Transcript: A Presentation from Dr. Robert P. Heaney

Beverages & Bone Health Sorting Out the Science

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R. HEANEY
Hello, everybody. I'm going to start with some basics of bone health and then we can begin to look at the factors that may influence that.

First of all, for healthy bones, for a good skeleton, there are two basic requirements: First is adequate nutrition, and second is mechanical loading, or a four-letter word – work.

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Now, there's been a lot of emphasis on bone health the last few years because in fact, our skeletal status, or bone health, has deteriorated over the past 50 years.

This is partly because of reduced effective inputs of calcium and vitamin D particularly, but of all key nutrients as well, as I'll show in a moment.

Now, by effective inputs, I mean either decreased absolute intake coming into the mouth; decreased absorption at the intestine; or decreased retention – that is, because of increased urinary loss. We either don't take it in or we lose it; then, for all practical purposes, we have a reduced effective input of calcium and other key nutrients.

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One of the reasons for that is that calcium intake has declined in our modern diets relative to primitive levels. Our hunter-gatherer forebears got their nutrition mainly from a very wide variety of low-calorie foods, and getting enough energy virtually ensured that they would be getting enough calcium as well, and other minerals and micronutrients on top of that, of course.

Modern diets, by contrast, often consist of reduced quantities of energy-dense, sometimes nutrient-poor, foods.

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That leads us to a potential role for food fortification, because in order to offset the reduced intake of essential nutrients without increasing calories exorbitantly, some sort of fortification will likely be necessary.

We're familiar with many examples of this: the addition of folate and niacin for instance in cereal grain products; the addition of fluoride to the water supply; iodine to salt; vitamin D to various products, particularly milk in North America. These things have become a part of what we take for granted.

The question that is being debated at many levels right now is how far should we be going in terms of fortification. One factor, which we can't explore today but which is important, is we need to be assured – and this is a challenge for food manufacturers – we need to be assured that the fortificant is added to the food in a form that the body can assimilate. So I don't want to suggest that's not an important consideration; it's just that we can't talk about it today, there isn't time.

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Now, the second factor that's important with respect to why our skeletons aren't quite so healthy as they once were is that in fact we do much less physical work.

We use power lawn mowers if we don't pay somebody else to cut our grass. We ride instead of walk. We take an elevator or escalator instead of climbing stairs. We sit at a computer screen where we use energy in our brains but nowhere else in our body, so we're not loading the skeleton anywhere near as much as our grandparents did. This has been a very recent change in how humans live and work. Those two things taken together are responsible.

Now, our focus today is not on the physical activity side of the story, but on nutrition, and improved nutrition will not solve this problem of reduced physical work. That's a topic for another conference, actually. But improved nutrition will solve the problem of reduced effective input of calcium and vitamin D, so I want to keep our focus on where we can make a difference, and it's right there.

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I want to show you, however, before we leave this topic, that nutrition and exercise work together. There have been a lot of studies making this point, and here's just one of them. It's a study performed by Bonnie Specker about ten years ago in which she analyzed the results of many published trials of individuals who were given extra calcium and sometimes given exercise as well.

If we look at those who were sedentary, they didn't get any change in bone mineral density when you gave them extra calcium, so calcium did nothing without exercise. Conversely, the exercisers didn't do anything if they didn't have extra calcium in the diet. The key is to get calcium plus exercise. It's the two of these things that are taken together that are going to be important.

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That brings us back to the two basic requirements we started with: that is, adequate nutrition and good mechanical loading, or work. Now, what are the nutrients concerned? This is going to have to be our focus here today.

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I think we all know these. Calcium and vitamin D come first on the list, but protein is important as I'll show you in a moment. Magnesium, vitamins C and K, copper, zinc and manganese – all of these, and many other nutrients as well. But all of these are clearly linked in either animal models or humans, to building and maintaining a strong skeleton.

We have focused over the past 25 years almost exclusively on calcium, but it's extremely important to recognize the role of total nutrition under these circumstances. Vitamin D has become a point of considerable interest in the last five or six years. Protein is just now emerging as being important for bone, although I guess we should have known that all along, because bone after all is 50% protein by volume. It's probably one of the most protein-rich tissues in the body, certainly more so than muscle. But in any case, these are the nutrients we're going to be looking at.

