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ZINC CONTENT OF HUMAN CANCELLOUS BONE

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The zinc content of cancellous bone from the iliac crest was determined by the X-ray fluorescence technique in an autopsy series of 28 women and 66 men. The bone-zinc content was statistically related to age, but there was a large variation. It reached a maximum value in the fifth decade and thereafter decreased with age in both sexes. Men with a chronic disease had a lower zinc content than those who had died suddenly. There was a significant correlation between the zinc content and the bone strength in women ($p < 0.01$) and in men ($p < 0.05$). Zinc is thought to play a part in osteoporosis.

Key words: zinc; bone and bones; osteoporosis; bone strength

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Zinc is one of the most abundant of the essential trace elements in the human body. It has been reported to exert an effect upon enzymes and enzymatic function (Mikac-Dević 1970), protein synthesis (Fujioka & Lieberman 1964), carbohydrate metabolism (Mikac-Dević 1970) and bone formation (Haumont & McLean 1966). Quite a lot is known about the zinc content of the skeleton, but we know little about any changes in osteoporosis or bone fragility (Aitken 1976).

The purpose of the present investigation was to study the zinc content in the cancellous bone of the iliac crest with regard to age, sex, disease, bone strength and mineral density.

MATERIAL

Two bone specimens were taken post-mortem from the anterior iliac crests of 28 women and 66 men, both urban and rural dwellers in the central hospital district of Kuopio. One of the specimens was macerated and the other was fixed in 40 per cent ethyl alcohol. The age and sex distribution is shown in Figure 1. Fourteen of the women and 45 of the men had died suddenly from acute coronary-artery disease or accidents. The remaining 14 women and 21 men had died from chronic immobilizing diseases.

METHODS

a) *Macerated specimen:*

The sample was placed in a 5 per cent solution of sodium hypochlorite until the soft organic tissues were destroyed. It was then washed carefully with water, and then incubated at 20° C in 5 per cent sodium bicarbonate for 48 hours and re-washed with water. The sample was then left in 5 per cent hydrogen peroxide for 48 hours and washed again. Residual fat was removed from the dry sample with xylene (72 hours), which was then evaporated off. The dry sample could then be stored for further investigation.

The zinc of the cut surface of the trabecular bone area of the iliac crest was measured by the ^{238}Pu-excited semiconductor detector X-ray fluorescence analysis (Patomäki & Olkkonen 1974, Olkkonen et al. 1976). The area of the zinc Kα X-ray peak (8.6 keV) was calibrated by adding different amounts of internal standard ($ZnCl_2$) to a series of ten samples. The reproducibility of the method was tested in ten samples from the bone material containing 50 $\mu g/g$ of zinc. The coefficient of variation was 3.5 per cent.

b) *Fixed specimen:*

A strain-transducer (Nokso-Koivisto et al. 1976) was used for measurements of the compressive strength of trabecular bone. The diameter of the measuring pin was 3.0 mm. The result was expressed as the mean of three measuring values obtained at different locations on the cut surface of the specimen.

Bone-mineral density was determined using a modification of the gamma-ray attenuation method presented by Karjalainen (1973).

RESULTS

The zinc content of dry fat-free cancellous bone showed large distributions in both sexes as a function of age (Figure 1). The second-degree regression curves fitted to the distributions show that zinc concentration reaches its statistical maximum in the fifth decade in both sexes and thereafter decreases with age. Males with a chronic disease had a significantly lower zinc content than those who died suddenly ($p < 0.01$; t-test).

Both the bone strength and mineral-density distributions showed a significant ($p < 0.01$) decrease with age after the age of 30 in both sexes.

Bone strength correlated highly significantly with the mineral density of cancellous bone both in females ($r = 0.59$, $p < 0.001$) and in males ($r = 0.65$, $p < 0.001$).

Correlations of the zinc content with bone-compressive strength and age are summarized in Table 1. In the statistical analysis of the results for a linear correlation with the zinc concentration, bone strength and age, bones under 30 years of age, that is, those in the ascending part of the parabolic zinc distribution, were excluded. The zinc concentration correlated significantly with the bone strength in females and in the whole male group. The correlation was also significant for the male cases of sudden death, but not for deaths due to chronic disease. The zinc content was significantly related to age in females, in the whole male group and male sudden deaths. On the other hand, males with chronic disease had a

