Karl Landsteiner Institut für Neurorehabilitation und Raumfahrtneurologie

Austrian Society for Aerospace Medicine Life Sciences in Space

Space Neurology and the Use of astronauts/cosmonauts Equipments in Neurorehabilitation

F. Gerstenbrand[1), 2)], Vienna, Innsbruck
St. Golaszewski[3)],Salzburg,
G. Pichler[4)], Graz

[1)] Karl Landsteiner Institute for Neurorehabilitation and Space Neurology
[2)] Department of Neurology, University of Innsbruck
[3)] Department for Neurology, Christian Doppler-Klinik Salzburg
[4)] Apallic Care Unit, Albert Schweitzer-Klinik Graz

Special Meeting for Abu Dhabi Neurologists
March 31st, 2011
Abu Dhabi

Requirements for Space Missions

- Development of technical equipment
- Radiation effect on technical equipment and biological structures
- Communication system
- Influence on crystallization phenomena
- Biomedical problems in manned space mission
  - biophysiological exposure
  - radiation exposure

Organization and cooperation

- Organization of Space Agencies
- Development of an International Space Organization
- Cooperation of national, regional space agencies (NASA, ESA, Japanese Space Agency, Chinese Space Agency, Russian Space Agency)

- Research in ground based laboratories
- Research programs during space flights
- Construction and preparation of orbit station
- Preparation of moon flight missions, moon based laboratories
- Preparation of a mars mission

Research in Manned Space Missions

Is based on
- The biological predisposition for a stay of a human being out of the normal earth gravity
- Physiological adaptation in the microgravity
- Preparation time for a space flight
- Research on pathophysiological reaction during the start phase
- Research on the pathophysiological problems during a space flight
- Research after return to the earth gravity

First Intentions: Military Space Flight

Research in Space
Space Medicine in real microgravity

- Influence of the real microgravity on human beings, animals, plants and biological material
- Radiation effects in space – biological and technological material
- Influence of psycho-social factors
- Technological development of equipment for human beings during space flight
- Communication system between control center and orbit crew

Construction of a Control System for the Orbit Station

„Our job is not only to make sure astronauts can function adequately in space, but also that they can function on their return to earth." (Frank Sulzmann)

Source: G. Gerstenbrand

Space Medicine
Influence of Microgravity

- Research in biomedical problems
  - space neurology
  - cardio-vascular alterations
  - immunology, infection and hematology
  - human performance factors, sleep and chronobiology
  - nutrition and digestion
- Development of new medical devices for counter measure during space missions

Statement to Manned Space Flight

Wernher von Braun, 1951:

"I believe that the time has arrived for medical investigation of the problem of manned rocket flight, for it will not be the engineering problems but rather the limits of human frame. That will make the final decision as to whether manned spaceflight will eventually become a reality."

History of Space Medicine 1

- Take-over of experiences in aviation medicine
- Research in training centrifuge
- Research in rocket sledge
- First Department for Space Medicine in Randolphsville, TX, USA
- Institute for Biomedical Problems (IBMP), Moscow, Russia
- Animal experiments in the orbit (IBMP Moscow – Laika, first dog in space)

Laika, Nov 3rd,1957

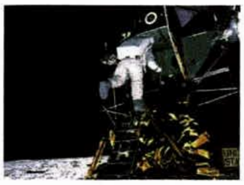
„Ham the Astrochimp", Jan 31st, 1962

History of Space Medicine 2

- April 12th, 1961 - Juri A. Gagarin
  first manned space flight, space capsule Wostok 1
- May 5th, 1961- A. Shepard
  first American in space,
- March 18th, 1965 - Alexei Leonov
  first space walk
- July 16th, 1969 - first moon landing
- July 20th, 1969 - Neil Armstrong,
  first moon walk
- Feb 20nd, 1986 - start of space station MIR
  (base module)
- Nov 20nd, 1989 - start of construction of ISS –
  first module SARJA
- Manned Mission to Mars, in preparation