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My primary focus today has to be calcium, simply because there isn't time to talk about everything else. But I do want to remind you that all tissues need all nutrients. All too often, in the watered-down courses that we may get in secondary school or the work we do for the public, we tend to equate a single nutrient with a single organ system, and that simply is incorrect. All tissues need all nutrients, and for that reason, a mono-nutrient approach will usually be wrong, or at least inadequate.

Furthermore, I think most of us as nutrition professionals know that diets low in one nutrient tend to be low in many nutrients, so mono-nutrient approaches would be wrong on that count alone. I want to show you a couple of examples of why mono-nutrient approaches may not work and how different nutrients work together.

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I could give many examples, but again, there simply isn't time. I just want to capture your attention with one of them here. Ten years ago, Dr. Bess Dawson, who's from Boston, published a landmark study of calcium and vitamin D supplementation in healthy elderly subjects. It was a three-year trial with a fracture end point, but they also measured change in bone mineral density.

You see on the left here the increase in bone mineral density at the femoral neck site in those given calcium, as contrasted with a loss in bone density at the same site in those given placebo**.** What I'm going to focus on is what was necessary for those individuals getting the extra calcium to show this increase in bone mineral density at the femoral neck, and I'm going to look specifically at protein here.

We're looking only at the calcium-only group, and the three vertical bars there are for protein intake tertiles – low intake on the left, medium in the middle of course, and a high protein intake on the right. What you see there is that the bone gain at the hip site was virtually confined to those in the highest protein intake. That is, the women who had low protein intakes but were still getting calcium did not show an improvement in bone mineral density at the hip.

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Now, we looked further at this when Dr. Dawson, who's published these data, and a huge database that I've accumulated in my laboratory over the years; got over 600 metabolic balance studies in women studied on diets that had been matched to their home diet, so that they were already equilibrated to the study diet when we started them on an inpatient study. The mean age was about the time of menopause, 50.

Here you see on the right is the calcium balance as a function of calcium intake, and there's a highly statistically significant upward trend there, so that the higher your calcium intake, the better your calcium retention. It kind of makes sense. If you don't have enough calcium coming into the body, you can't retain very much.

These data were the basis for the original calcium intake recommendations of the National Institutes of Health Consensus Conference on Osteoporosis way back in 1984. So these are old data. We went back and we looked at these with respect to protein intake, and I'm going to focus on the slope of balance on intake; that is, if it's a positive slope as you see here, then increasing calcium intake will help. If it's not, then increasing calcium intake doesn't do very much.

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Here are the data from these same 644 balances, including the dataset at the median protein intake for these women, which turned out to be 62 grams of protein per day, which you'll recognize immediately is at or above the recommended protein intake of eight-tenths of a gram per kilo of body weight.

And what you see here very clearly is that above that median protein intake, the slope of calcium retention on calcium intake was significantly positive – that's what the vertical axis is – whereas below the median protein intake, there was no correlation of calcium retention with calcium intake, which meant that on average, these women taking extra calcium didn't have any improved calcium balance. It just wasn't doing them any good.

So both the Dawson-Hughes study, which was a controlled trial, and these studies, which were controlled metabolic studies, both using protein intake as the controlling variable, we see that calcium provides a benefit only if you have a high protein intake.

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We kind of summarize that point here, pointing out that instead of thinking about these two nutrients by themselves, and we've done that in the past, unfortunately, we have to realize that calcium and protein interact constructively on bone so long as the intakes for each nutrient is adequate.

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Against that background, I'd like to look at the factors that may be influencing nutritional adequacy, with particular emphasis on the issue of carbonated beverages.

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Now, many studies have reported negative associations between carbonated beverage intake and a variety of carbonated beverage intake and a variety of measures of bone health or bone status such as bone mineral density or fractures, and these studies keep being published at the rate of one or two a year.

The usual conclusion that some of the authors or at least the media will draw is that the carbonated beverages, and colas in particular, have kind of leeched calcium out of bones, principally by causing an increase in urinary calcium excretion. That's part of the effective intake, that if you can't retain it, then you could have a problem.

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Now, is this conclusion correct? I think the answer is no, I don't believe it is correct, and I'll show you why I say that.

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But first of all, let's look at what could conceivably be going on if the mechanism were in fact what the popular conception seems to be, and that is because some constituent of the carbonated beverage has a negative effect on the calcium economy so as either to increase urine calcium or decrease intestinal absorption of calcium.

