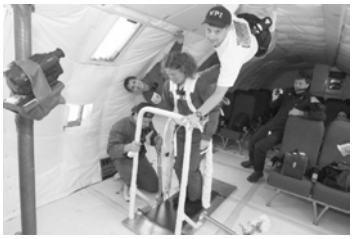
# Microgravity

## Microgravity Environments

- Microgravity
  - spaceflight
  - parabolic flight
  - free fall



## Simulated Microgravity

- bed rest
- water immersion
- dry immersion
- limb immobilization
- suspension
- limb suspension
- air bearing floor

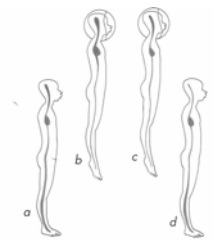
## 6 degree HDT Model

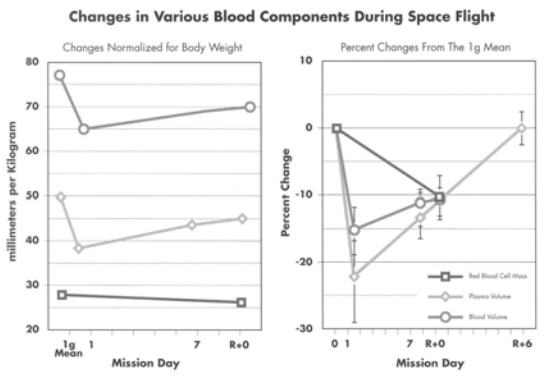
## Spaceflight Medical Issues

**Living and working in a weightless environment**

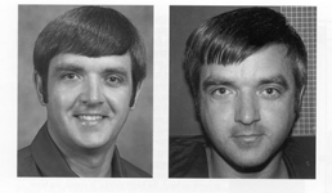
## Fluid Shifts

- **Fluid moves to the upper body**
  - **increased upper body pressures**
  - **loss of blood volume**
  - **decreased cardiac work**
  - **deconditioning of vascular reflexes**

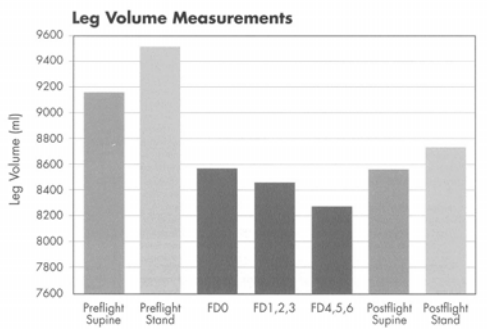





## Puffy Faces and Bird Legs



## Leg Volume Changes



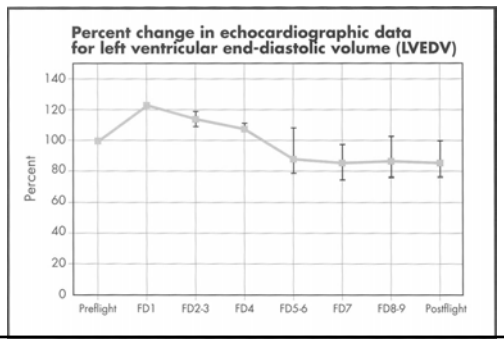

## Space Adaptation Syndrome

- **Symptoms**
  - **headache**
  - **nausea**
  - **difficulty concentrating**
  - **insomnia**
- **Causes?**
  - **increased intra-cranial pressure**
  - **cerebral edema?**
  - **Neurovestibular mismatch**

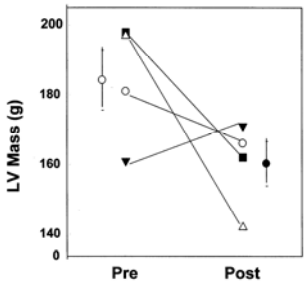
## Cardiac Arrhythmias

- **Causes?**
  - **electrolyte imbalances**
  - **↑ central bv**
  - **ans changes**
  - **cardiac changes**
- **Prevention?**
  - **Drink fluids**
  - **prevent Ca+ loss**
  - **exercise**

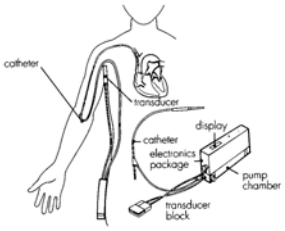
## Cardiac Volume Changes

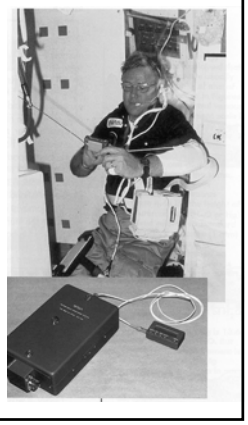


## Changes in Cardiac Mass after 10 d spaceflight




## CVP Device



## CVP and microgravity

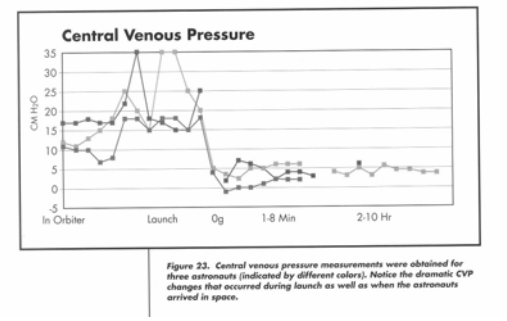



*Figure 23. Central venous pressure measurements were obtained for three astronauts (indicated by different colors). Notice the dramatic CVP changes that occurred during launch as well as when the astronauts arrived in space.*

