Rationale for Excercise in Space Flight

W. Thornton, M.D.

Musculoskeletal Effects of Weightlessness

These findings led Rambaut and Johnston to postulate that a year of weightlessness could result in a loss of 25% of the body's total calcium reserve, 99% of which is stored in bone apatite.

Results of studies of metabolic balance also showed a profound loss of total body nitrogen, reflecting a concomitant precipitous loss of muscle mass.

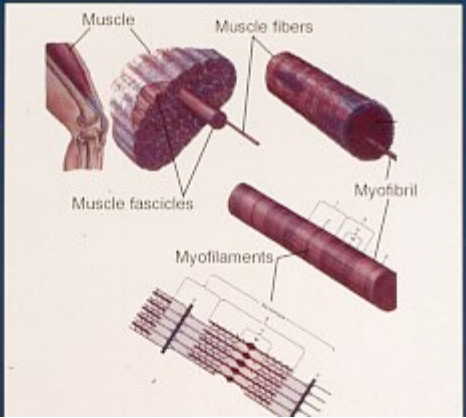
Astronauts on later Skylab missions excercised vigoroulsy, but this did not restore or lessen their calcium loss.

Osteoporosis caused by weightlessness is more severe and unrelenting than any form of disuse osteoporosis.

First, the prolonged time in space required for interplanetary travel is likely to result in the severe and permanently disabling complications of profound osteoporosis.

Ciba Collection V-8, F. Netter, Ed.

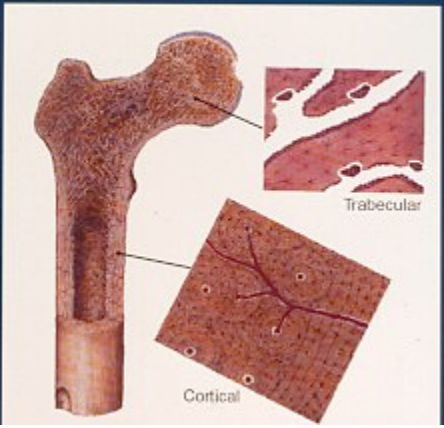
Skeletal Muscle Fiber Arrangement



Shoulder Joint

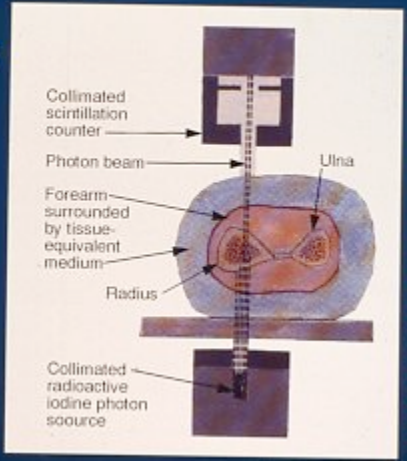
From Netter

Structure of Bone



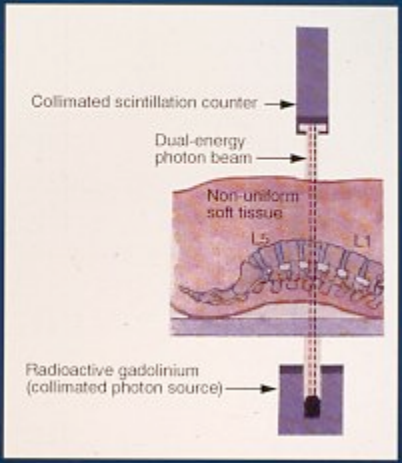
From Netter

Single-Photon Absorptiometry



From Netter

Dual-Photon Absorptiometry



From Netter

Energy Division

Resting Metabolic Rate (-60-75%)

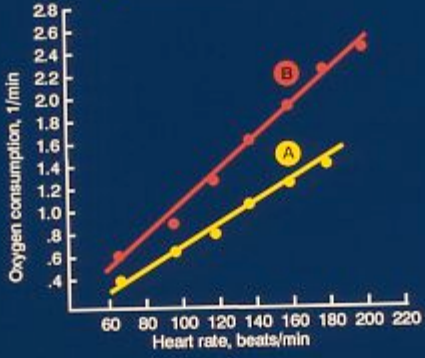
- Sleeping metabolism
- Basal metabolism
- Arousal metabolism

Thermic effect of feeding (±10%)

