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Nutrition and Space Flight
Research DPG

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Physiological Adaptations to Spaceflight

Psychological/Behavioral/Performance

Neurosensory adaptations

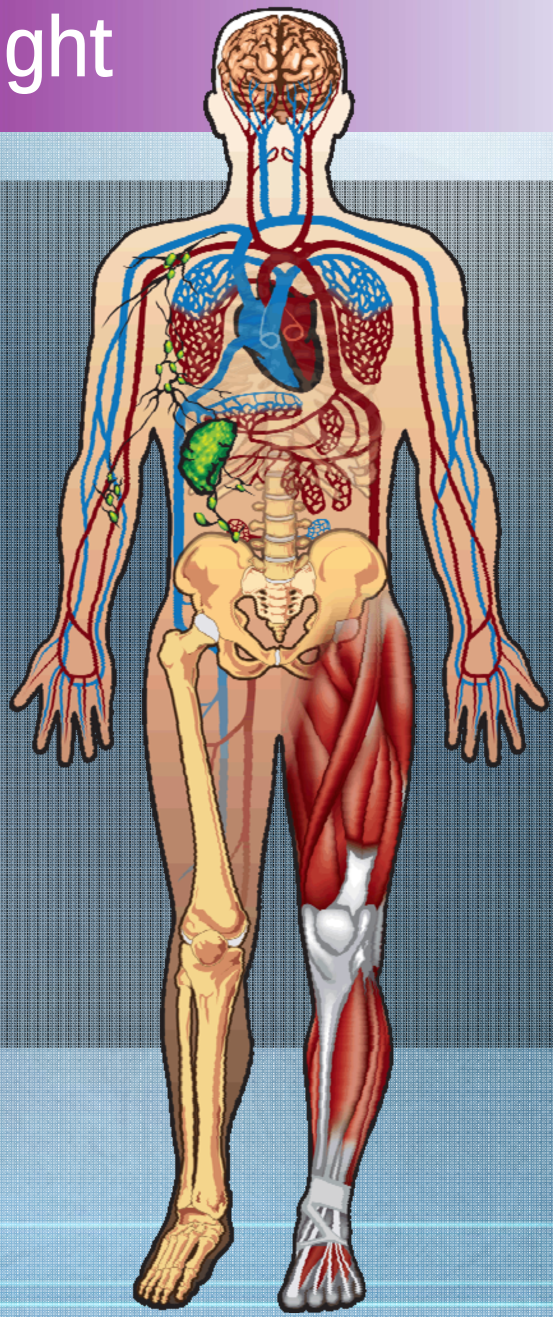
Cardiovascular adaptations

Fluid shifts, hematological changes

Musculoskeletal changes

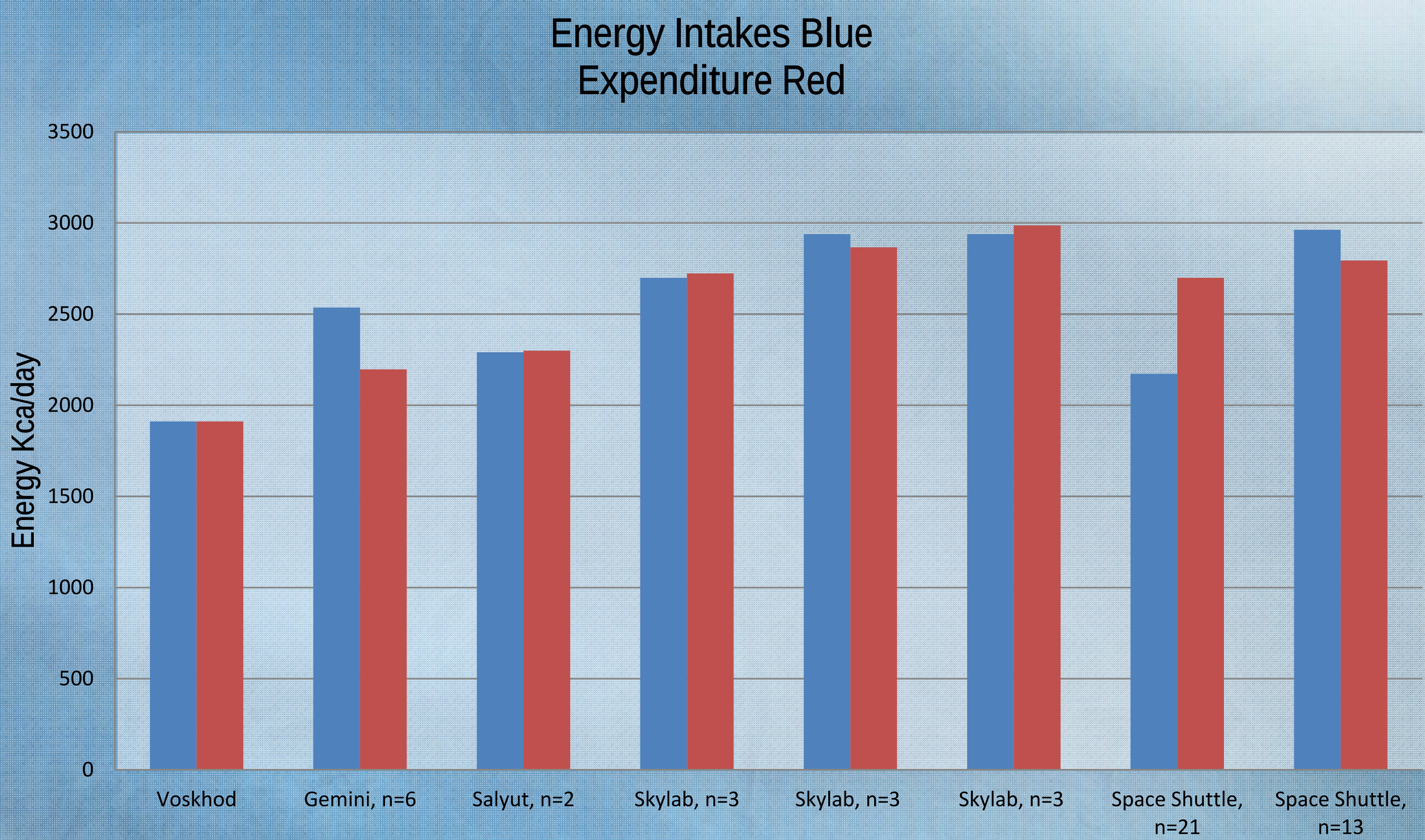
Gastrointestinal alterations

Taste and odor sensitivity

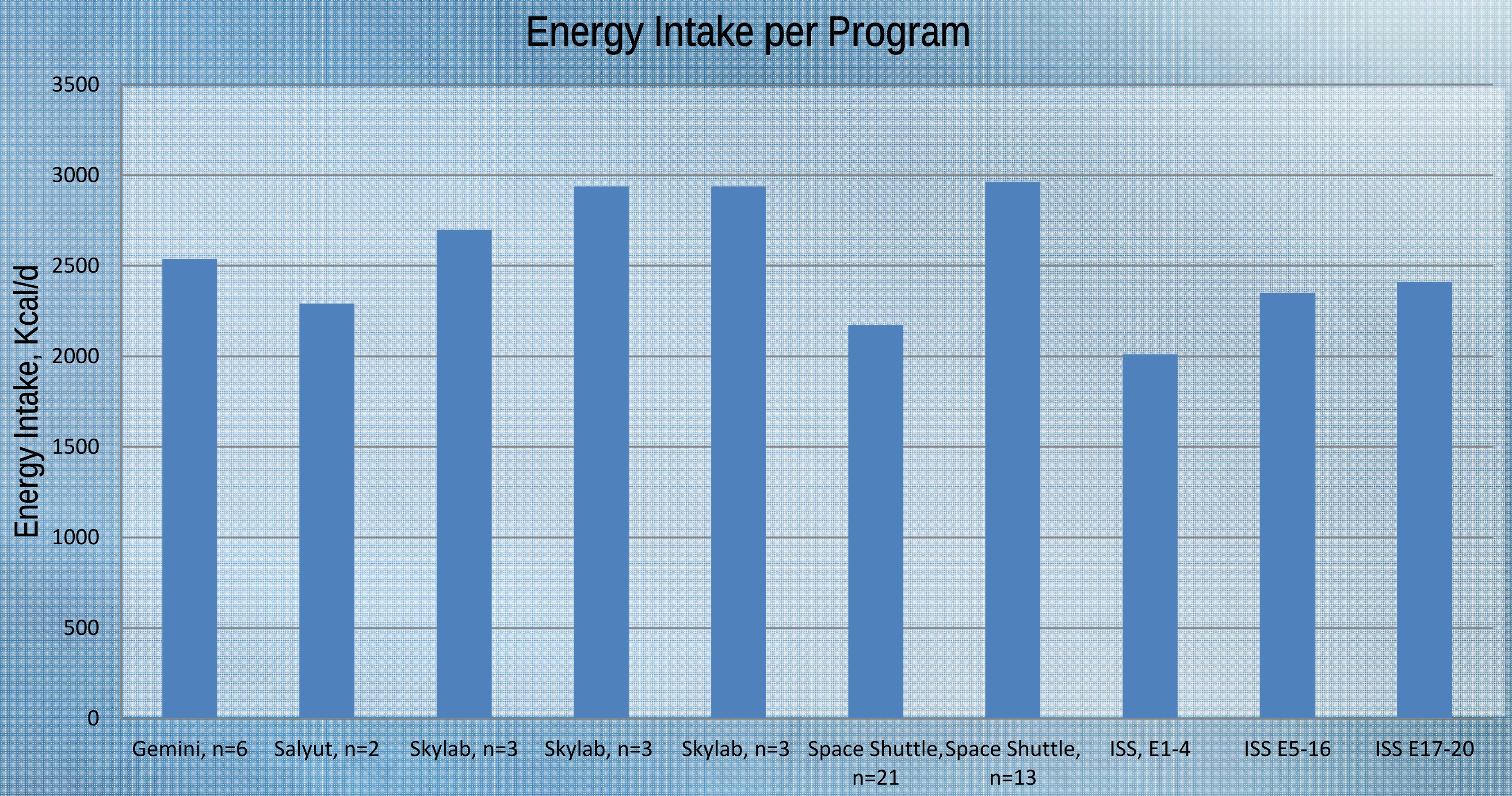



ENERGY
intake
ENERGY
utilization

Energy Intake and Expenditure



Energy Intake per Program



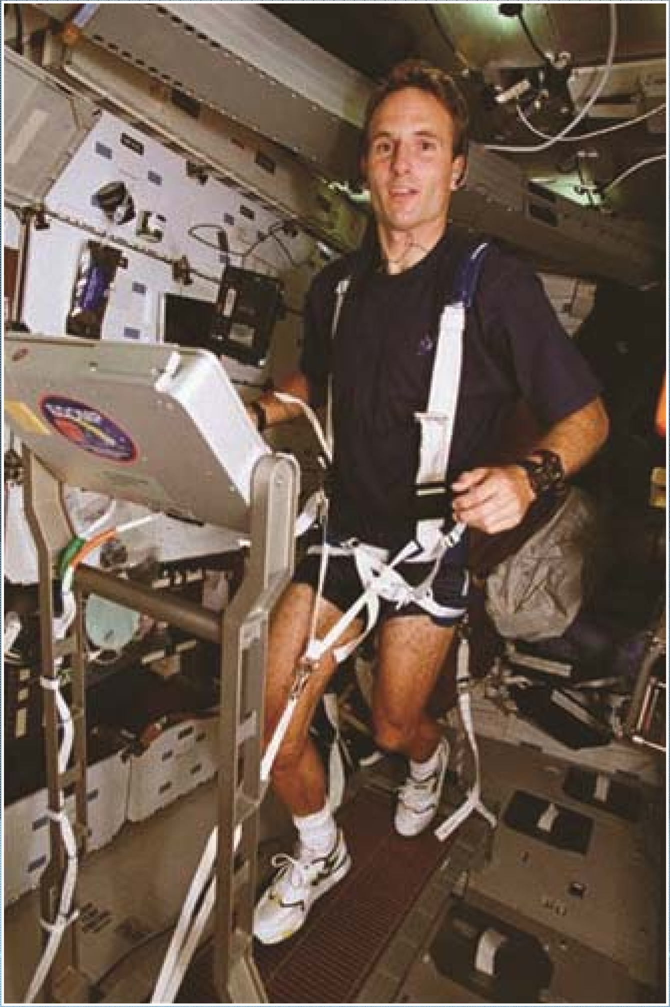
Energy Consumption for Exercise

Space shuttle flights, O_2 consumption as l/min measured to determine fitness - oxygen consumption per standard exercise level: 5 subjects during space shuttle flight.

Preflight	In-flight
2.05 ± 0.12	1.86 ± 0.12

Was there a training effect?

Studies on-going



