

Is “vegetarianism” a serious risk factor for osteoporotic fracture?^{1,2}

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In the West, there are now appreciable numbers of individuals who are classified as “vegetarian” (those who exclude meat, fish, and poultry) or “vegan” (those who exclude all foods of animal origin). A recent 2009 survey suggests that $\approx 3.2\%$ of US adults adhere to a vegetarian-based diet and $\approx 0.5\%$ of US adults consume no animal products at all (1). Similar 2009 figures have also been published for the United Kingdom ($\approx 3\%$ are completely vegetarian) (2). Concomitantly, there has been considerable interest as to the health benefits and health-adverse effects of following such a dietary pattern. We have many more questions than answers, and certainly the debate as to whether “vegetarianism” increases an individual’s risk of osteoporosis over the long term has been raging for well over a quarter of a century (3).

From a public health nutrition perspective, it is critical to address whether adhering to particular dietary habits puts an individual at an increased or decreased risk of disease outcome. Given that we are now in an epidemic of osteoporosis, with >10 million Americans affected and with estimated costs in the United States and Europe rising above \$17.9 billion and €13.9 billion annually, respectively, we need conclusive evidence on how exogenous (modifiable) factors can significantly improve (or harm) bone health at the population level (4).

In this issue of the Journal, Ho-Pham et al (5) report the findings of a Bayesian meta-analysis that examines the effect of vegetarian diets on bone mineral density. This is a most timely and important piece of work. Results included 2749 individuals (ratio of females to males: 2:1) and showed that, overall, bone density was lower in those subjects who adhered to a vegetarian/vegan diet than in those who consumed an omnivorous one but at a level that is unlikely to be clinically relevant.

The particular strengths of this study are the careful selection of studies for inclusion in the analysis and the rigorous methodology of Bayesian-type meta-analysis. In particular, Bayesian analysis considers the *probability* of the hypothesis of treatment effect and is not reliant on *P* values but instead allows the reporting of direct probability statements that are of interest and of importance. That said, this study does not provide the “conclusive” evidence that public health specialists require. The numbers of subjects are relatively small given the number of vegetarians worldwide; the study design of all but one of the studies is cross-sectional rather than longitudinal/prospective; and although the quality of the studies selected is in one way a strength, this meta-analysis is not fully representative of the many studies published in this area.

The results point to a significant (albeit very small) difference in bone density in those who adhere to a vegetarian/vegan lifestyle compared with those who adhere to a mixed, omnivorous one, but it is important to note that the results do not fully adjust for key confounding factors, such as for differences in 1) body weight, 2) physical activity levels, and 3) smoking, as well as for differences in the considerable genetic-ethnic backgrounds in the population studied (Asian compared with white). Indeed, several of the studies on vegetarianism and bone health published before 1984 (not included in this meta-analysis) were based on Seventh Day Adventists who had a significantly different lifestyle compared with those who follow an omnivorous diet (6). In this Bayesian meta-analysis, in $>50\%$ of the articles included, body weight was significantly lower in the vegetarian group compared with the omnivorous group, and it is well established that body weight is a key determinant of bone mineral density. It is also important to point out that, in the article by Ellis et al (1972), which is quoted in the study but not included in the analysis, there was a fundamental error in the interpretation of the photographic density measurements, and their conclusions should have been the opposite to what they claimed (7–10).

The effect of a vegetarian diet is hugely complex (a point noted by the authors) and includes differences in 1) the nutrient components of the diet, 2) lifestyle factors, 3) serum concentrations of estrogen, and 4) problems with the methods that are available for researchers to accurately assess the food-nutrient consumption patterns in the population groups, to name but a few key factors. This meta-analysis of course does not provide us with any information on mechanisms of action. Historically, the fundamental theories linking vegetarianism to the skeleton were focused on there being a link between acid-base homeostasis and the skeleton and on the assumption that the long-term ingestion of a vegetable-based diet would provide an alkali (ash) and hence be beneficial to bone health. Theoretical considerations of the role played by alkaline bone minerals in the defense of the organism against acidosis date back as far as the late 19th century, and the pioneering work of Lemann, Barzel, and Sebastian over the past 30 y

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have shown the effects of “acid” from the diet on bone in humans and animals (11). Novel work by Arnett and Dempster (12) and Bushinsky et al (13) shows the detrimental effects of acid on bone mineral in vitro. It is impossible in this Bayesian meta-analysis to fully address how important dietary intake is to the findings because 2 of the studies did not report in detail the dietary intakes of subjects. In particular, it would be useful to examine the ratio of protein to potassium intake fully in vegetarian/omnivorous groups; this would give us an idea of the net endogenous non-carbonic acid production (NEAP), which is important because of the growing awareness of the link between high NEAP (ie, high dietary acidity) and poorer indexes of bone health (14). It would also be very useful to have information on the effect of other dietary constituents that are likely to be different in the groups, including phytoestrogen content and vitamin K concentrations as well as the extent of vitamin D insufficiency (15).

On the basis of the results of this Bayesian meta-analysis as well as the findings of the 5-y prospective study of changes in radial bone density in elderly white American women (which showed no differences in bone loss rates between vegetarians and omnivores) (16), it can be concluded that vegetarianism is not a serious risk factor for osteoporotic fracture. Future research should focus attention on whether there are any particular components of a vegetarian/vegan diet (eg, higher intake of fruit and vegetables) that would yield specific benefits to the skeleton, including the determination of the specific concentrations that would be required for optimum bone health, and what are the underlying mechanisms that affect overall bone health.

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