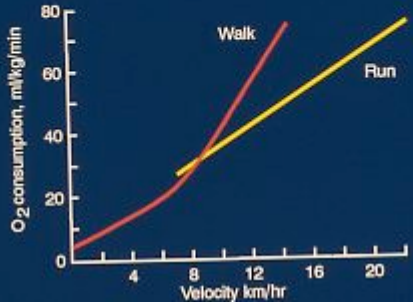
Thermic effect of physical activity (±15-30%)

From Katch

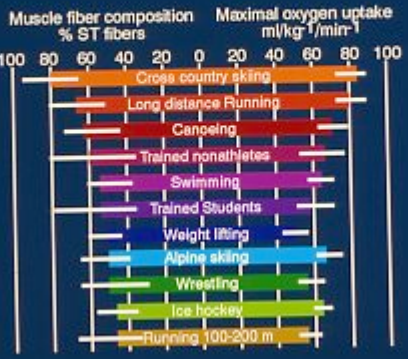
$\dot{V}O_2$ vs. Heart Rate



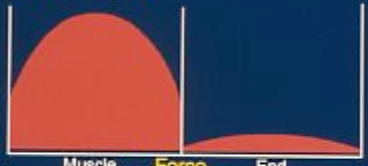
$\dot{V}O_2$ vs. Heart Rate

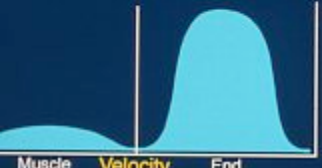


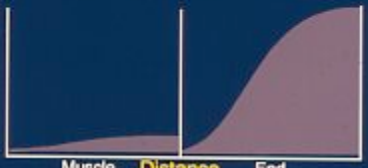
Fiber Composition



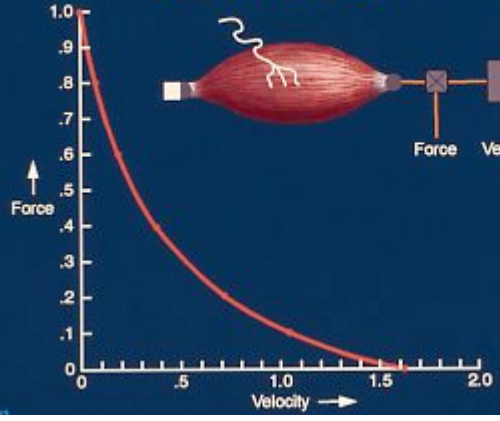
Arm Leverage



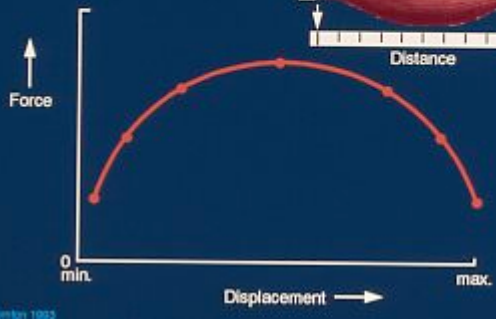




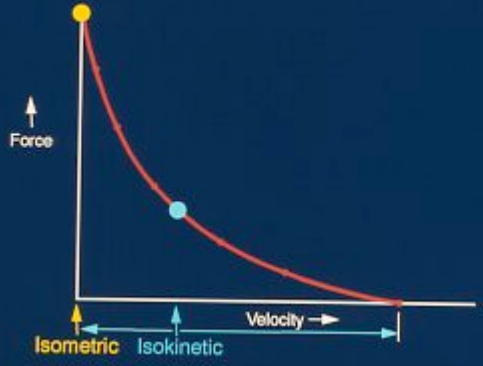
Force/Velocity



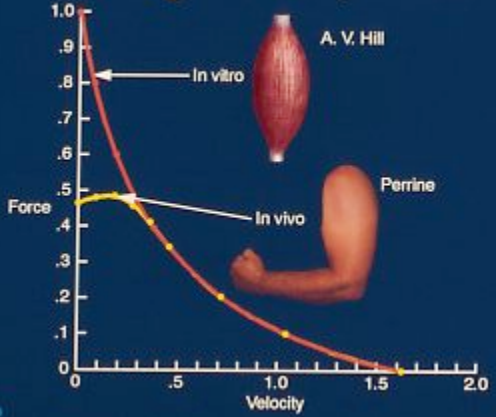
Force/Distance



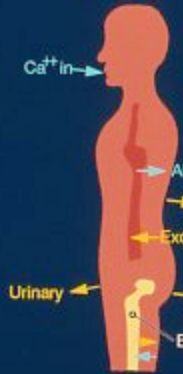