Fluid Intake During Space Flight

Fluid Balances as ml/day

Apollo	Skylab	Shuttle
1647 ± 188	2829 ± 529	2223 ± 669

Early space flight assumed weigh loss due to fluid balance, primarily a diuresis effect of microgravity.

Research completed by USSR, European, and US to the effect on the cardiovascular system and the orthostatic intolerance that occurs at landing.

Changes in body water, Skylab and Space Shuttle measured in flight

Program Name	Extracellular Fluids % change	Plasma Volume% change*	Body Mass % change
Skylab, n=9	- 7.2 to 10..2	-10 to -15	-1 to 5
Space Shuttle, n=20	-10 to -14	-10 to -17	0 to -1.5
Mir, n=5	-7 to -8	-9 to -10	-4 to -12

**Related to the orthostatic intolerance at landing.*

Fluid Balances: Why did these changes happen?

Skylab studies provide the best answer: all nine crewmembers excreted less urine, mean 400 ml less per day than preflight and water intake decreased 700 ml/d.

Russians and US also showed increase osmolality of in-flight urine. Until the Space Shuttle flight water had to be launched, for some program managers this reduced consumption was a plus.

Water turn over using double label water with 14 shuttle astronauts:

Preflight	In-flight
3768 ± 509 ml/day	2731±607 ml/day

The decreased plasma volume may relate to the changes within the cardiovascular system, with the head ward shifts of fluids during microgravity, regulatory systems may adjust to lower blood volume of space flight. As of yet, except for landing day, this has not cause problems in space flight. However, there are still active questions, esp. for extended durations with many crew members as with ISS.

Protein Requirements

Protein intakes are complicated by early observations that high protein diets maybe related to renal stones. Astronauts consume less than ideal water levels and with the concentrated urines, was there an increase of bone loss and renal stones?