The other possible alternative is that carbonated beverages are neutral in themselves but act by displacing beverages that have a positive effect on the calcium economy, so it would be taking away a positive effect rather than contributing a negative effect. I'm going to look at the first of these mechanisms.

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Possible culprits that we encounter in carbonated beverages are caffeine, phosphorus, acid load and carbonation; and I'm going to focus primarily on the first three, because that's where the best data are concerned.

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Now, we've known for a long time that caffeine in short-term studies, that is, measured over two to five hours, will increase urinary calcium. But before I go into those data, let me tell you about the studies I'm going to be using here to look at this issue.

First of all is a big study that we performed in our unit here at Creighton, looking at a variety of carbonated beverages in a complex crossover design, looking specifically at the effect of caffeine in say colas with and without caffeine; and looking at the effects of caffeine in colas versus citrate-based products; and then finally, looking at the effects of phosphoric acid again crossing over between beverages that did and didn't use phosphoric acid as...

The second group of studies I'm going to refer to are metabolic balance calcium kinetic studies of coffee that was consumed with and without caffeine; that is, decaf coffee was used, and the participants took a capsule – a double-blind placebo control, so it was either a placebo capsule or it was a caffeine capsule, and I'll go into those in a little bit more detail in a moment.

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Let's start with the recognized effect of caffeine itself. These are some data taken from Linda Massey's group. Bergman, the senior author in this case, published now 17 years ago, looking at two-hour urine calcium content in individuals who were given either no caffeine or were given a large dose of caffeine – that is, six milligrams per kilo. That's a big caffeine dose, by the way. For a 70-kilo person, that translates to 420 milligrams of caffeine or three cups of coffee in a single setting– strong coffee, for that matter.

But what you see here is that if you give a lot of caffeine, you do get an increase in urinary calcium excretion. What Massey's group subsequently showed, and many others have shown the same thing, is that once that happens, then the body compensates and it rebounds and goes in the other direction, so that if you look at a 24-hour urine calcium excretion, there's no difference between those who get the caffeine and those who don't. There's a quick loss of calcium immediately following the absorption of the caffeine, and then there's a conservation of calcium that follows it, so it all averages out and there's no change.

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Now, we looked at that in our crossover beverage consumption, and here I'm showing you data from four of those beverages. The first two on the left are Coke and Coke Free; then there's Mountain Dew and there's Sprite. And you'll recall that Coke and Mountain Dew have caffeine, and Coke Free and Sprite don't. What you see here is the difference in the five-hour excess calcium excretion in the beverages that contained caffeine. This is very consistent with the data that Linda Massey and her colleagues have presented.

Now, it's a small effect, but I'm going to show you in a moment that it translates to zero in the final analysis. But even over this five-hour period, we're only talking about six milligrams of calcium over and above what would otherwise have come out, say with the Coke Free, for example.

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Now, I'd like to move to this caffeine metabolic study which looks at the 24-hour excretion. We performed this study in 16 pre-menopausal women. As I've already suggested, they were in a randomized, placebo-controlled crossover study. They received decaf four times a day, and they got a capsule with each cup, and it either contained placebo or 100 milligrams of calcium.

The treatment lasted for three weeks at a time, with a 37-day washout in between the treatment periods so that there was time for the body to adjust to the different regimens, as the case may be. At the end of each three-week period, we brought them into our clinical research center unit for a 12-day inpatient metabolic study where we did calcium balance and calcium kinetic measurements. And it's important to understand that the women consumed the same diet under all conditions, so whether they were getting caffeine or not, the food content and the nutrient content was otherwise identical.

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To make a long story short, what we have here is – and I'm having trouble advancing my slide; I'm sorry about that. It doesn't seem to want to go down further. So I'm just going to speak to this until perhaps there's some way to fix this problem.

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But to make a long story short, what happened was that there was no change in urinary calcium over a 24-hour period. There was no change in calcium absorption efficiency. There was no change in the secreted calcium going into the gut under the circumstances; so that the conclusion was that there was simply no effect of the caffeine at a dose of 400 milligrams of caffeine per day – again, a fair-sized dose.

Now, I'm going to try a different approach here, and we'll see if this doesn't work a little bit better for us. I'm going to switch to take a look at phosphorus now. I think we can conclude that although there is a short-term acute effect of caffeine, it doesn't last; and over a 24-hour period, caffeine for all practical purposes has no negative effect. But as I say, let's look at phosphorus.