Strength Measurements



Strength in vivo, in vitro



Calcium Balance



$$\text{Balance} = \frac{Ca^{++}\text{ (out)}}{Ca^{++}\text{ (in)}}$$

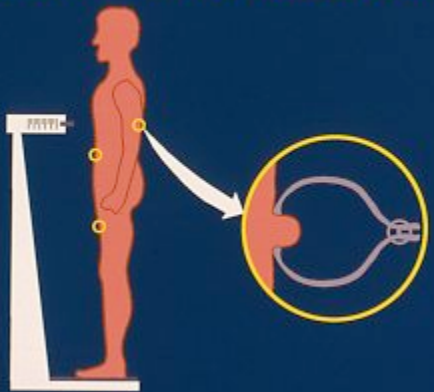
Energy Balance

Balance

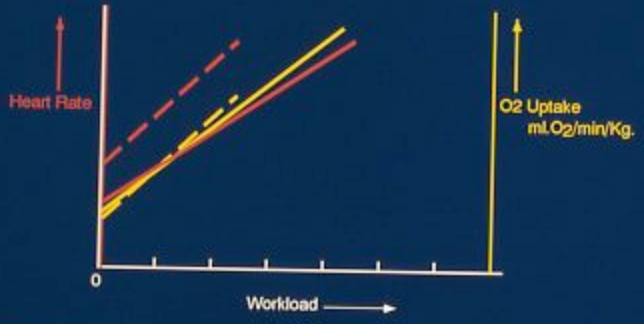
In = Basic requirements
+ Physical Work
± Fat (stored)

External
work
F x D
(~20% efficiency)

Energy Balance Measurements

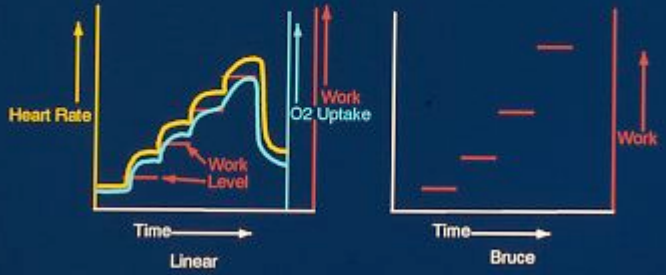


Individual Response to Aerobic Training
(Metabolic)

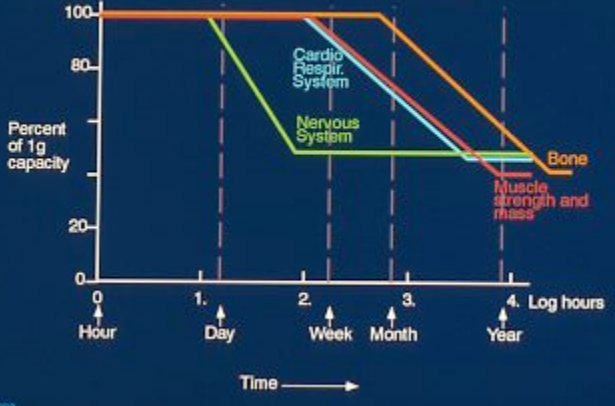


Stress Tests

$\dot{V}O_2$ $\frac{\text{ml. } O_2 \text{ (consumed)\min}}{\text{Kg. (of body mass)}}$