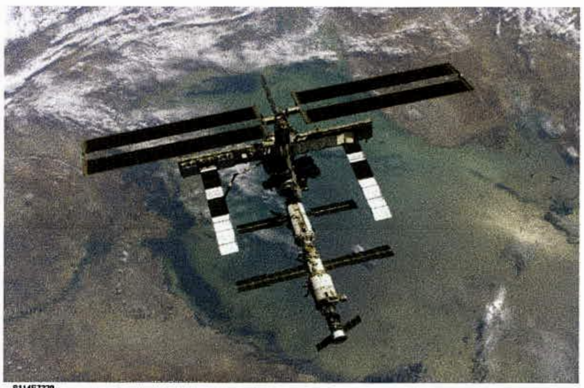
Neil Armstrong, 1969

Buzz Aldrin, 1969



MIR in space, destroyed March 23rd 2001

Launch of Soyuz TMA-5



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International Space Station (ISS) organized by Americans, Russians, Europeans

Surface of Mars

Northpole of Mars, ice on polar cap, NASA

Twinpeaks, photographed by Pathfinder Lander, 1997, NASA

Space life in MIR

Austrian cosmonaut Franz Viehböck with Russian crew at MIR

Space life in MIR

Cosmonauts at MIR in free time

"Lunch-time"

Counter Measures in Real Micrograviy

- Treadmill exercises
  - Daily fixed program
- Special exercises legs and arms
- Adaptation of fine motor skills
  - Target training
- Adaptation training of cognitive functions
- Electrode trousers
- Penguin suit

Real Microgravity


Cosmonauts at MIR in training

Real Microgravity

Cosmonauts counter measure:
Electrode trousers: stimulation of muscle receptors

Penguin-Suit, worn for hours per day. Every movement has to be carried out against resistance of the suit.

Research in Microgravity

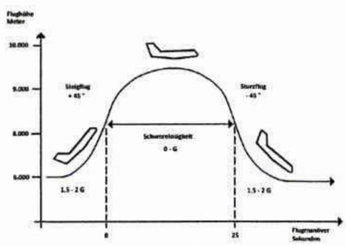
- Real microgravity
- Parable flight
- Simulated microgravity
  - Ground based laboratory

Research Experiment in Space Real Microgravity

Motor exercises, recording with EMG

Source: http://images.jsc.nasa.gov/images/pao/STS44

Transient Microgravity - Parable Flight



Microgravity only for few seconds.
Diminishes research program.

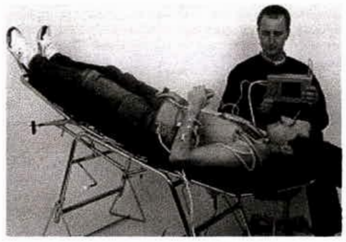
Simulated microgravity

Ground based laboratory

Special equipment necessary

- Methods
  - Bedrest system
    - Head down tilt-system – HDT
  - Body weight discharge
  - Dry water immersion model – DWI-method

Simulated microgravity



Head down tilt position (HDT), bedrest method

Unilateral body weight discharge

Simulated microgravity
Dry water immersion model – DWI-method

Healthy volunteer, experiment 72 hours, consequent neurological control.

Simulated microgravity
Dry water immersion model – DWI-method

DWI institution, Innsbruck, Neurospace Institute, 2 healthy volunteers, 48 hours experiment

DWI experiment, healthy volunteer lift out for showering

Simulated microgravity
Dry water immersion model – DWI-method

Preparation phase, EMG control

Preparation phase

Experimental phase

Experiment for exact hitting a changing target

Simulated microgravity
Dry water immersion model – DWI-method

Optomotoric examination

Examination of the positional reflexes

Neurological examination, healthy volunteer

Ground based laboratory IBMP, Moscow

Space Neurology - 1

- Research content: influence of microgravity
  - Real microgravity
    - Influence on the proprioceptive system
    - Influence on the vestibular system (otholit system)
  - Simulated microgravity, ground based laboratory
    - Influence on the proprioceptive system