Changes in Muscle Volume

Deconditioned muscles including decreased leg volume due to inability to load muscles in microgravity

Muscle	% Change R+1	% Change R+15
Calf		
Anterior	-3.9 ± 0.5[a]	-3.3 ± 1.1[b]
Soleus+Gastroc	-6.3 ± 0.6[a]	-4.4 ± 2.2[b]
Thigh		
Quadriceps	-6.0 ± 1.7[b]	-3.1 ± 2.3
Hamstrings	-8.0 ± 0.9[a]	-4.8 ± 1.3[a]
Lumbar		
Intrinsic	-10.3 ± 2.4[a]	-5.9 ± 1.5[a]
Psoas	-3.1 ± 1.5	-2.4 ± 1.6

Changes in Muscle Volume of Four Astronauts 1 and 15 Days After an 8-Day Space Shuttle Mission

[a]$p<0.05$
[b]$p<0.07$ versus preflight
R = recovery day
% change = flight vs. preflight

Protein Requirements

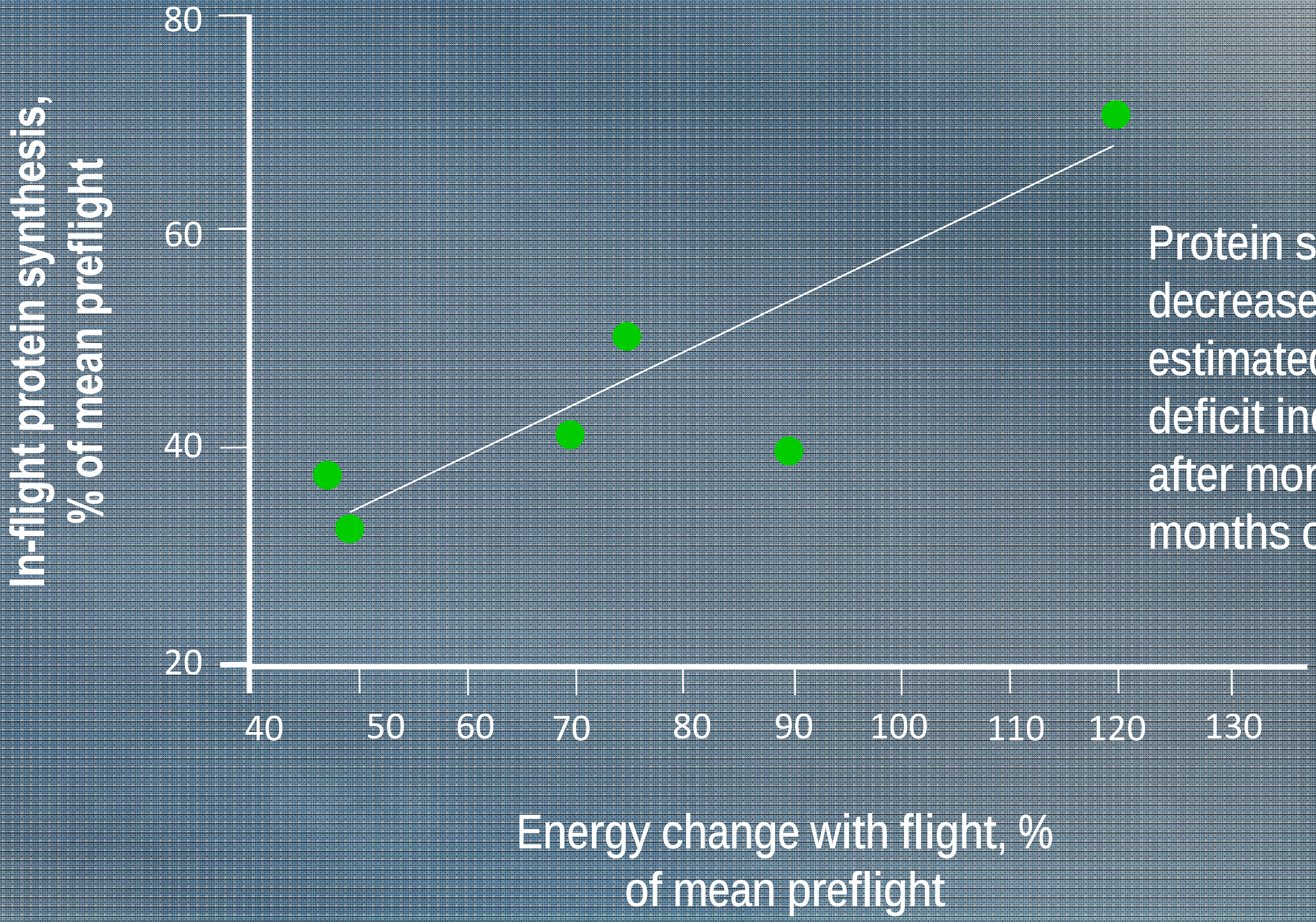
Historically, muscle loss was a significant issue for crew members especially after landing.

Both muscle volume, especially in the weight bearing legs and strength decreased with several studies showing changes in the muscle fibers.

Question: Can dietary protein and various amino acid supplements prevent some of the muscle losses?

Research by Ferrando and Wolfe demonstrated no long term effect of branch chain amino acids liquid supplement on skeletal-muscle protein balance during supplement using simulated microgravity, bed rest.

