# Drinking Water Constituents and Disease[1–3]

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## Abstract

Several epidemiological investigations over the last 50 y have demonstrated a relation between risk for cardiovascular disease and drinking water hardness or its content of magnesium and calcium. An additional parameter, first suggested in a study from Japan 50 y ago, is the acidity of the water. It is known that acid load influences the reabsorption of calcium and magnesium in the renal tubuli. Intervention studies have shown that acid-base conditions influence the homeostasis of minerals. Data from intervention studies using magnesium, calcium, and hydrogen carbonate are reviewed. It is suggested that the health effects related to drinking water found in some studies may be caused by an increased urinary excretion of minerals induced by acid conditions in the body and that drinking water should contain sufficient amounts of hydrogen carbonate to prevent this effect.   J. Nutr. 138: 423S–425S, 2008.

## Introduction

Drinking water plays an important role for health and well-being. During the course of evolution, cells and later more complex organisms had an internal milieu that was the same as the mineral conditions present in the Cambrian oceans. An adequate homeostasis of iodine, magnesium, calcium, and potassium at concentrations present in these oceans is essential for life. It is maintained by the balance between intake of minerals in food and water and the excretion through the kidneys. An important factor determining the excretion is the acid-base conditions in the body, where an increase in acidity causes an increase in urinary excretion of calcium and magnesium.

A lack of magnesium and calcium may cause severe disease. These cations regulate muscular contractility, and a lack of magnesium leads to an increase in vascular tension and a lower muscular contraction threshold. This results in an increased risk of cardiovascular disease in terms of arrhythmia, muscular contraction, and a decreased fibrillation threshold, which may cause sudden death. Lack of calcium induces a deficiency in the bone reservoirs with consequent brittleness of the bones and an increased risk of fractures (osteoporosis).

### Drinking water and disease

Some data suggest that the supply of minerals from drinking water is of importance for the mineral homeostasis. The first study demonstrating a relation between water quality, other than microbial contamination, and health risks came from Japan (1). The study related the death rate in apoplexy (sudden death) in different parts of Japan to the acidity of river waters. This was followed by a number of studies in different countries where water hardness and later the content of magnesium and calcium was used as the criterion for water quality. Critical evaluations of these data have been presented (2,3). Ecological studies in which groups of populations in different geographical areas are compared have been made in many different countries, and 10 of 23 such studies demonstrate an inverse relation between hardness and cardiovascular death.

Only 3 case-control studies with a control of other sources of magnesium intake and with a relevant range in the content of magnesium in the drinking waters have been reported (4–6). The risk of death by heart infarction was inversely related to the amount of magnesium in the drinking water, but significant differences were only found at 7.8 mg/L and above. At 17 mg/L Mg, the odds ratio was 0.65 (4). Similar results were found in the other studies (5,6). Another case-control study in which no relation was found compared only very low levels of magnesium and thus did not have the power to evaluate the relation (7).

Epidemiological studies can never prove causality, and intervention studies are required to assess this. Regarding diseases with a long-term induction such as cardiovascular disease, such intervention studies are not feasible. One must thus rely on studies that measure the homeostasis of the minerals or the effects on risk indicators for cardiovascular disease such as blood pressure.

### Intervention studies

A number of intervention studies have been performed to assess the effect of minerals on risk indicators of cardiovascular disease. A meta-analysis of 33 studies on potassium intervention concluded that there might be a beneficial effect on blood pressure (8). Several of the studies reviewed were, however, dietary intervention studies, and thus, the intervention in reality comprised several minerals and other agents.

Regarding single minerals, several studies have been reported in which hypertensive persons were treated orally with nutritional doses of magnesium, and a review has been published (9). It was concluded that there was a suggestion of a dose-dependent reduction in blood pressure from the magnesium intervention but that the relation must be confirmed in larger studies, using higher doses of magnesium. The information was not considered sufficient for clinical application. Patki et al. (10) found no effect of magnesium supplementation but a decrease in blood pressure after treatment with potassium. Two studies reported a very small effect of calcium supplementation (11,12).

