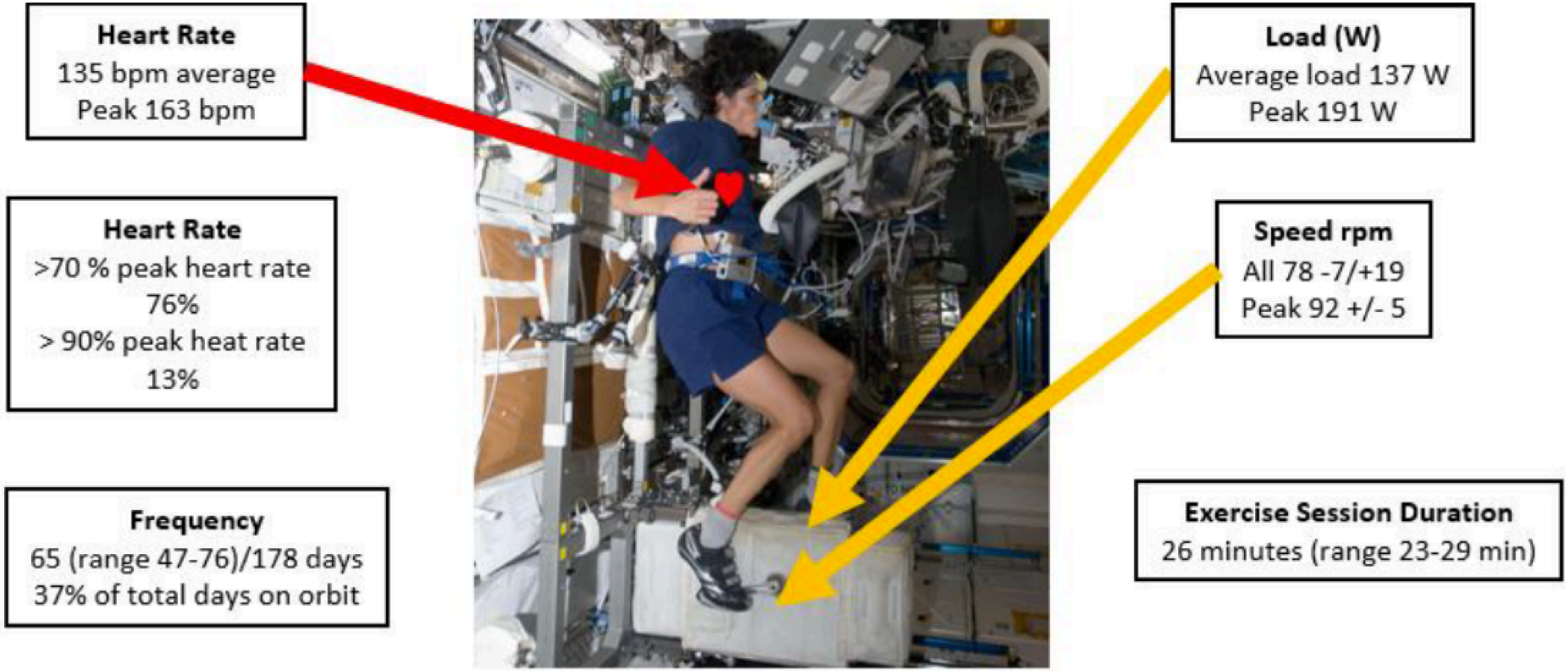


Figure 4. ISS CEVIS

Overview of CEVIS capabilities

Directions of future research on the impact of long-term space flights on the human body

Human body system	Research direction
All systems	Creating an artificial gravity station whose conditions would faithfully reproduce terrestial conditions, which would expand knowledge on human physiology in space
Respiratory system	Determining how exposure to cosmic radiation affects the human respiratory system, and in particular what is the specific relationship between such exposure and the potential development of cancer in astronauts
Nervous system	Investigating the impact of exploration, meaning specific stressors, including isolation and confinement, on the wellbeing, cognitive function, and immune health of crew members
	Designing space station for greater physical and psychological comfort: reducing noise and vibration, adequate lighting to benefit the circadian rhythm
	Developing emergency management schemes for neurological diseases and psychiatric emergencies in space
Specialized senses	Identifying potential changes in the perception of taste and smell as a means of preventing anorexia in space
Musculoskeletal system	Determining the relationship between baseline bone mineral density (BMD), muscle strength, and muscle mass Determining the condition of the musculoskeletal system after spaceflight, and checking whether higher initial physical fitness has a positive effect on regeneration after long-term spaceflight
	Exploring the potential use of eccentric training as a supplementary method to current resistance training practices in space, and how it builds upon the effects of higher-load resistance training
Excretory system	Developing standardized experiments to determine changes in hormone fluctuations and their effect on humans as data on hormone levels in space are often contradictory
Reproductive system	Investigating the effects of space conditions on fetuses and children development in the perspective of life in space