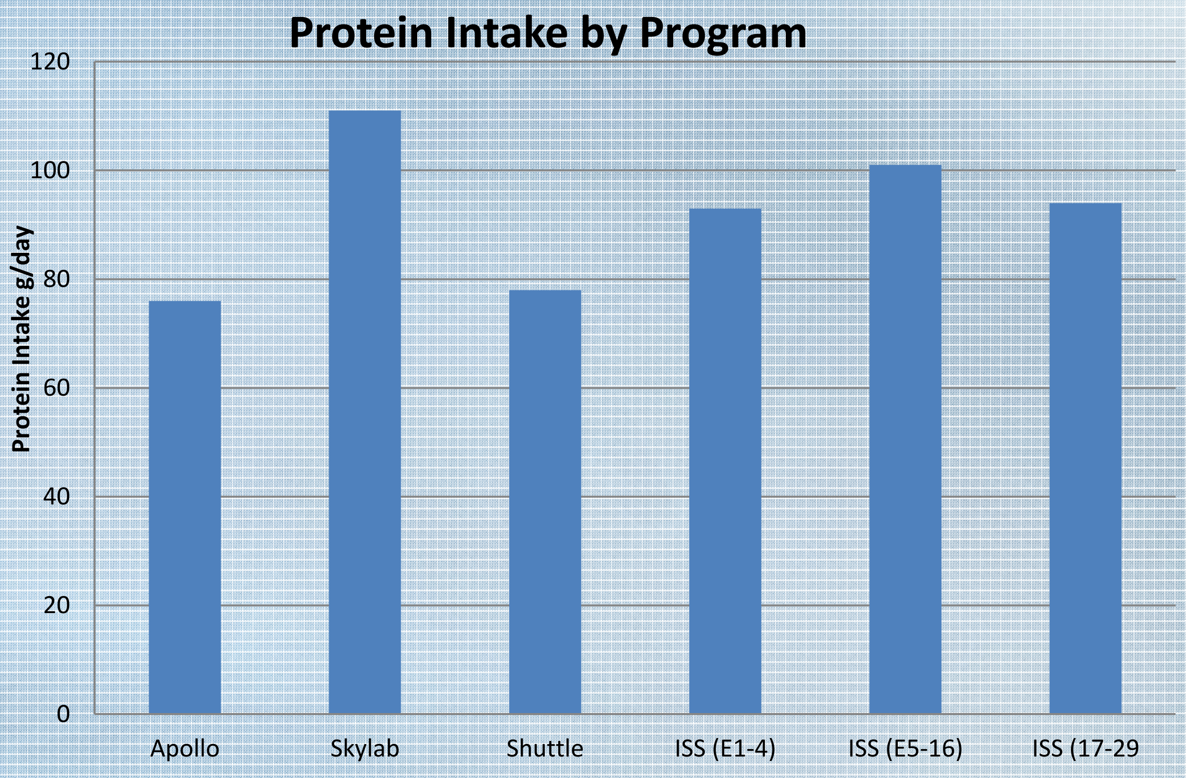
Effect of Energy Intake on Protein Synthesis