Space Neurology - 2

- Use of the research results in acute neurology
  - Neurodiagnosis
  - Neurorehabilitation
- Development of new methods and development of new devices
  - Acute neurology
  - Neuro-rehabilitation

Neurological Disturbances in Real Microgravity

- Adaptation phase to real microgravity
  - disturbances during start phase
    - Space Adaptation Syndrome
- Neurological disturbances during space mission
  - Cosmonaut syndrome

Space Adaptation Syndrome (SAS)

- Vestibular disturbances (vertigo, nausea, vegetative symptoms)
- Motor disturbances (hypermetria, dysmetria, etc.)
- Optomotoric disturbances
- Proprioceptive disturbances
  - Body scheme disturbances
  - Pseudoapraxia

Space Adaptation Syndrome

Astronauts acclimating during parabolic flight.

Complaints:
- Disorientation
- Visual illusion
- Motion sickness (Nausea)

Source: http://science.nasa.gov/science-news/science-at-nasa/2001/ast07aug_1/

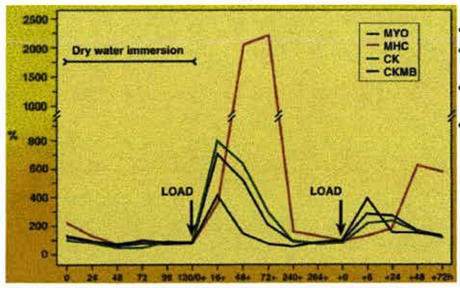
Cosmonaut Syndrome
(Astronaut Syndrome)

- Primary muscle atrophy (changing of muscle enzymes)
- Polyneuropathy
- Proprioceptive disturbances (joint position recognition, vibration perception, hypo/areflexia, spinal ataxia)
- Thalamic disturbances, changing in body scheme
- Programmed motor disturbances (eye-head-coordination, etc.)
- Cerebellar ataxia
- Body scheme disturbances
- Decrease in vigilance
- Vegetative dysregulation
- Osteoporosis

Bedrest Syndrome

- Primary muscle atrophy with muscular changes and structural lesions
- Changing in muscle enzymes
- Polyneuropathy
- Proprioceptive disturbances (spinal ataxia, deep sensation disturbances)
- Thalamic symptoms
- Decrease in vigilance
- Cognitive disturbances
- Body scheme disturbances
- Osteoporosis

Pattern of Skeletal Muscle Proteins after DWI for 5 days followed by isometric muscle load



- Myoglobin: Myo
- Myosin heavy chain fragments: MHC
- Creatine kinase enzyme activity: CK
- Creatine kinase MB isoenzyme enzyme mass: CK-MB

Source: Artner Dworzak et al, 1993

Pattern of skeletal muscle proteins which were measured in the plasma of a healthy male volunteer. The concentrations are shown as percent increase from baseline value. Total immobilization (DWI) lasted for 5 days followed by a standardized isometric muscle load. After a regeneration period of 14 days the same procedure of muscle load was performed but with a 2-fold increased isometric load.

Bedrest Syndrome - Etiology

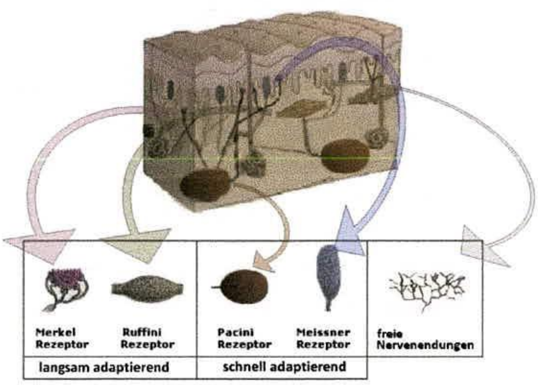
- Experimental induced – ground based laboratory
- Pathogene origin
  - Long-lasting coma-states, apallic syndrome, etc.
  - Cardio-vascular disturbances, long bed stay
  - Post-traumatic states, severe bone fractures, Parkinson Syndrome – reduced mobility
  - Dementia – reduced mobility
  - Spasticity
- Psychiatric patients, reduced motion, drug induced
- Elderly people, reduced motion