Now, for some reason, phosphorus has been considered kind of the bad boy of nutrients, and that's partly because physicians who deal with end-stage renal disease understand that a high phosphorus intake can be a problem. But for the rest of us it's not a problem, and I think it's important to recall that dietary phosphorus does not increase urinary calcium loss. That's been known for a long time, and in fact in the management of some patients with kidney stone disease, one of the treatment approaches over the years has been to use phosphorus supplements, because it tends to lower urinary calcium rather than raise it. So on its face, phosphorus is not a likely cause of an increased urinary calcium loss.

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Once again I'm having trouble, it's dancing here. But I would like to look at the food content of phosphorus, just a few samples here, which probably most people in the audience could duplicate many times over. A 12-ounce can of cola will typically contain about 45 milligrams of phosphorus, whereas an eight-ounce glass of orange juice contains nearly as much – 27 milligrams – and if it's a calcium-fortified orange juice, then depending upon the fortificant that may be used, it could be up to 90 milligrams of calcium.

I make that contrast because people tend to look negatively at colas and say, oh, too much phosphorus; and yet you never hear the same thing when somebody talks about a calcium-fortified orange juice, which would contain twice as much phosphorus in many cases – once again depending on the fortificant used – but for most brands, there's going to be some calcium phosphate getting into that mix.

Peanuts, as I suspect most people know, or other nuts for that matter, can be a rich source of phosphorus – 113 milligrams per ounce. A chicken breast, which is generally considered to be the epitome of a healthy food, 124 milligrams; and a glass of milk, 232 milligrams.

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So it's important, I think, to recognize that the colas contribute only a negligible amount of phosphorus to the diet, unless they're consumed in huge excess. But an ordinary consumption of colas is going to add 5 to 10% to the total phosphorus intake of many people.

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Let me look at the phosphoric acid side of the phosphorus study. There's been some concern about acid kind of leeching calcium out of the bones, whatever that might mean, but that's how it's commonly expressed. It turns out that the amount of acidity in phosphoric acid as it's added to colas is relatively minor in comparison with say the acid load that would be produced by metabolizing protein in a typical breakfast, for instance – just not a lot of acid. But let's look at it anyhow.

What I've done here in this slide that you see is contrast the excess urine calcium for the colas which use phosphoric acid as the acidulant, and for the citrus-based beverages that use citric acid as the acidulant. Since citric acid is metabolized to carbon dioxide and water, it doesn't produce any net acid residue, so it's generally considered to be kind of a stand-in for a healthy source.

But if you look here at the excess urine calcium, calculated in four different ways – for example, depending upon whether we use the woman's experience when she was getting only water, or the woman's experience that very morning when we gave her the particular beverage concerned – what you see is that there is no excess urine calcium for the phosphoric acid. In fact, there's a reduction, and that's probably because phosphorus tends to reduce urine calcium, as I've already indicated. So calculated in four different ways, there's not a shred of evidence that the phosphoric acid, as acid, is doing anything negative with respect to the calcium balance.

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The bottom line, therefore, is that the individual components of carbonated beverages are without harmful effects on bone and the calcium economy, and so we're kind of left with only the displacement mechanism as the possible explanation for the observation in epidemiological studies that there seems to be a negative association between carbonated beverage intake and bone status.

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So I want to look with you for a moment at what has happened over the last 50-plus years in terms of beverage consumption. We see the solid blue line there represents milk, and that consumption since the end of World War II has dropped by nearly 50%. Per capita milk consumption has just been going down and down and down, and of course milk is a good source of protein, a good source of calcium and vitamin D, and so that's one of the reasons why there's been a change in nutritional status of the critical variables.

Carbonated beverage intake, on the other hand, has more than quadrupled over the same period of time, so that there is at least the possibility that the carbonated beverage may well have been displacing some of the milk. Whatever the mechanism may be, the carbonated beverage consumption has gone up and the milk has gone down. But I think what the data I've shown you will point out is not that the carbonated beverages were responsible for the decrease in bone status. It was the decline in milk intake that was responsible.

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So my conclusion as we wrap this up until we come to questions is that the carbonated beverages themselves are not harmful. There actually is room for both milk and carbonated beverages in a healthy diet, but – and I have to stress this – bone, and in fact total body health, absolutely require adequate total nutrition, and unfortunately they require work as well. The bones, as I've shown you, won't thrive unless we use them.