## Why did CVP decrease?

- Adaptation had already occurred on the launch pad?
- Effect of microgravity to decrease intra-pleural pressure?
- Fluid movement into the low pressure pulmonary circulation?

## Pulmonary Changes in Microgravity

- West, Prisk, et al.
- Hypothesized that inhomogeneity of ventilation and perfusion would disappear in microgravity
- Diffusing capacity of the lungs should improve
- Results showed that region changes were reduced but still much still remained.

## Musculoskeletal Changes

- Possible causes
  - gravitational unloading
    - no high impact
    - no eccentric movements
  - hormonal changes
    - ↓ GH, testosterone, ↓ muscle
    - ↓ thyroid hormone
    - ↑ cortisol, ↓ bone
- anorexia, ↓ body mass

## Loss of Muscle Mass

- Decreased muscle volume (DXA)
- Decreased muscle fiber size
  - type 1 and type 2 (muscle biopsy data)
  - decreased oxidative enzymes
  - increased glycolytic enzymes
- altered myosin isoforms (fast twitch)

## LBM Changes after 4-14 mo of spaceflight

| Variable | N | % change/month |
|---|---|---|
| **Lean total** | **17** | **-0.57*** |
| **Lean leg** | **16** | **-0.1.00*** |
| **Lean arm** | **17** | **-0.00** |
| **Fat total** | **17** | **+1.79** |

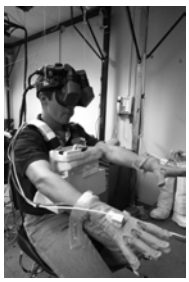
* $P < 0.01$

## Changes in muscle strength and endurance

- Decreased strength
  - initially greater losses of extensor muscles
  - loss of strength across all velocities of shortening
- Initial losses of strength > loss of mass
- Increase in muscle fiber velocity of shortening
- Decreases in muscle endurance
- Changes in strength are not ~ to flight length

## Loss of neuromotor reflexes

- eye-hand dys-coordination
- Neuro-motor dys-coordination
  - balance
  - voluntary strength
  - agility



## Loss of Bone Mass

- Immediate increase in calcium excretion
  - kidney stone risk
- Early increase in bone resorption markers (n-telopeptides, hydroxyproline)
- Uncertain changes in bone formation markers (osteocalcin, bone spec. alkaline phosphatase)
- Regional differences in bone loss
- Losses are ~ to flight length

## Changes in BMD after 4-14 months of spaceflight

| Variable | N | % Change/mo |
|---|---|---|
| **BMD spine** | **18** | **-1.06*** |
| **BMD Neck** | **18** | **-1.15*** |
| **BMD troch** | **18** | **-1.56*** |
| **BMD total** | **17** | **-0.35*** |
| **BMD pelvis** | **17** | **-1.35*** |
| **BMD arm** | **17** | **-0.04** |
| **BMD leg** | **16** | **-0.34*** |

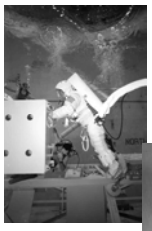
## Changes in Body Composition

- Decreased LBM
- Increased FM
- Large decreases in body mass in some crewmembers

F = M x A

## Operational Issues

- **Training**
- **Launch**
- **Extra-vehicular Activities**
- **Intra-vehicular Activities**
- **Landing**
- **Rehabilitation**



**KC-135**

**NBL**

## Launch

- **3.4 g for 20 min**
- **Pre-launch position**
- **LES suits in case of decompression or bail-out**

## Extra-Vehicular Activities

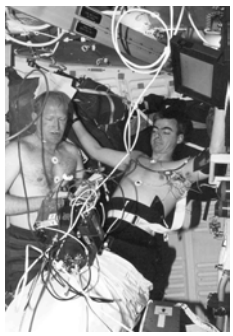
- **Upper body strength**
- **DCS risk**
  - **Cabin pressure is 14.7 psi**
  - **US Suit pressure is 4.3 psi**
  - **Nitrogen bubbles form with decreased ambient pressure**
- **6-8 hr. endurance capacity**

## EVA Pre-breathe Exercise Countermeasure

- **DCS Countermeasures**
  - **breathe 100% $O_2$**
    - **4-12 hrs**
    - **staged decompr.**
      - **10.2 psi, 12 hrs**
      - **2 hr O2 prebr.**
    - **ISS campout**
    - **2 hrs w/exercise**