Pathophysiological sequences in Cosmonaut and Bedrest Syndrome

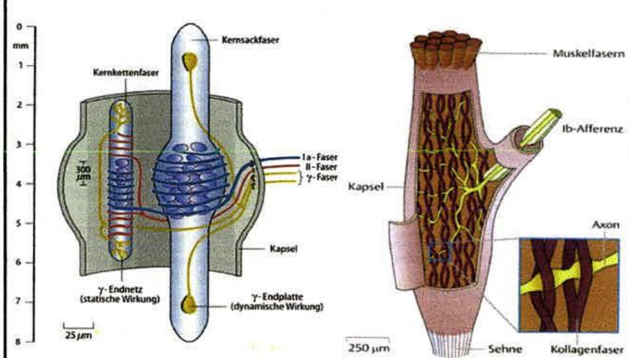
(real and simulated microgravity)

- Experimental state and patients
- Microgravity influencing the gravity receptors with disturbances of the proprioceptive system
  - Disturbances of motor system, body movement
  - Disturbances of the upright position
  - Disturbances of the sensor system, reafference
  - Disturbances of the thalamic function
  - Disturbances of frontal lobe functions, cognitive abilities (psycho-motoric coordination, associativity, critic s, emotional control)
  - Disturbances of vigilance

Scheme of Mechano-Receptors

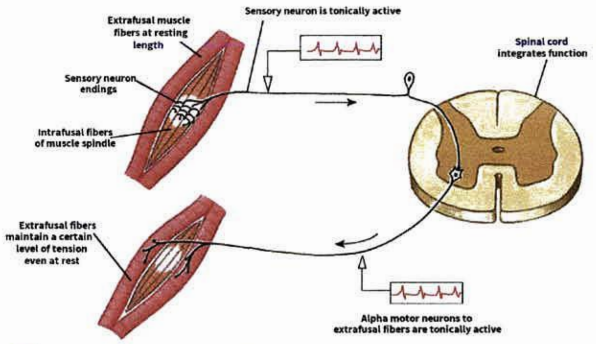


Scheme of muscle spindles

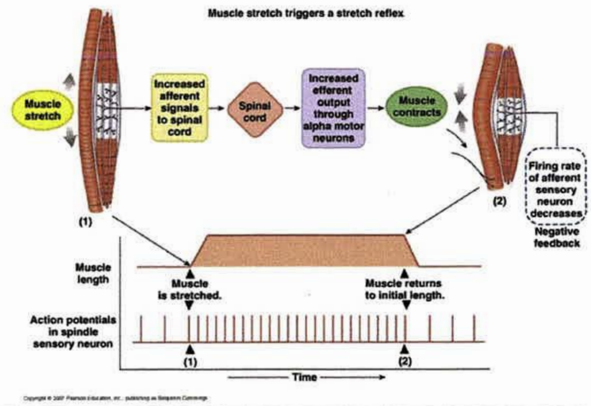


Schmidt, Lang, Heckmann. Physiologie des Menschen, Springer, 2010

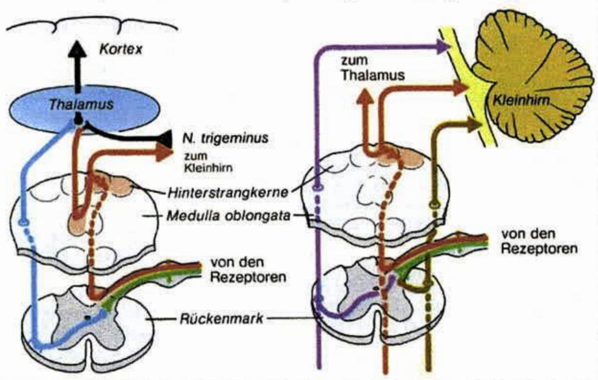
Function of muscle spindles



Function of muscle spindles



The Proprioceptive System
Responsible for the perception of gravity



Experimental Verification
Influence of foot sole vibro -stimulation

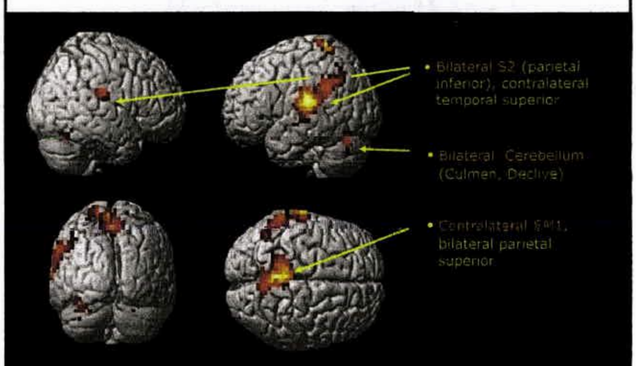
- Functional MRI (fMRI) in healthy volunteers
  - BOLD-effect (Blood oxygenation level-dependent), main focus in centers of the postural system (motoric, proprioceptive, epicritic, cerebellar centers)
  - BOLD effect in other foci like frontal lobe, temporal lobe, thalamus, cingulate gyrus, inferior part of parietal lobe

Vibrotactile Stimulation of the Foot Sole, Moving Magnet Actuator System

Vibration frequency 50 Hz

Stimulation of muscle spindles and Paccini-corpuscles

Result of vibrostimulation of the foot sole
Different methods in neuro-rehabilitation



Use of Research Results in Neurology and Neurorehabilitation

- Bedrest examinations, acute results
  - manifestation of minimal brain lesions during examination phase
- Use of research results in real and simulated microgravity