Tomsia M. et all Long-term space missions' effects on the human organism: what we do know and what requires further research. Front Physiol. 2024 Feb

Health strategies

Health Strategy	Health goals	Health indicator	Data coding
Preventive	Prevent the occurrence of health conditions Prevent mortality related to the occurrence of health conditions Prevent the loss of functioning related to the occurrence of health conditions	Morbidity Mortality Biological Health (intrinsic health capacity)	ICD ICF ICD11
Promotive	Optimal health	Biological Health (intrinsic health capacity)	ICF
Curative	Cure (full recovery) Remission Disease control	Mortality Morbidity Functioning (intrinsic health capacity)	ICD ICD11
Rehabilitative	Optimal functioning	Functioning	ICF
Palliative	Optimize wellbeing	Appraised functioning (quality of life)	ICF

Adapted from Table I in Stucki G, Bickenbach J. Functioning: the third health indicator in the health system and the key indicator for rehabilitation. Eur J Phys Rehabil Med 2017;53:134-8.

Rehabilitation is…

*…a set of interventions designed to **optimize functioning and reduce disability** in individuals with **health conditions in interaction with their environment***

Integrity in

Body functions
Body structures

Activities and

Participation

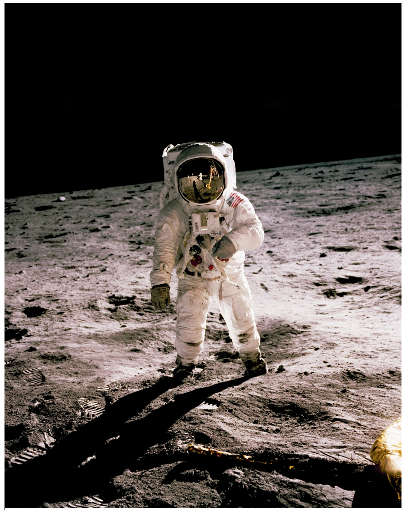


Photo by History in HD on Unsplash

Impairments in

Body functions and
Body structures

Limitations in activities and

Restrictions in participation

Complete **functioning** ⟷ Complete **disability**

Università degli Studi della Campania *Luigi Vanvitelli*

Cochrane Rehabilitation, Functioning, and Disability

WRA WHO hosted network

World Rehabilitation Alliance

ISPRM International Society of Physical and Rehabilitation Medicine

Microgravity as a model for validating the effectiveness of new scaffolds designed for bone regeneration in counteracting bone loss

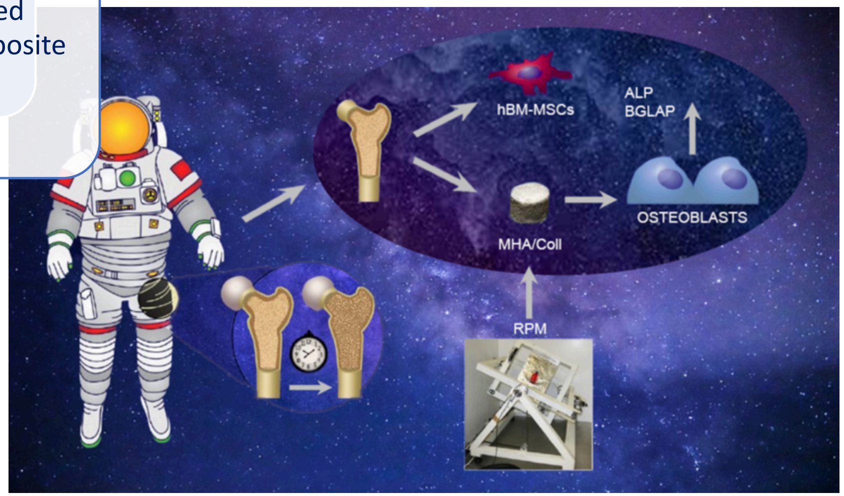
Prolonged exposure to microgravity (MG) during long-duration space flights induces severe dysregulation of osteoblast functions connected to significant bone loss, similarly to osteoporosis. **Hence, we presented MG as a promising model to challenge the effectiveness of new scaffolds designed for bone regeneration in counteracting bone loss.**