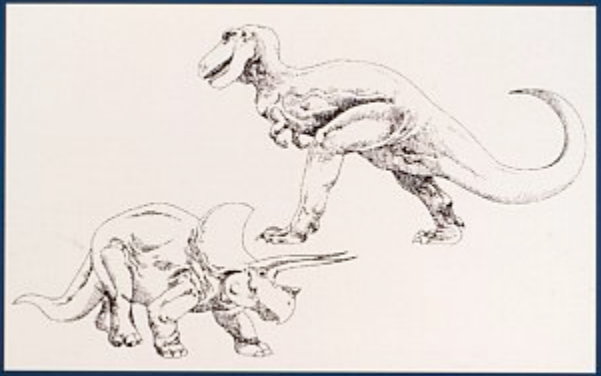


Time Course of Adaptation to Weightlessness



Gender Adaptation

Species Adaptations



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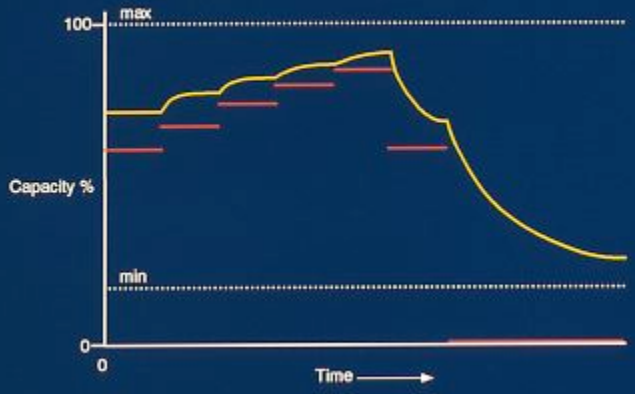
Generic Adaptation

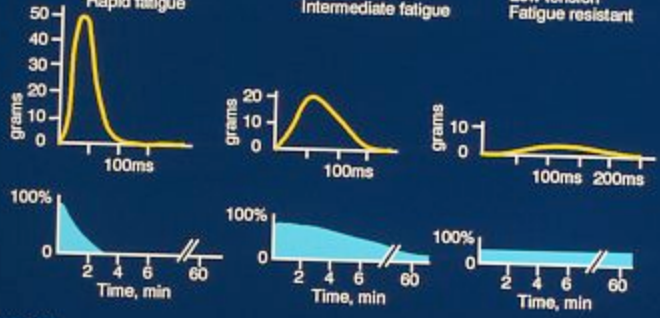


Muscle Fiber Types

Type II A
(White, FG)
Fast twitch
High force
Rapid fatigue

Type II B
(White, FOG)
Fast twitch
Moderate force
Intermediate fatigue

Type I
(Red, SO)
Slow twitch
Low tension
Fatigue resistant



Endurance Excerise
100% Capacity
Energy
Force
Energy
Time
Strength Excerise
100% Capacity
Force
Energy
Energy
Time
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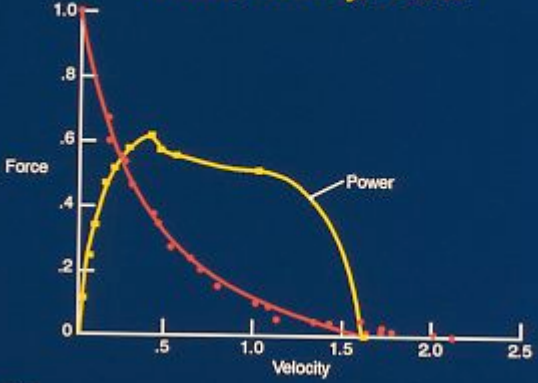
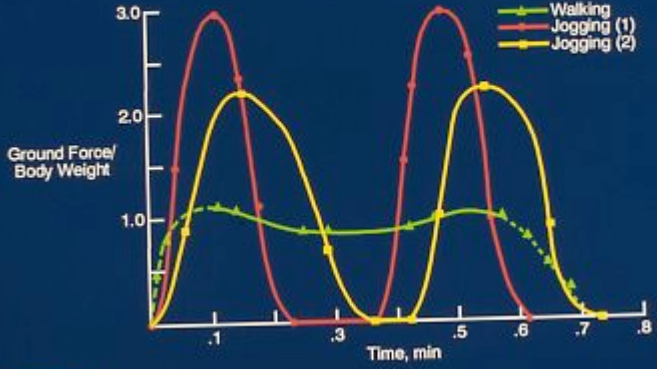
Muscle Force/Velocity/Power



Foot Ground Forces, Stationary Walk, Jog



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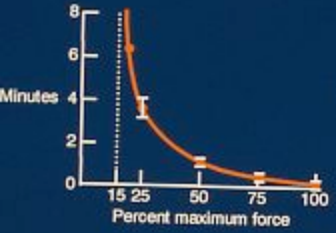
Muscle Fatigue

Isometric Duration



Rate of Work