  - Different methods in neurorehabilitation
  - Geriatrics
  - Psychiatric disorders
  - Methods in wellness

Counter Measures in Real Microgravity

- Treadmill exercises
  - Daily fixed program
- Special exercises legs and arms
- Adaptation of fine motor skills
  - Target training
- Adaptation training of cognitive functions
- Electrode trousers
- Penguin suit

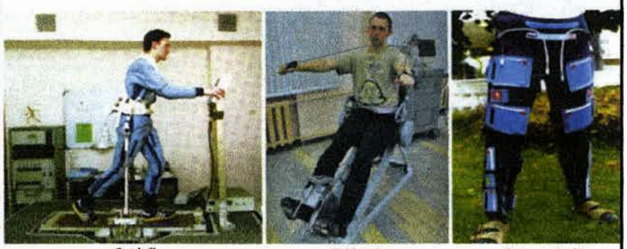
Use of counter measures in Neuro-rehabilitation

- Motor disturbances (Parkinson Syndrome, spasticity, cerebellar disturbances, disturbances of the peripheral nerve system)
- Apallic syndrome, Locked-in syndrome
- Severe conditions after stroke, motor disturbances, cognitive failures
- Severe conditions after traumatic brain injury
- Prevention of bedrest syndrome
- Dementia

Different Devices as a Spin-off effect of Space Neurology

- Prevention tools for space missions (treadmill, weight trainer, trousers with electrostimulators)
- Pressure shoe – Austrian model
- Pressure shoe – Russian model
- Korvit System – Foot loading imitator
- Regent – treatment suit
- Penguin System
- Adeli System

New Neuro-Rehabilitation Methods



Treadmill Weight trainer Electromyostimulator

Prevention tools for space mission

Used in:
minimal neurological disturbances (spasticity, cerebellar disturbances, Parkinson Disease, polyneuropathy, early dementia state)
Geriatrics, wellness training

Source: Manned Mission to Mars, Russian Academy of Cosmonautics, 2006

Pressure shoe – Austrian model

Used in:

long-lasting coma states (intensive care units)

Locked-in syndrome

Apallic syndrome

Severe stroke defects

Severe states after traumatic brain injury

Planned:

Geriatric institutions

Korvit - Foot loading imitator Imitating gait movement

Used in:
Gait disturbances; Parkinson's Disease; Spasticity, different origin; Spinal cord lesions; Polyneuropathy;

