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 $H^+$ corresponding to $H_2SO_4$

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

\[ r = 0.80^* \]

\begin{align*}
\text{N-telopeptide (nmol/d)} \\
\text{Apro/K (g/mEq)}
\end{align*}

\begin{align*}
\text{Bed rest} \\
\text{Ambulatory}
\end{align*}

\begin{align*}
\text{Urinary pH} \\
\text{Urinary NTX (nmol/d)}
\end{align*}

\begin{align*}
\text{Pre} \\
1 \\
2 \\
3 \\
4
\end{align*}

\begin{align*}
\text{Weeks of bed rest}
\end{align*}

Zwart et al., J Appl Physiol, 2005
Submariners

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

**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

<table>
<thead>
<tr>
<th>L-180</th>
<th>L-45</th>
<th>FD15</th>
<th>FD30</th>
<th>FD60</th>
<th>FD120</th>
<th>FD180</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-d High APro:K</td>
<td>4-d Low APro:K</td>
<td>4-d Low APro:K</td>
<td>4-d Monitored Diet</td>
<td>4-d Low APro:K</td>
<td>4-d High APro:K</td>
<td>4-d High APro:K</td>
</tr>
</tbody>
</table>
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**

**NTX (nmol/mmol creat, %)**

**Urinary sulfate (mmol/d)**

**Urine pH**

- **PRELIMINARY Results**
PRELIMINARY Results

Variability between subjects – confounding factors?

Energy (i.e., kcal, % requirement, metabolic rate), Protein (% of kcal), CO2, Exercise, Inflammation, Gender, Exercise, Other (?)
PRELIMINARY Results
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.
3500 mg/d = ISS requirement; and the “old” RDA
2300 mg/d = US Dietary Reference Intake Tolerable Upper Intake Level (UL)**, and NASA exploration requirement

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

** 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.

Glycosaminoglycans

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

Blood pH

H+ release contributes to acid load

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

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

High protein, low potassium diet

**Acid Load >> Alkali Load**

**H+ >> Organic anions**

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

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

\[ \text{Na}^+ / \text{H}^+ \text{ exchange in skin GAGs} \]

\[ \text{Excess dietary sodium} \]

**Acid Load**

\[ \text{H}^+ \]

\[ \text{Organic anions} \]

\[ \text{Na}^+ \text{/H}^+ \text{ exchange in skin GAGs} \]

\[ \text{Excess dietary sodium} \]

\[ \text{Na}^+ \text{ / H}^+ \text{ exchange in skin GAGs} \]

\[ \text{Excess dietary sodium} \]