



## pH ARTICLES & ABSTRACTS ON BONE HEALTH

### Regulation of bone cell function by acid-base\* balance.

Arnett T, *Proc Nutr Soc* 62:511-520 (2003)

Abstract:

#### Regulation of bone cell function by acid-base balance.

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Bone growth and turnover results from the coordinated activities of two key cell types. Bone matrix is deposited and mineralised by osteoblasts and it is resorbed by osteoclasts, multinucleate cells that excavate pits on bone surfaces.

It has been known since the early 20th century that systemic acidosis causes depletion of the skeleton, an effect assumed to result from physico-chemical dissolution of bone mineral. However, our own work has shown that resorption pit formation by cultured osteoclasts was absolutely dependent on extracellular acidification; these cells are inactive at pH levels above about 7.3 and show maximum stimulation at a pH of about 6.9.

Bone resorption is most sensitive to changes in H<sup>+</sup> concentration at a pH of about 7.1 (which may be close to the interstitial pH in bone). In this region pH shifts of < 0.05 units can cause a doubling or halving of pit formation. In whole-bone cultures, chronic HCO<sub>3</sub><sup>-</sup> acidosis results in similar stimulations of osteoclast-mediated Ca<sup>2+</sup> release, with a negligible physico-chemical component. In vivo, severe systemic acidosis (pH change of about -0.05 to -0.20) often results from renal disease; milder chronic acidosis (pH change of about -0.02 to -0.05) can be caused by excessive protein intake, acid feeding, prolonged exercise, ageing, airway diseases or the menopause.

Acidosis can also occur locally as a result of inflammation, infection, wounds, tumours or diabetic Ischaemia. Cell function, including that of osteoblasts, is normally impaired by acid; the unusual stimulatory effect of acid on osteoclasts may represent a primitive 'fail-safe' that evolved with terrestrial vertebrates to correct systemic acidosis by ensuring release of alkaline bone mineral when the lungs and kidneys are unable to remove sufficient H<sup>+</sup> equivalent.

**The present results suggest that even subtle chronic acidosis could be sufficient to cause appreciable bone loss over time.**

(Note: Base is the scientific term for substances that are alkaline i.e pH higher than 7.0)



## pH ARTICLES & ABSTRACTS ON BONE HEALTH #2

### **Bone buffering of acid and base in humans.**

*Lemann et al., Am J Physiol Renal Physiol 285:F811-F832 (2003)*

Abstract:

#### **Bone buffering of acid and base in humans.**

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The sources and rates of metabolic acid production in relation to renal net acid excretion and thus acid balance in humans have remained controversial.

The techniques and possible errors in these measurements are reviewed, as is the relationship of charge balance to acid balance. The results demonstrate that when acid production is experimentally increased among healthy subjects, renal net acid excretion does not increase as much as acid production so that acid balances become positive.

These positive imbalances are accompanied by equivalently negative charge balances that are the result of bone buffering of retained  $H^+$  and loss of bone  $Ca^{2+}$  into the urine.

The data also demonstrate that when acid production is experimentally reduced during the administration of  $KHCO_3$ , renal net acid excretion does not decrease as much as the decrease in acid production so that acid balances become negative, or, in opposite terms, there are equivalently positive  $HCO_3^-$  balances.

Equivalently positive  $K^+$  and  $Ca^{2+}$  balances, and thus positive charge balances, accompany these negative acid imbalances. Similarly, positive  $Na^+$  balances, and thus positive charge balances, accompany these negative acid balances during the administration of  $NaHCO_3$ . These charge balances are likely the result of the adsorption of  $HCO_3^-$  onto the crystal surfaces of bone mineral. There do not appear to be significant errors in the measurements.