Planned: Dementia, Geriatric institutions

Regent – Treatment Suit

Used in

Spasticity

Parkinson's Disease

Spinal cord lesions

Polyneuropathy

Stroke, severe defects

Planned In:

Dementia, Geriatric

Penguin suit

Used in:

Cerebral palsy

Spastic spinal paralysis

Planned:

Parkinson's Disease

Dementia

ADELI-SYSTEM

Used by:

Cerebral palsy

Spastic spinal paralysis

Stroke

Some diseases of vertebral spine

Planned:

M. Parkinson

Dementia

Source: ADELI Folder

Partial microgravity in underwater Neurorehabilitation method

- Scuba Diving - 4-5m depth
- Scuba Diving - 20-30m depth
- Scuba Diving in underwater tower
- Snorkel-Diving-System

Scuba Diving – A New Neurorehabilitation method – 1

Partial microgravity,
influence to proprioceptive system

- Diminishing in stimulation of the proprioceptive system
- Diminishing of the vestibular system
- Relaxation of vertebral spine system
- Pathophysiological explanation open
  - Reduced stimulation of the proprioceptive system

Scuba Diving – A New Neurorehabilitation method - 2

Partial microgravity,
influence to proprioceptive system

- Indications:
  - minimal spinal cord lesions (traumatic, MS, etc.)
  - vertebral spine disturbances
    - cervical myelopathy
    - lumbago with radicular/pseudoradicular symptoms

Scuba Diving – A New Neurorehabilitation method - 3

Partial microgravity
influence to proprioceptive system

- Additional method in neurorehabilitation
  - Mild Parkinson Syndrome
  - Mild spasticity (after stroke, TBI, etc.)
  - Mild form of cerebellar ataxia

Scuba Diving in depth 4 - 5 m

Precondition:

Always in pairs with special trained physio-therapist

Development of new medical devices for neurodiagnosis in neurological diseases

- Using bedrest method in early state of Parkinson Disease, spasticity, cerebellar disturbances, frontal lobe syndrome, etc.
- Examination during a stay in a bedrest monitoring program, lasting for 72 hours
- Monitoring of a neurological state, clinically and with additional methods (EEG, EMG, MRI pre- and post examination program, other specific methods)
- Multiplication of minimal symptoms, subclinical to a veritable clinical level (rigidity, spastic signs, frontal lobe signs, etc.)

Space Neurology in Future - 1

- Scientific programs focused on simulated microgravity methods (ground based laboratory)
  - More detailed results in knowledge of the proprioceptive system and its influence to the highest and higher brain functions
  - New methods in neurorehabilitation
  - New methods in neurodiagnoses

Space Neurology in Future - 2

- Scientific program in real microgravity based on orbit flights (ISS)
- Cooperation of NASA, ESA, Russian Space Program including Chinese Space Program as well as Japanese Space Program
- Combined programs with neuropharmacological methods
- Scientific program in partial microgravity in underwater conditions

EMA EMINS

كليفلاند كلينك أبوظبي
Cleveland Clinic Abu Dhabi

EMA
جمعية الإمارات الطبية
EMIRATES MEDICAL ASSOCIATION

Univ. Prof. Dr. Franz Gerstenbrand
Rummelhardtgasse 6/3
1090 Vienna
Austria

Abu Dhabi, Jan. 8th 2011

Dear Prof. Dr. Gerstenbrand,

On behalf of the Emirates Neurological Society, Abu Dhabi and the Emirates Medical Association, Dubai and in the name of the President of the Neurological Society Dr. Mustafa Shakra I have the honor to invite you to present a lecture on Neurology, title at your discretion, before Neurologists of the United Arab Emirates. Afterwards, we kindly request your permission to ask questions.

March 31, 2011
17:00

Emirates Palace Hotel
West Corniche Road
Abu Dhabi, UAE

Following the discussion we request your participation in the buffet reception.

We look forward to an interesting presentation and to fruitful discussions.

Sincerely yours,

صباحات عاصم الواسطي

Sabahat Asim Wasti