Diet
Acid/Base
Bone

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Forward Work

Bone Strength?
Fracture risk?

↑ resorption
↑ formation

Optimization
Exercise
Diet
Excess protein: beneficial or harmful to bone?

Oxidation of excess protein yields $\text{H}^+$ corresponding to $\text{H}_2\text{SO}_4$
Bone: reservoir of base
Osteoclasts are more active at lower pH

Other factors
Calcium
Base-components
Type of protein

*Dawson-Hughes et al. 2002*
Animal protein
Diets rich in animal protein tend to have greater overall acid potential

Vegetables/fruits
Contain substantial amounts of base precursors (and K)

APro/K provides an estimation of acid/alkali load
Bed Rest

Zwart et al., *Am J Clin Nutr*, 2004

Zwart et al., *J Appl Physiol*, 2005

**Figure:**
- **Left:** Scatter plot showing the relationship between Apro/K (g/mEq) and N-telopeptide (nmol/d) for Bed rest (blue) and Ambulatory (pink) groups. The correlation coefficient is marked as *r = 0.80*.
- **Right:** Graphs showing changes in Urinary pH and Urinary NTX (nmol/d) over Weeks of bed rest for AA (red) and CON (yellow) groups. Small asterisks (*) indicate significant differences.
Submariners

Serum carboxy-terminal cross linked telopeptide of type 1 collagen (ICTP)

- Summer patrol (0.75% CO2)
- Winter patrol (0.70% CO2)

Pro K

- 4-d controlled diets 2x before and 4x during flight
  - High Apro/K: 1.0-1.3 g/mEq
  - Low Apro/K: 0.3-0.6 g/mEq
- Blood/urine samples collected at end of session
Pro K

NAE = PRAL + Organic acids

PRAL = 2 x [(0.00503 x mg met/d) + (0.0062 x mg cys/d)] + (0.037 x mg P/d)
- (0.021 x mg K/d) - (0.026 x mg Mg/d) - (0.013 x mg Ca/d)

Remer & Manz 1995
PRELIMINARY Results

- **High Apro/K**
- **Low Apro/K**

**Urinary sulfate (mmol/d)**

**Urine pH**

- **NTX (nmol/mmol creat, %)**
Variability between subjects – confounding factors?

Energy (i.e., kcal, % requirement, metabolic rate), Protein (% of kcal), CO2, Exercise, Inflammation, Gender, Exercise, Other (?)
PRELIMINARY Results

**Graph 1: NTX nmol/d vs. ATM CO₂ (mmHg)**
- **X-axis:** ATM CO₂ (mmHg)
- **Y-axis:** NTX nmol/d
- **Legend:**
  - Red dots: High diet
  - Blue squares: Low diet

**Graph 2: Urine pH vs. ATM CO₂ (mmHg)**
- **X-axis:** ATM CO₂ (mmHg)
- **Y-axis:** Urine pH
- **Legend:**
  - Purple dots
Excess sodium intake (and related effects on acid/base physiology) is associated with a number of health issues:

- Bone loss
- Increased renal stone risk
- Impaired muscle performance/protein catabolism
- Altered glucose metabolism
- Hypertension

With the exception of hypertension, all of these other factors have been raised as concerns for space travelers.
In 2005-2006, the average US intake of Na was estimated at 3,436 mg Na/d*
In 1990-1999, the average US intake of Na was estimated at: 3,377 mg for 31-50 yo M**
3,539 mg for 31-50 yo F

* http://www.cdc.gov/media/pressrel/2009/r090326.htm
** IOM, Dietary Reference Intakes, 2004
Sodium and Bone

SOLO

Frings-Meuthen et al., JAP, 2011
Sodium and pH

Excess sodium intake leads to non-osmotic (i.e., non-fluid retaining) storage of sodium.

The excess sodium is bound to glycosaminoglycans in skin, exchanging with a hydrogen ion.

H+ release contributes to acid load.

Heer, et al., BJN, 2009
Frings-Meuthen et al, 2011

50 mEq = 1150 mg
200 mEq = 4600 mg
550 mEq = 12,650 mg

H+ release contributes to acid load
SOLO
Acid/Base and Bone

High protein, low potassium diet

**Acid Load >> Alkali Load**

\[ H^+ >> \text{Organic anions} \]

\[ \text{CO}_3^{2-} \quad \text{Ca}^{2+} \quad \text{CO}_3^{2-} \quad \text{Ca}^{2+} \]

\[ \text{Ca}^{2+} \text{excretion} \]

**Na\(^+\)/H\(^+\) exchange in skin GAGs**

**Excess dietary sodium**