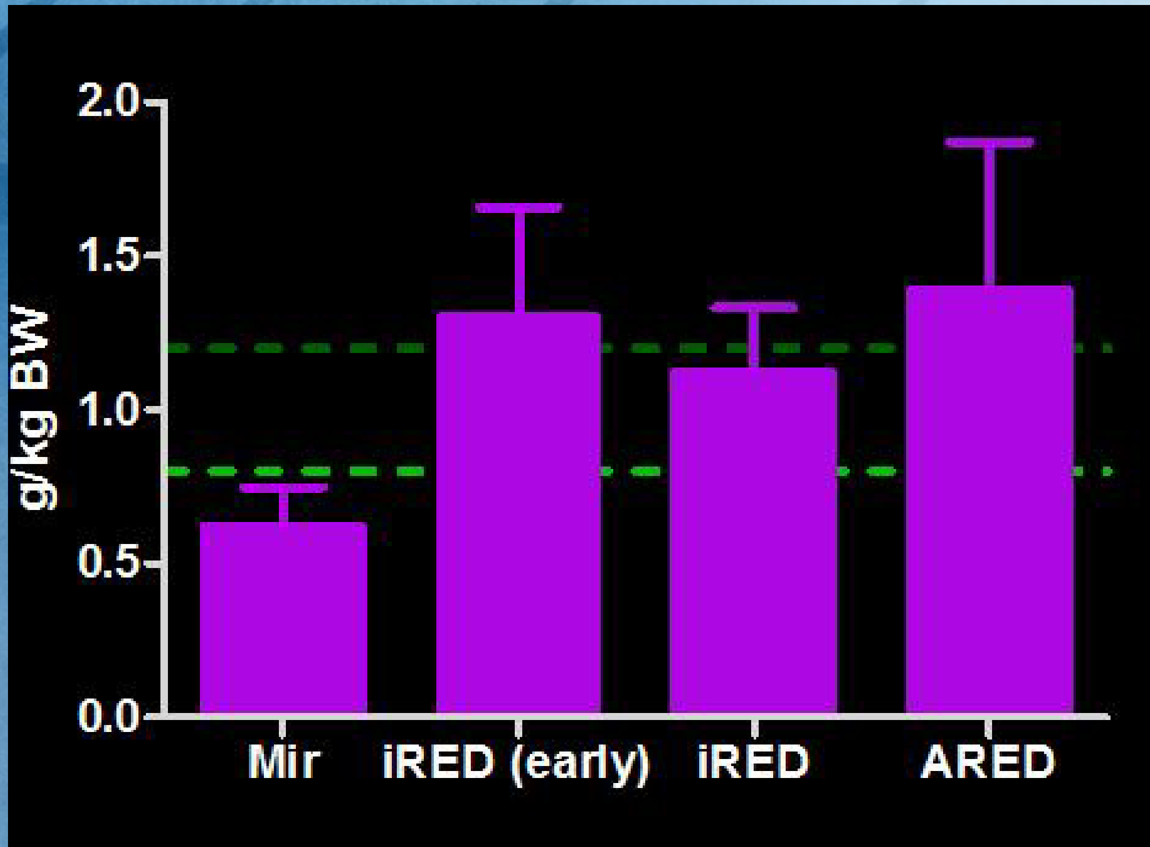


Protein synthesis decreased as the estimated energy deficit increased after more than 3 months on Mir.

From: T. Stein, et al., 1999.

Protein Intake

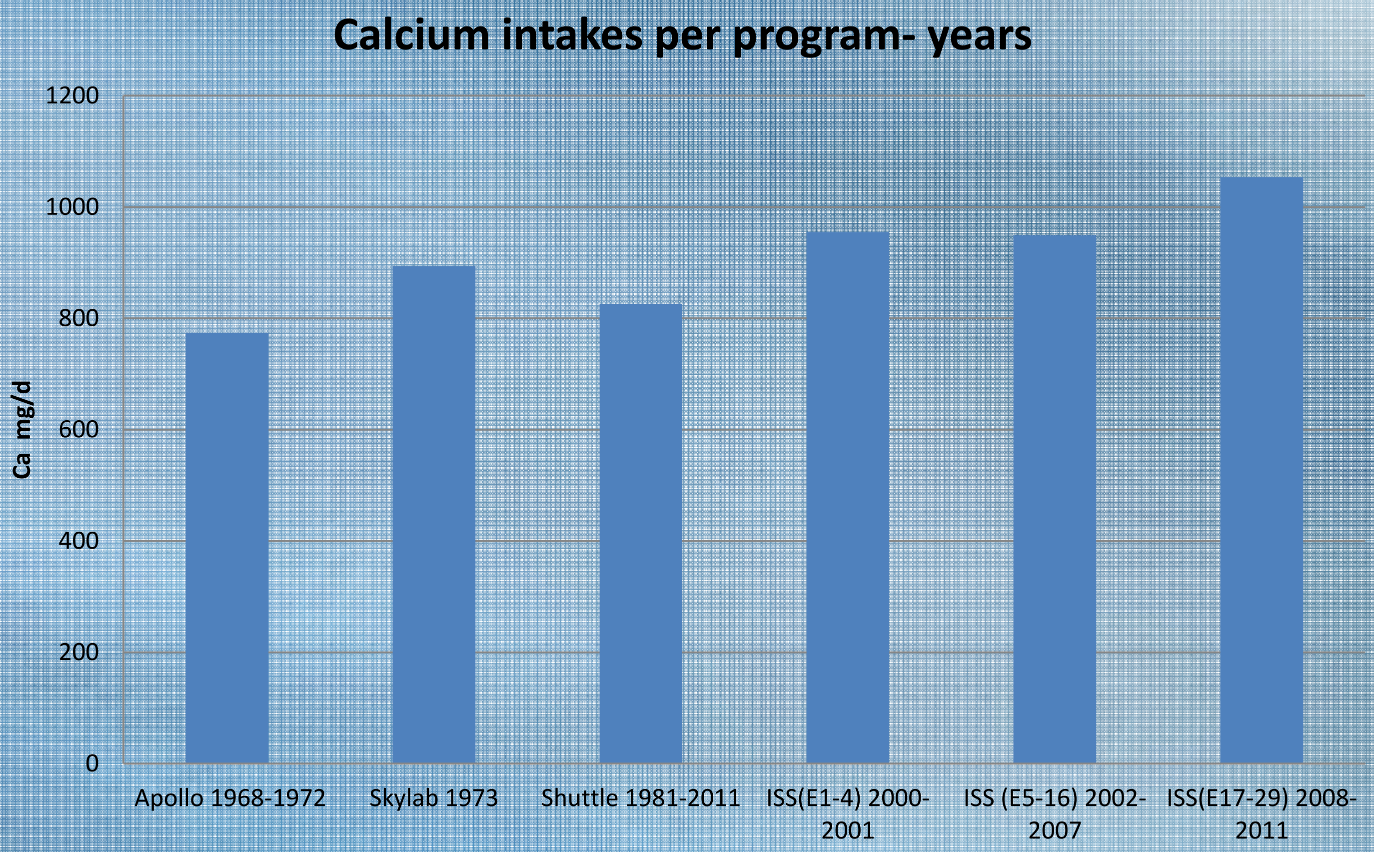




Protein intakes per body weight over different types of Resistive Exercise

Mir is Russian Space Station
iRED is early resistive exercise equipment
IRED is initial resistive exercise equipment
ARED is the resistive exercise equipment now on ISS