We evaluated in the extreme condition of Random Positioning Machine-simulated MG, the osteoinductive potential of nanocrystalline magnesium-doped hydroxyapatite/type I collagen composite scaffold (MHA/Coll).

> Front Bioeng Biotechnol. 2020 Jul 8;8:722. doi: 10.3389/fbioe.2020.00722. eCollection 2020.

Bioinspired Scaffold Action Under the Extreme Physiological Conditions of Simulated Space Flights: Osteogenesis Enhancing Under Microgravity

Elisabetta Avitabile [1], Laura Fusco [2 3 4], Silvia Minardi [5], Marco Orecchioni [1], Barbara Zavan [6 7], Acelya Yilmazer [8 9], Martina Rauner [10], Proto Pippia [11], Ennio Tasciotti [12], Lucia Gemma Delogu [1 3 13]



This study demonstrated MHA/Coll capabilities in promoting osteogenesis even in extreme long-term condition of MG, suggesting MG as an effective model for future studies to validate the ability of advanced scaffolds to counteract bone loss, facilitating their application in translational Regenerative Medicine and Tissue Engineering.

Università degli Studi della Campania *Luigi Vanvitelli*

Cochrane Rehabilitation, Functioning, and Disability

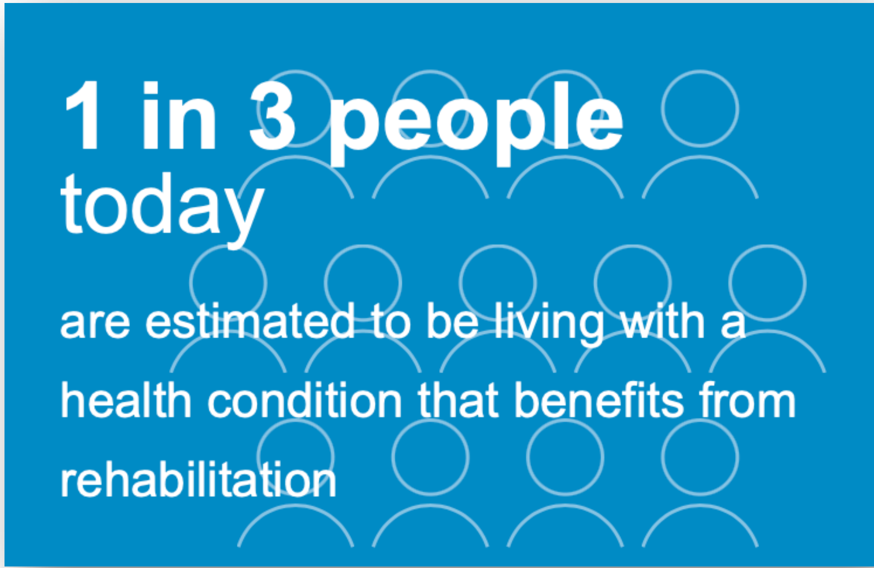
WRA WHO hosted network

World Rehabilitation Alliance

ISPRM International Society of Physical and Rehabilitation Medicine

Global estimates of the needs of rehabilitation

2.6 billion people, one third of worldwide population **could benefit from rehabilitation** at least once in the course of their illness or injury



Cieza A, Causey K, Kamenov K, Hanson SW, Chatterji S, Vos T. Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2021 Dec 19;396(10267):2006-2017. doi: 10.1016/S0140-6736(20)32340-0. Epub 2020 Dec 1. Erratum in: Lancet. 2020 Dec 4;: PMID: 33275908; PMCID: PMC7811204

WHO Rehabilitation Need Estimator | Viz Hub
Institute for Health Metrics and Evaluation © 2021 University of Washington http://ihmeuw.org/5cpi.