## pH ARTICLES & ABSTRACTS ON BONE HEALTH #3

### Dietary acid-base balance and intake of bone-related nutrients in Cambridge teenagers.

*Prynne et al., Eur J Clin Nutr 58:1462-1471 (2004)*

Abstract:

#### Dietary acid-base balance and intake of bone-related nutrients in Cambridge teenagers.

*Prynne CJ, Ginty F, Paul AA, Bolton-Smith C, Stear SJ, Jones SC, Prentice A. MRC Human Nutrition Research, Elsie Widdowson Laboratory, Cambridge, UK. celia.greenberg@mrc-hnr.cam.ac.uk*

#### OBJECTIVES:

To evaluate the diet of 16-18-y-old boys and girls with particular reference to intakes of nutrients believed to affect bone health and dietary acid-base balance.

#### DESIGN:

A 7-day food diary was completed between the months of October and December. SETTING: Cambridge, UK.

#### SUBJECTS:

A total of 111 boys and 101 girls aged 16-18 y who were recruited into the Cambridge Bone Studies.

#### MAIN OUTCOME MEASURES:

Mean daily intakes of foods and selected nutrients (protein, calcium, phosphorus, magnesium, potassium, vitamins C and K) were calculated. Two estimates of acid-base balance were calculated from the diet using the formulae of Remer (net acid excretion, estimated indirectly; NAE(ind)) and Frassetto (protein/potassium ratio).

#### RESULTS:

Mean calcium and phosphorus intakes were above the UK Reference Nutrient intake (RNI). In all, 39% of the boys and 36% of the girls had vitamin K intakes lower than 1 microg/kg body weight/day. Calcium intake was positively correlated with all other nutrients except vitamins C and K. Boys had a significantly higher estimated net acid excretion (NAE(ind)) than girls ( $P < 0.001$ ). Although a strong correlation ( $r = 0.76$ ,  $P < 0.001$ ) was found between the two methods, at higher acid levels a divergence was observed. A significant positive correlation was found between NAE(ind) and the weight consumed per day of milk, cheese, meat and cereal foods and a negative correlation was found with the weight of potatoes and fruit. Diet composition is such that a lower NAE(ind) is accompanied by a lower calcium intake.

#### CONCLUSIONS:

The interpretation of the effects of calcium and other nutrients on bone cannot be considered in isolation from the other components of the diet. These results challenge some of the accepted perceptions about what constitutes an optimal diet for the promotion of bone health in adolescents.



## pH ARTICLES & ABSTRACTS ON BONE HEALTH #4

### The role of the skeleton in acid-base homeostasis.

*New SA, Proc Nutr Soc 61:151-164 (2002)*

Abstract:

#### The role of the skeleton in acid-base homeostasis.

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Nutritional strategies for optimising bone health throughout the life cycle are extremely important, since a dietary approach is more popular amongst osteoporosis sufferers than drug intervention, and long-term drug treatment compliance is relatively poor.

As an exogenous factor, nutrition is amenable to change and has relevant public health implications. With the growing increase in life expectancy, hip fractures are predicted to rise dramatically in the next decade, and hence there is an urgent need for the implementation of public health strategies to target prevention of poor skeletal health on a population-wide basis.

The role that the skeleton plays in acid-base homeostasis has been gaining increasing prominence in the literature; with theoretical considerations of the role alkaline bone mineral may play in the defence against acidosis dating as far back as the late 19th century.

Natural, pathological and experimental states of acid loading and/or acidosis have been associated with hypercalciuria and negative Ca balance and, more recently, the detrimental effects of 'acid' from the diet on bone mineral have been demonstrated.

At the cellular level, a reduction in extracellular pH has been shown to have a direct enhancement on osteoclastic activity, with the result of increased resorption pit formation in bone.

A number of observational, experimental, clinical and intervention studies over the last decade have suggested a positive link between fruit and vegetable consumption and the skeleton.

Further research is required, particularly with regard to the influence of dietary manipulation using alkali-forming foods on fracture prevention. Should the findings prove conclusive, a 'fruit and vegetable' approach to bone health maintenance may provide a very sensible (and natural) alternative therapy for osteoporosis treatment, which is likely to have numerous additional health-related benefits.