In summary, the results from these and other intervention experiments with the single elements calcium and magnesium are ambiguous and do not allow a clear-cut conclusion regarding causality.

## An alternative hypothesis

There is considerable evidence that acid-base conditions in the body influence the mineral homeostasis. Each nutrient has an influence on the renal acid load (13). This is determined by the sum of major anions less the sum of major cations. Protein is a major inducer of acid load because of the formation of sulfur ions during the metabolism of amino acids.

The importance of acid-base conditions for mineral homeostasis has been demonstrated in a number of intervention studies (14,15). There is also evidence on health outcomes. In an investigation on 1413 women and 1125 men, a relation was found between osteoporosis and consumption of cola beverages but not other carbonated soft drinks (16). The likely explanation is that the phosphoric acid present in cola beverages leads to an increased acid load with a higher secretion of minerals (17). In an intervention study on 181 postmenopausal women, the administration of potassium citrate, which shifts the balance to the basic side, led to an increased bone mineral density and a reduction in urinary calcium excretion (18). A study on a population sample demonstrated a close association between the net excretion of acids and the amounts of magnesium and calcium in the urine (19). In comparison to a younger age group, the effects were more pronounced, suggesting that the elderly are a risk group for mineral deficiency caused by acid conditions in the body (20).

There is also support for the concept that drinking-water-related acid-base conditions play an important role for mineral homeostasis. Natural mineral waters represent a substantial alkaline load and may influence the calcium homeostasis and bone remodeling (21,22). In an intervention study, drinking water containing 403 mg/L hydrogen carbonate was found to reduce the blood pressure in a group of 20 subjects with mild hypertension (23).

Regarding the previously discussed studies on the relation between death in heart infarction and the content of magnesium in drinking water (4–6), it is of interest that there is a close relation between the concentrations of magnesium and hydrogen carbonate in drinking water sources in Sweden. **Figure 1** illustrates the relation between death from heart infarction and the drinking water concentration of magnesium (4) as well as the corresponding values for hydrogen carbonate.

The figure illustrates that the risk for death in heart infarction was lower with levels of hydrogen carbonate higher than 110. According to previous discussions on the recommended amount of magnesium in drinking water, a recommended level for hydrogen carbonate could be 250 mg/L. Additional research in terms of epidemiological studies and intervention trials is required to verify this suggestion.
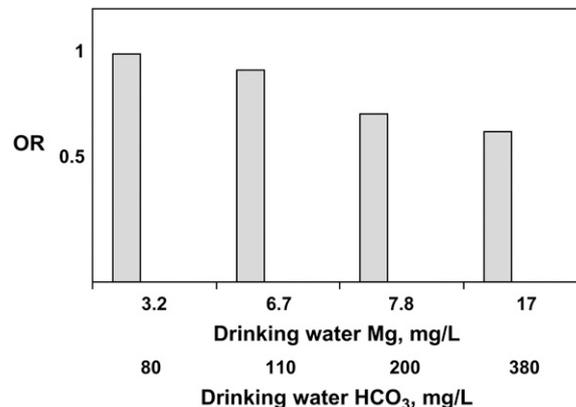


**FIGURE 1** Risk for death from heart infarction among men (986 cases, 854 controls) in the south of Sweden in relation to drinking water concentrations of magnesium and hydrogen carbonate [modified from Rubenowitz et al. (4)].

From evaluations of the literature, it has been concluded that there is some evidence for a relation between the drinking water content of magnesium and calcium and the risk for cardiovascular disease. New data suggest that acid/base conditions in the body are of importance for the homeostasis of the minerals calcium and magnesium. Because drinking water contains hydrogen carbonate and thus influences mineral homeostasis, health criteria for a good drinking water should include a sufficient content of hydrogen carbonate.

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