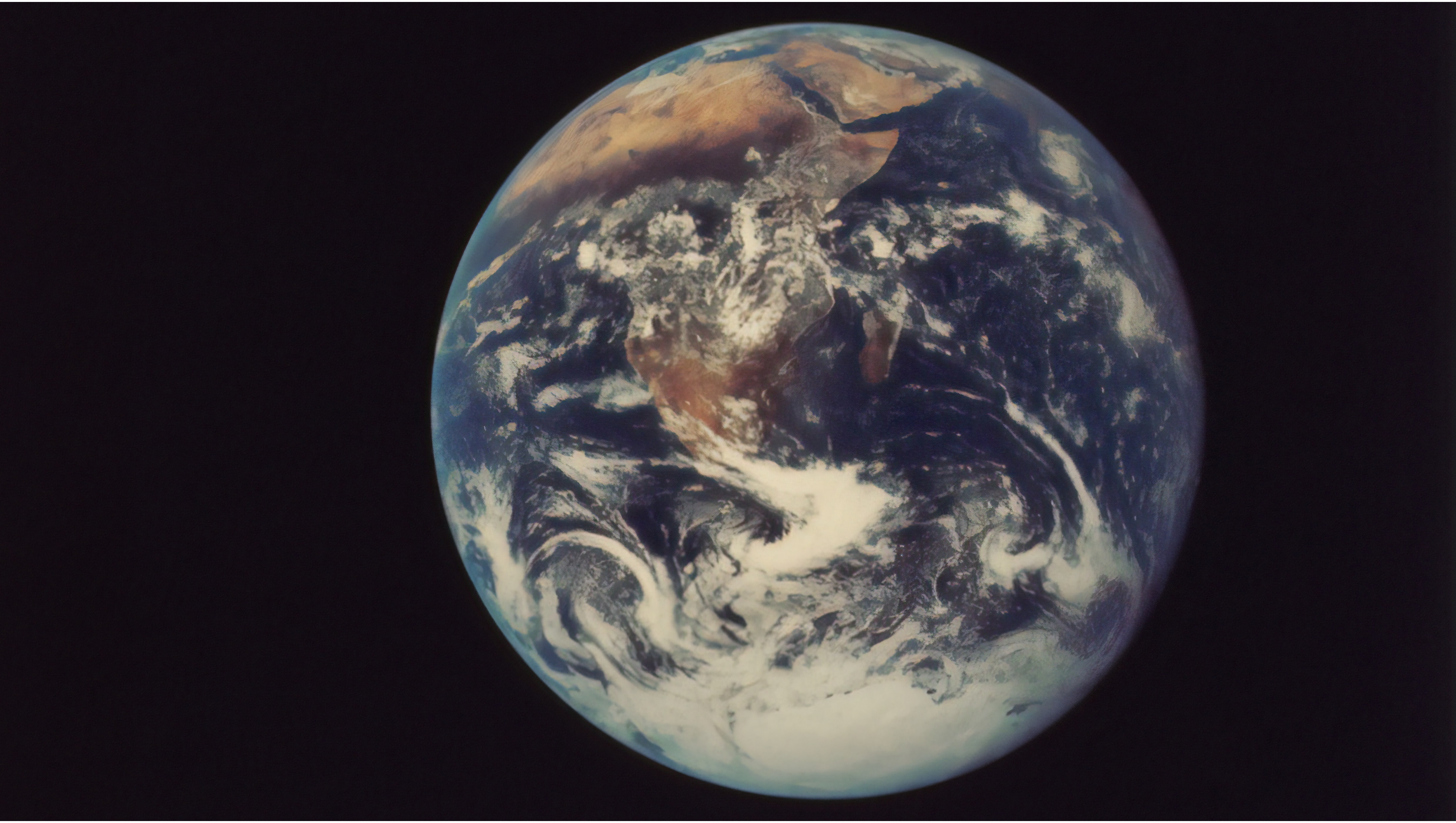
Università degli Studi della Campania *Luigi Vanvitelli*

Cochrane Rehabilitation, Functioning, and Disability

WRA WHO hosted network

World Rehabilitation Alliance

ISPRM International Society of Physical and Rehabilitation Medicine



ISPRM 2025

https://isprm25.com/about-us/

THANK YOU for your attention b140 and for listening d115