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Special Section on Bone and Nutrition

Does a High Dietary Acid Content Cause Bone Loss, and Can Bone Loss Be Prevented With an Alkaline Diet?

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Abstract

A popular concept in nutrition and lay literature is that of the role of a diet high in acid or protein in the pathogenesis of osteoporosis. A diet rich in fruit and vegetable intake is thought to enhance bone health as the result of its greater potassium and lower ''acidic'' content than a diet rich in animal protein and sodium. Consequently, there have been a number of studies of diet manipulation to enhance potassium and ''alkaline'' content of the diet to improve bone density or other parameters of bone health. Although acid loading or an acidic diet featuring a high protein intake may be associated with an increase in calciuria, the evidence supporting a role of these variables in the development of osteoporosis is not consistent. Similarly, intervention studies with a more alkaline diet or use of supplements of potassium citrate or bicarbonate have not consistently shown a bone health benefit. In the elderly, inadequate protein intake is a greater problem for bone health than protein excess.

Key Words: Acid-ash hypothesis; acid-base balance; alkaline potassium; fruits and vegetables.

Introduction

In this work we examine evidence that a change in acid-base balance through dietary means can affect bone health. This concept is sometimes termed the ''acid-ash hypothesis'' and is often promoted as an important factor in the development of osteoporosis. This hypothesis suggests that foods high in ''acidic'' content (e.g., animal protein and grains) cause a chronic acidemia because of their sulfate and phosphate content, whereas fruits and vegetables create a more alkaline environment because of their greater potassium-organic anion content and may even prevent age-related bone loss and osteoporosis. It proposes that the acidic anions provide an increased acid load on the kidney and that the increased net acid excretion (NAE) is accompanied by increased calcium loss in the urine. Furthermore, proponents of the acid-ash hypothesis suggest that, to maintain a normal acid-base homeostasis, there is an increase in bone resorption to buffer the excess dietary ''acid.''

Further credence was given to this concept when the Dietary Reference Intake recommendation for potassium in 2005 by the Institute of Medicine *(1)* made a specific reference to increasing alkaline sources of potassium, that is, fruits and vegetables, to enhance bone health. However, recommendations that restrict protein intake to reduce NAE, and restriction of otherwise-healthy foods because of their ''acidity.'' may also have implications that could be detrimental to bone health. A recent review of the impact of acid-base balance on bone suggests the proponents of the acid-ash hypothesis of osteoporosis have underestimated the ability of the kidney and respiratory system to deal with dietary sources of acid *(2)*. The purpose of this work is to examine the different types of evidence for an acid-base effect on bone and to provide recommendations for dietary intakes that are in-line with the evidence.

Acid–Base Effects on Bone: Observational Studies

A role for dietary vegetables and fruit on bone health has emerged in the literature. Population-based studies have

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reported that increased potassium intake through vegetables and fruits is associated with increased bone mineral density. For example, in 1999 Tucker et al, by using cross-sectional and prospective Framingham data of subjects 69−97 yr, showed that potassium and magnesium intakes, as well as fruit and vegetable intake, were significantly associated with greater bone mineral density (BMD) and with a slower rate of bone loss, albeit the latter only in men *(3)*. Fruit and vegetable intake has been associated with a lower NAE, and thus, some authors have related these studies to the concept of alkaline diets being beneficial to bone.

Observational studies on protein, however, have not been consistent in linking a protein-induced change in NAE to changes in bone measures or fracture risk. Prospective as well as intervention studies on the effect of protein intake and BMD and/or fracture rates have almost all shown that elderly women benefitted from an increase in protein intake *(2)*. Indeed, the most recent European osteoporosis guidelines recommend a daily protein intake of 1 g/kg body weight, a value greater than the current dietary recommendations in the United States and Canada *(4)*. Thus, attempts to change NAE by reducing protein intake may be detrimental to skeletal health.