Calcium Intakes per Program-years



Bone Health

Vitamin D status significatnly decreases in space flight due to lack of sun

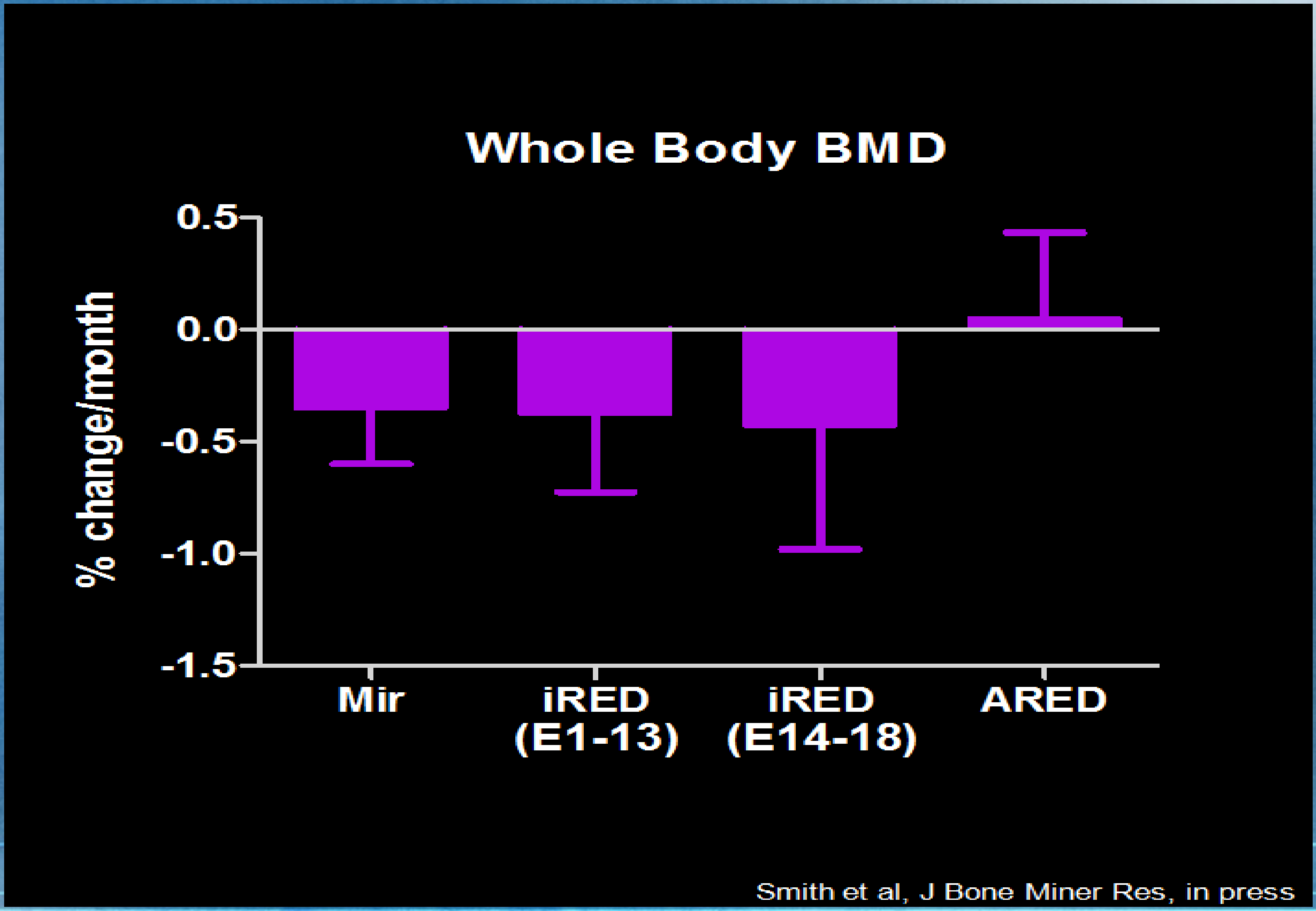
Measure of Bone resportion increased

Blood levels of Calcium do not change, but urinary calcium increases

Interactions of the role of exercise, bone health and adequate nutrition

Exercise and Body Mass Measurements

Efficy of Resistive Exercise on Bone Mineral Density (BMD)



Food Preparation and Dietary Monitoring

Dietary Intakes

In-flight dietary intake on Apollo, Skylab, and Shuttle.

	Apollo	Skylab	Shuttle
Protein intake, g/d	76 ± 19	111 ± 18	78 ± 19
Protein intake, % of kcal	16 ± 2	16 ± 2	15 ± 2
Carbohydrate intake, g/d	269 ± 49	413 ± 59	304 ± 67
Carbohydrate intake, % of kcal	58 ± 7	58 ± 9	58 ± 5
Fat intake, g/d	61 ± 21	83 ± 14	64 ± 18
Fat intake, % of kcal	29 ± 6	27 ± 9	27 ± 4

Modification of Sodium Content - 37% reduction

Shuttle and Early Space Station (ISS) Sodium Levels – 5600 mg/d for typical menu.

Modified 90 foods, thermostabilized and rehydratable of 200 foods.

