Nutritional Biochemistry of Spaceflight
Functions of Nutrition

- Meet Energy / Nutrient Requirements
- Psychosocial Aspects
- Countermeasure
Adaptation to Weightlessness

- Muscle
- Bone
- Fluid shifts, hematological
- Cardiovascular
- Gastrointestinal
- Environmental

- Psychological/Behavioral/Performance
- Taste & odor
- Neurosensory
- Sleep & circadian rhythm
Radiation
Extravehicular Activity
Early Space Food
ISS Foods
ISS Fresh Food
Nutrition Experiment
Study Design

Schedule
- 3 pre-flight blood/urine collections (L-180, L-45, L-10)
- 5 in-flight blood/urine collections (FD15, FD30, FD60, FD120, FD180)
- 2 post-flight blood/urine collections (R+0, R+30)

Samples are analyzed for a battery of tests
- Vitamins, Minerals, Proteins, Hormones/General Chemistry
- Bone Markers, Renal Stone Risk
Inadequate food intake will compromise crew health and performance.

- Intake of all nutrients is dependent on the adequacy of energy intake.

<table>
<thead>
<tr>
<th>Apollo</th>
<th>Skylab</th>
<th>Shuttle</th>
<th>E1-4</th>
<th>E5-16</th>
<th>E17-29</th>
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</thead>
<tbody>
<tr>
<td>Energy Intake (% WHO Requirement)</td>
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SLAMMD

- Space linear acceleration mass measurement device
  - Linear acceleration
    - Newton’s 2nd Law of Motion
      \( F = ma \)
Body Mass

Body mass (% change from preflight)

Pre
FD1-30
FD31-60
FD61-90
FD91-120
FD121-150
FD151-190
R+0
R+30

Energy intake (% WHO recommendation)
Urinary Biomarkers

Collagen Crosslinks
Bone Resorption/Formation

NTX (% change)

Pre Mean  FD15  FD30  FD60  FD120  FD180  R+0  R+30

BSAP

Pre-flight  Early in-flight  Late in-flight  Late in-flight 2  R+0/1  R+3-17 d  R>1 mo

**
Bone Formation/Resorption

% Δ from baseline

Week of Bed Rest

BSAP (% Δ from baseline)

Week of Bed Rest
Energy Intake/Vitamin D

Energy Intake (% WHO Requirement)

Mir | iRED | ARED

Pre Mean | FD15 | FD30 | FD60 | FD120 | FD180 | R+0 | R+30

Vitamin D Stores (25(OH)Vitamin D) nmol/L

Smith et al., J Bone Miner Res, 2012
Bone Mineral Density

### BMD Spine

<table>
<thead>
<tr>
<th>% change/month</th>
<th>Mir</th>
<th>iRED</th>
<th>ARED</th>
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### BMD Pelvis

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### BMD Trochanter

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Smith et al., J Bone Miner Res, 2012
Iron, Oxidative Stress, and Bone

![Graph showing changes in Ferritin and 8OHdG over time.](image-url)
Fluid Intake

Preflight mean 24-h urine Ca (mg/dL)

Inflight 24-h urine Ca (mg/dL)

0 5 10 15 20 25 30 35

0 5 10 15 20 25 30 35 40 45

70%
75%
85%
Bone Strength?
Fracture risk?
↑ resorption
↑ formation

Optimization
Exercise
Diet
MTHFR C677T Polymorphism

- Methylated Acceptor
- SAH
- SAM
- Methionine
- CBS
- HCY
- CYS
- α-KBT
- PRP-CoA
- 2MCA
- D-MM-CoA
- MMA
- L-MM-CoA
- SUC-CoA
- AA, FA
- B6
- B12
- Dietary Protein Muscle Catabolism
- Dietary Folate
- Serine
- SHMT
- 5-MTHF
- 5, 10-MTHF
- MS
- MTRR
- B12
- MTHFR
MTHFR C677T Polymorphism
Everybody has 2 sets of blueprints (mom and dad), resulting in four possibilities of this polymorphism.

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<tr>
<th></th>
<th>% Pop</th>
<th>Enz Act.</th>
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<tr>
<td>C/C</td>
<td>~35%</td>
<td>100%</td>
</tr>
<tr>
<td>C/T(T/C)</td>
<td>~50%</td>
<td>~66%</td>
</tr>
<tr>
<td>T/T</td>
<td>~15%</td>
<td>~50%</td>
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Earth Benefits

- Research
- Countermeasures
- Technology
- Education/Outreach
Now available on iTunes!

http://go.nasa.gov/QS1KW1

Nutritional Biochemistry of Space Flight

Space Nutrition