The Dietary Approaches to Stop Hypertension (DASH) diet, which emphasizes the intake of vegetables, fruits, and low-fat dairy products and the avoidance of processed foods (Table 1), may have bone benefits. In a 3-month trial among 186 middle-aged men and women, investigators reported that the DASH diet significantly reduced biochemical markers of bone turnover *(5)*. However, the DASH diet does not necessarily provide evidence for an acid-base effect because it also incorporates many important healthful changes, including sufficient calcium and protein intakes (>1000 mg and >75 g, respectively); and a sodium intake below the upper level of 2300 mg, which may reduce sodium-induced hypercalciuria.

A large study has corroborated the bone-health effect of increasing fruits and vegetables. In the Women's Health Initiative Dietary Modification study, a low-fat and increased fruit, vegetable, and grain educational intervention in close to 50,000 postmenopausal women was evaluated with respect to incident hip, other site-specific, and total fractures and self-reported falls, and, in a subset, BMD *(6)*. After an 8-year follow-up, the intervention group had a lower rate of reporting 2 or more falls than did the comparison group. Although few trials have been conducted in humans, many animal and cell studies indicate that a diet high in fruit supplies carotenes, polyphenols, and other active plant compounds that may play beneficial roles in bone metabolism *(7)*.

The Alkaline Potassium Hypothesis

Advocates of the Alkaline Potassium Diet Hypothesis use the Paleolithic diet as being ''ideal'' for preserving bone integrity *(8)*. The Paleolithic diet of hunter−gatherers is high in potassium and bicarbonate precursors from vegetables and fruit, which advocates believe counteracted the very high protein intakes of those early humans. Herein dietary potassium at levels of 400 mEq per day (close to 3 times the current adequate intake for potassium) would be essential to maintain bone integrity. In contrast, the modern western diet is low in alkaline equivalents, and cereals, although they are plant-based, do not provide the alkalizing effect of fruits and vegetables. In addition, the modern western diet is high in sodium, mainly because of processed foods. To return to a more favorable ratio of potassium (K)-to-sodium (Na) in the diet, that is, to a ratio that is comparable with what humans ate in preagricultural diets, both an increase in potassium and an avoidance or severe restriction of sodium chloride is necessary *(8)*. Interestingly, Canadian and American food guide revisions have reduced the amount of cereal grains servings and increased the amounts of fruit and vegetable servings, that is, Eating Well with Canada's Food Guide (released in 2007) and MyPyramid (released in 2005). Both of these food guides resemble the DASH diet. As illustrated in Table 1, the DASH diet (and food guides that resemble it) is probably the ''best'' dietary pattern that can be achieved today, via the use of largely unprocessed foods available in the marketplace. By following the DASH diet, one can attain a dietary Na:K ratio of approximately 1:1. This ratio is a marked improvement over dietary intakes that typically occur, that is, $\sim$2:1, in the United States and Canada.

The Acid-Ash Hypothesis

The Acid-Ash Hypothesis is a variant of the Alkaline Potassium Hypothesis. Both are premised on the argument that acidic compounds in the diet (high protein, high phosphate, or other ''acidic'' anions like sulfate) have an adverse effect on bone, whereas alkaline components, such as fruit and vegetables, will counter this effect. Early work centered on measuring NAE after consumption of diets varying in protein, with or without variations in alkaline salts or alkaline foods *(2)*. However, it has never been demonstrated that, in healthy subjects, manipulation of the diet caused any disturbance in blood pH or bicarbonates. The ''metabolic acidosis'' predicted with the Acid-Ash Hypothesis has remained hypothetical.

Systematic Reviews of Acid-Base and Bone

A moderately large amount of literature exists on the influence of dietary acid or alkali on bone. Although the common theme is that a diet high in protein or phosphate would be detrimental to the skeleton, recent systematic reviews of this literature have not supported these premises.

The proponents of the Acid-Ash Hypothesis have suggested that a diet providing high phosphate content would be acidic and that this would result in negative calcium balance and bone loss. However, a recent meta-analysis of studies of dietary intervention with phosphate supplements found no support for this concept *(9)*. This analysis examined studies of phosphate supplementation that also controlled calcium intake by the subjects. Control of sodium intake was not consistent in the studies reviewed, and only one of the studies used randomization and provided the Institute of