Strategy – use commercial products and reduced Na equivalents or replace Na with other spices.

Spices – disodium inosinate, disodium guanylated to increase umami flavor in savory foods. Lemon juice, basil, oregano, sugar, Mrs Dash Fiesta Lime and Mrs Dash Garlic Herb Seasoning.

Sensory evaluation completed on all foods to determine acceptability with some needing to be reformulated. Final products all receive high scores on evaluations.

Modification of Sodium Content 40% reduction

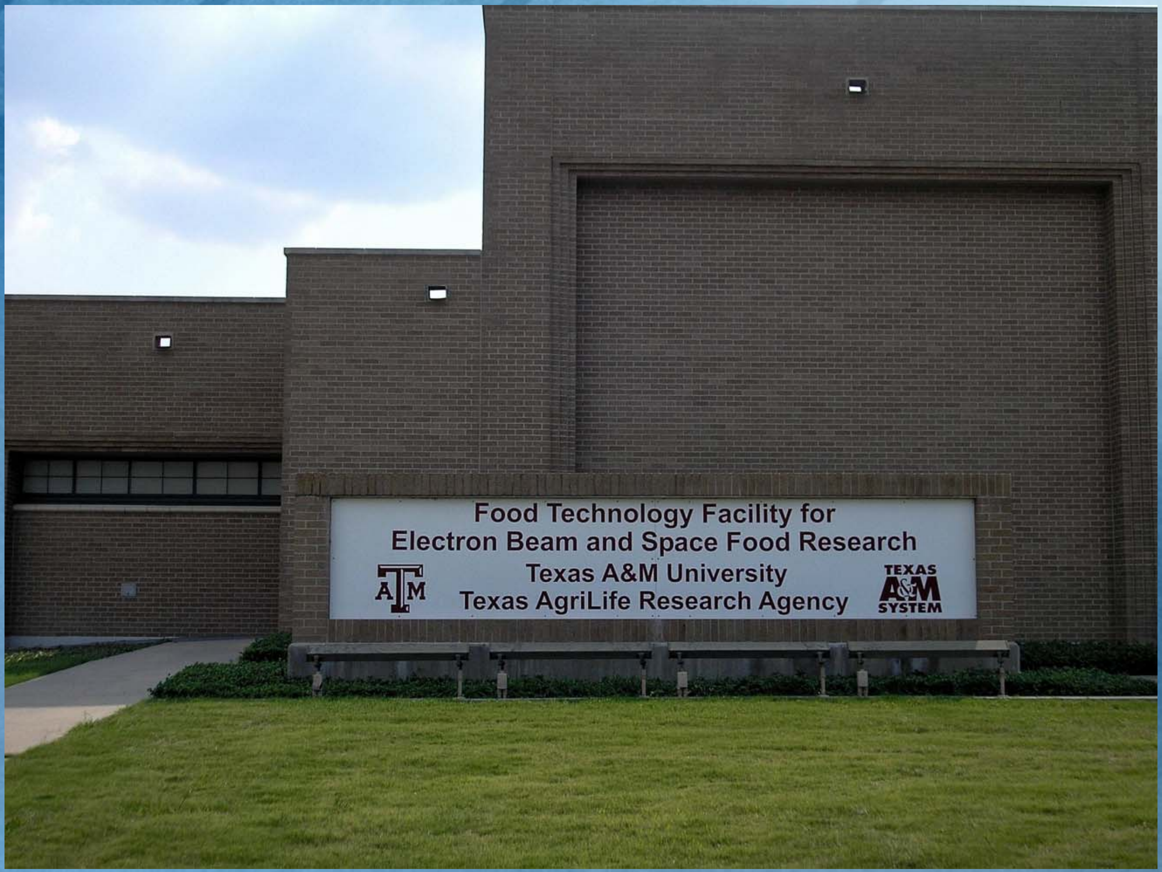
ISSUES

- Other foods high in sodium including
  - Russian – provides half of the ISS foods
  - Japanese
  - European
  - Bonus foods to enhance acceptability and personal preferences

International Space Station Foods

- U.S. Foods
- Russian Foods
- International Community
  - Japan
  - Europeans
  - Canada
- US Food Stored by boxes as pantry style
- Set up as cycle menu 8 day
  - Bonus foods – 10%
  - Allows crew members to chose their meal combination
- Issues – expiration of foods

Foods on ISS



Texas A&M provides Thermostablized food

Summary and Conclusions

Between 1971 and 2011 learned the following:

- Energy intake to meet needs can be achieved, but unless there is good training and available food, it can be a problem
- There is no evidence to raise protein intakes for the short term flights of less than 2 weeks
- Weight loss is primarily due to a combination of lower water and energy intakes, but in general weight loss is less than 5% of body weight.
- Weight loss is not due to diuresis or changes in renal or cardiovascular adaptations to space flight

Questions answered through research on ISS

- Protein type and quality, is it important?
- Role of protein, minerals, exercise, and calcium on bone health during long duration space flight?
- Are there other medical issues related to diet such a vitamin metabolism, such as one carbon metabolism?
- During ISS, US foods are becoming lower in sodium, will this have any long term health effects?