The Journal of Nutrition
The Importance of Calcium, Potassium, and Acid-Base Homeostasis in Bone Health and Osteoporosis Prevention

The Importance of Calcium, Potassium, and Acid-Base Homeostasis in Bone Health and Osteoporosis Prevention[1,2]

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The acid ash hypothesis proposed by Wachman and Bernstein (1) in 1968 put forth the paradigm that the net acid produced from the Westernized diet could contribute to the development of osteoporosis. Algorithms designed specifically to quantify the relative acidity of the diet have been developed. These equations are empirically derived relationships between nutrient analysis from food tables and the quantity of acid excreted in the urine (2,3) and estimate net endogenous acid production (4). The underlying premise of these diet-based algorithms is that dietary intake is the modulating factor that protects bone against excess metabolic acid production. In healthy individuals, the buffering of metabolic acid is under control of the kidneys, lungs, and skeleton. In theory, when the diet is unable to provide sufficient buffering, the skeleton is utilized to maintain blood hydrogen ion concentrations, keeping pH between 7.35 and 7.45 (5).

Research documenting the detrimental effects of a relatively acid-producing diet on bone mineral density in free-living individuals has yielded small but not always statistically significant effects (6–11), causing some to speculate about the effects of an acid-producing diet per se. The long latency period required before current technology can assess detrimental effects on bone mineral density has been a limitation of many studies. The long-term studies of MacDonald and New and their colleagues (12,13) support Wachman and Bernstein's assertion that 15% of skeletal calcium can be lost over a decade to buffer a mild metabolic acidosis as a result of dietary practices (1). Researchers investigating metabolic acidosis have shown that small downward deflections of pH lead to increased osteoclastic activity, an indicator of bone resorption (14–17). Metabolic studies support the concept that a higher alkaline state manipulated by diet or pharmacological agents yields positive effects on calcium balance and increased blood pH levels (17). It is through these clinical studies that potassium has emerged as a pivotal factor in determining whether a person's diet is a net acid- or alkaline-producing entity.

Rafferty et al. (18) assert that increases in dietary potassium result in decreased urinary calcium but are balanced by a compensatory decline in calcium absorption, thus resulting in no net change in calcium balance. Others (19) have challenged their findings by stating that these results are applicable only when the increasing source of potassium is from dairy products. Although fruits and vegetables are important sources of potassium, they also provide buffering through the generation of bicarbonate (19). Regardless of source, higher potassium intake has been positively associated with bone metabolism (5,12).

The role of dietary potassium in modulating bone mass resides in the complex interaction between the interstitial fluid that surrounds the crystalline bone and the systemic extracellular fluid. The bone's interstitial fluid has higher concentrations of potassium and sodium and lower concentrations of calcium and phosphorus compared with bone crystals or plasma (20). The potassium content of the bone's interstitial fluid is directly related to the quantity of potassium consumed and is the skeletal compartment's first line of defense in buffering metabolic acid loads (5,20). Thus, if potassium intake is higher regardless of food source, then there will be adaptations that affect not only calcium balance (18) but metabolic indices of bone metabolism such as markers of bone resorption (20). The presence of potassium and bicarbonate in fruits and vegetables may be dually important in providing an increased buffering capacity, although other components such as essential oils and monoterpenes (21–23) may also be responsible for that action.

In concert with the acid-base literature, protein intake is considered to be a net acid-producing substance and thus a net negative risk factor for bone dissolution. However, substantial literature supports the beneficial effects on skeletal metabolism when higher protein levels are consumed in concert with adequate calcium, potassium, and other minerals, regardless of the

[1] Published as a supplement to *The Journal of Nutrition*. The opinions expressed in this publication are those of the authors and are not attributable to the sponsors or the publisher, Editor, or Editorial Board of *The Journal of Nutrition*. Supplement contents are solely the responsibility of the authors and do not necessarily represent the official views of the National Dairy Council. Publication costs for this supplement were defrayed in part by the payment of page charges. This publication must therefore be hereby marked "advertisement" in accordance with 18 USC section 1734 solely to indicate this fact. Presented at the Nutrition and Bone Health Working Group program at the "American Society of Bone Mineral Research 28th Annual Meeting," held in Philadelphia, PA, September 15–19, 2006. The Nutrition and Bone Health Working Group program was organized by Laura Harkness and was sponsored by the National Dairy Council. Guest Editors for the supplement publication were Frances A. Tylavsky, University of Tennessee, The Health Science Center, Memphis, TN; Lisa Spence, National Dairy Council; and Laura Harkness, Nestle R&D Center. *Guest Editor disclosure*: F. A. Tylavsky and L. Harkness, no relationships to disclose; L. Spence is employed by the National Dairy Council, a sponsor of the supplement publication.

[2] Author disclosures: F. A. Tylavsky and L. Harkness, no relationships to disclose; L. Spence is employed by the National Dairy Council, a sponsor of the supplement publication.

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0022-3166/08 $8.00

source of protein (24–26). The Dietary Approaches to Stopping Hypertension (DASH) diet (27) is a calcium-rich diet that emphasizes fruits, vegetables, and low-fat dairy products. This diet underscores the importance of consuming a complement of foods from meats, grains, dairy, fruits, and vegetables as prudent for promoting optimal bone health. In the following articles, Rafferty and Lanham-New carefully review the evidence on the interaction of specific diet components that impact bone health and conclude that a balanced diet with recommended servings of dairy products and a variety of fruits and vegetables is prudent for optimal bone health. Additionally, they comment on future research directions for consideration by the scientific community.

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