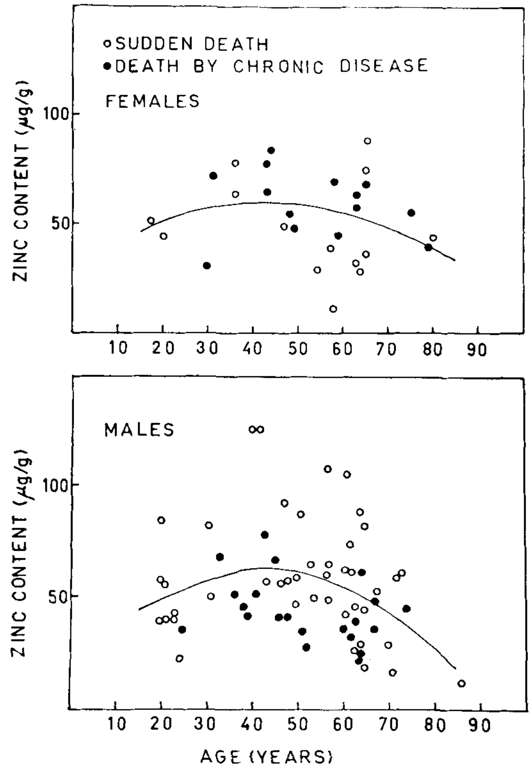

Figure 1. Distribution of the zinc content of dry fat-free cancellous bone according to age.

Table 1. Correlations of the zinc content of cancellous bone with strength and age in groups ≧30 years of age.

	Strength	Age
Females (Total, 26)	$r = 0.48$ $p < 0.01$	$r = -0.37$ $p < 0.05$
Males (Total, 57)	$r = 0.33$ $p < 0.05$	$r = -0.34$ $p < 0.01$
Males (Sudden deaths, 36)	$r = 0.40$ $p < 0.01$	$r = -0.47$ $p < 0.01$
Males (Deaths from *chronic disease*, 21)	$r = 0.23$ N.S.	$r = -0.36$ N.S.

N.S. = not significant.

zinc content which was not correlated with their age.

DISCUSSION

There is loss of bone mineral in chronic diseases which cause physical inactivity. We assume that our rough division of patients into cases of sudden death and chronic immobilizing diseases would separate osteoporotics from those with a normal mineral status. We used the area of iliac cancellous bone for the present study because metabolic changes are more detectable in trabecular than in cortical bone (Frost 1966). Moreover, in clinical work, histopathological studies are usually performed from the iliac bone biopsies. Our strain transducer is also constructed to measure the trabecular bone strength. We made the measurements at the cancellous bone area on the cut surface of iliac bone as far as possible from the periosteal borders. The determination of zinc by X-ray fluorescence is highly sensitive, but we have not found any reports on the use of this method for the measurement of bone zinc. The zinc values obtained in this work were between the values previously reported for bone ash and fresh weight (Calhoun et al. 1974). Close comparisons are difficult because of different pre-treatment procedures.

There are a number of studies of the zinc concentration in human bone (Nusbaum et al. 1965, Becker et al. 1968, Strehlow & Kneip 1969, Spadaro & Becker 1970, McBean et al. 1972, Aitken 1976). Becker's group studied the trace elements of archaeological and modern bones and reported that the zinc content was the same in old and newer bones. McBean et al. (1972) studied 30 adult subjects at necropsy. They divided the group into two categories: accidental deaths (controls) and deaths due to disease. Analysis of the bone did not reveal any statistically significant difference between the mean zinc concentrations in these two groups. In our study, men with a chronic disease had a lower zinc content than those who had died suddenly. Patients with diabetes, malignant disease or coronary-artery disease did not differ from the others in their bone-zinc content. This may be due to the relatively small number of patients in these groups.

Aitken (1976) showed a progressive increase with age in the bone-zinc content relative to calcium. We found an increase in our study up to the age of about 40, and thereafter a decrease in the zinc content of dry fat-free cancellous bone. Schroeder et al. (1967) showed a similar pattern of distribution with age in the zinc content of kidney as we did in bone.

Bone strength is generally correlated with the bone-mineral content (Bartley et al. 1966, Nokso-Koivisto et al. 1976). In our work it was not possible to compare the zinc concentration with mineral density because they were expressed in non-equivalent units of $\mu g/g$ and g/cm^3. The zinc concentration of cancellous bone was related to bone strength. It is difficult to explain what part collagen and what part mineral play in the strength of bone.

In osteoporosis, the basic abnormality is imbalance between bone resorption and apposition. Zinc is needed in bone formation, especially in matrix (Bergman et al. 1972). It is also evident from animal tests that extremely high dietary concentrations of zinc decrease the total ash content of bone (Huxley & Leaver 1966). Hence, the relationship of zinc to bone mineral is complicated.

In conclusion, we can state that the zinc content of bone is related to age and bone strength. The role of zinc in osteoporosis is obscure and requires further studies.

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