## Intra-vehicular Activities

- House-keeping
- Exercise and crew health activities
- Mission Objectives
- PR activities



## In-Flight Exercise Prescriptions: Aerobic

TVIS

Velogometer

## In-flight Exercise: Resistive

Interim Resistance Exercise Device

## Always time for fun!

## In-flight Medical Tests

- Submax cycle
- Arm ergometry (pre-EVA)

- Body Mass
- Medical debriefing

## Landing

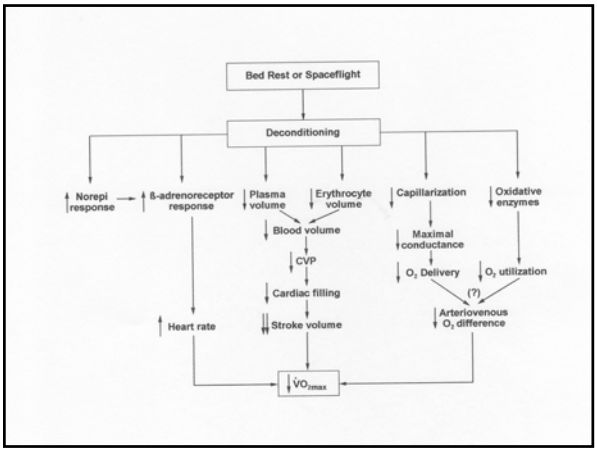
- 1.2 g, 17 min.
- LES suit
  - anti-g suit
  - liquid cooling garment
- horizontal seats (ISS)
- fluid loading countermeasure

## Ability to emergency egress

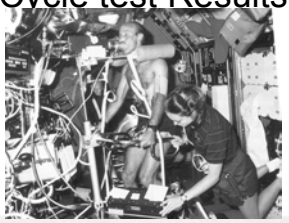
- Rise from seat
- Blow hatch
- Deploy slide
- Repel down slide
- Run to save area
- Oxygen runs out in 10 minutes!

## Pre-/post flight Medical Tests

- **Cycle tests**
- **Strength tests**
  - **isokinetic**
  - **free-weights**
  - **sit ups, jump test**
- **Tilt tests**
- **Blood tests**




## Cycle test Results

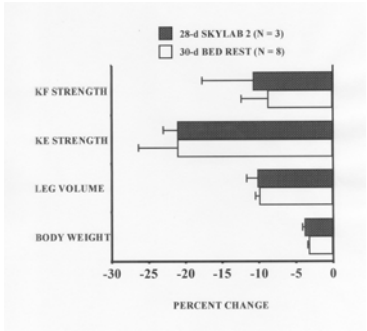


**MAXIMAL EXERCISE TEST DATA**

| | Power Output (Watts) | $VO_2$max (liters/min) | CO (liters/min) | HR (beats/min) |
|---|---|---|---|---|
| PREFLIGHT | 233 ± 63 | 2.76 ± 0.81 | 18.9 ± 2.3 | 179 ± 17 |
| INFLIGHT | 211 ± 59 | 2.65 ± 0.64 | N/A | 170 ± 24 |
| POSTFLIGHT | 200 ± 78* | 2.14 ± 0.49* | 14.5 ± 2.5* | 176 ± 15 |

★ – measurement is significantly different from preflight
N/A – data not available

## Isokinetic Muscle Strength




## Post-Flight Orthostatic Intolerance

- **↓ Blood volume**
- **↓ Cardiovascular reflexes**
- **Cardiac atrophy**

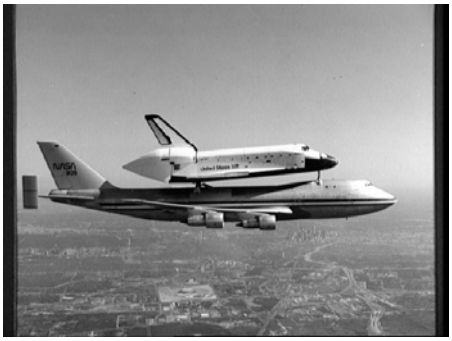
## Orthostatic Intolerance

- 30% of Shuttle crewmembers
- > 80% of ISS crewmembers
- women > men
- reclining seats during landing
- CTV use

## Rehabilitation Program

- **Individualized**
- **First few days, sitting, walking, stretching**
- **Exercise testing allowed after 5 days, submaximal of course!**
- **Water exercises at first**
- **30-60 days, strength usually returns**
- **30-60 days, $VO_2$pk usually returns**
- **Bone ????**

## Back to Flight?



## Goals of the "Renewed spirit of discovery for Space Exploration"

•To return to the moon by 2020 in preparation for human exploration of Mars and other destinations

•Focus US research and the use of the ISS on supporting these goals.. **with emphasis on understanding how the space environment affects astronaut health and capabilities and developing countermeasures**

*George Bush, Jan. 14, 2004*

## New Mexico Commercial Spaceport?