CHANGES IN THE SKELETON OF Papio hamadryas DURING PROLONGED AND EXCESSIVE INTAKE OF SODIUM CHLORIDE

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X-ray investigation of the skeleton of nine baboons (Papio hamadryas), five of which had undergone unilateral nephrectomy and which were receiving NaCl in excess with the object of producing salt hypertension, revealed generalized hypotrophy of the skeleton, osteoporosis, deformation of the vertebral bodies, especially in the lumbar region, and deformation of the limb bones. These changes were most marked in the animals which began to receive NaCl in excess in childhood or early adolescents, and in particular in animals with unilateral nephrectomy. No pathological changes were found in the skeleton of adult monkeys.

When monkeys were kept for 1.5-3 years on a diet containing an excess of NaCl in order to produce salt hypertension in the animals, considerable retardation in growth and development was observed. This retardation in the growth of the experimental monkeys demostrated the possible role of the skeletal system in the functional disorders due to excessive NaCl intake.

This paper describes an x-ray investigation of the skeleton of monkeys receiving an excess of NaCl for long periods.

Fig. 1. Retardation in growth and development of experimental male baboon No. 8093 (below) compared with control male No. 8084 (above) of the same age.

EXPERIMENTAL METHOD

Nine baboons (Papio hamadryas; seven males and two females), aged from two to nine years, were studied. Three of the males and one of the females had intact kidneys, while on the other four males and one female unilateral nephrectomy was performed before NaCl loading, as is usually done when "salt" hypertension is produced in other animals [4, 5].

Salt was given with the food (porridge, bread, fruit) and with the drinking water. The daily intake of NaCl was 2-3% of the quantity of food by weight, i.e., 12-16 g for adolescent and 22-27 g for adult monkeys.

The skeletal bones were investigated by x rays.

EXPERIMENTAL RESULTS

Retardation in growth and development of the experimental monkeys compared with the controls will be clear from Fig. 1.

Investigation of the skeleton revealed dystrophic changes in the bones of seven of the nine monkeys studied with different degrees of deformation. X-ray investigation of the skeletal system showed that distinct age differences were present: the older the animal was when the salt loading began, the less marked were the changes in the skeletal system.

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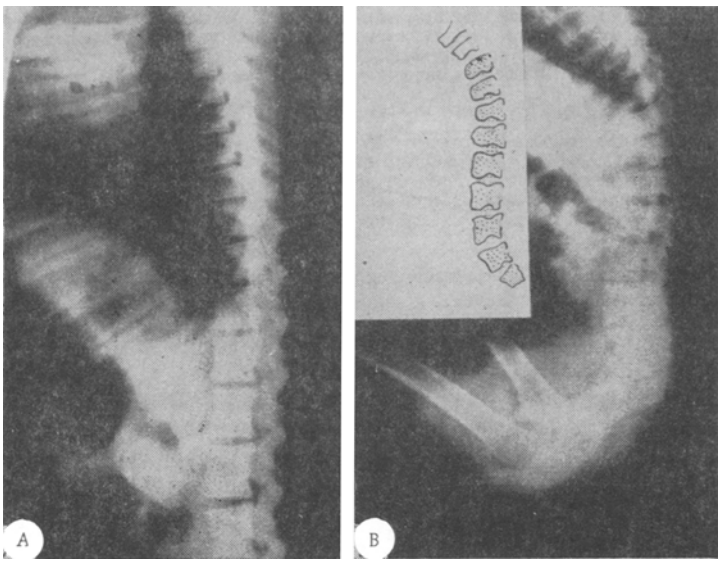

Fig. 2. X ray of thoraco-lumbar region of the spine of baboon No. 8084 (normal for comparison; A) and x ray of lumbo-sacral and part of thoracic region of the spine with diagramatic representation of baboon No. 8103 (B): osteoporosis, marked decrease in height of vertebral bodies, Schmorl's nodules, compressing upper and, in particular, lower surfaces of vertebral bodies; kyphosis of thoracic region of the spine.

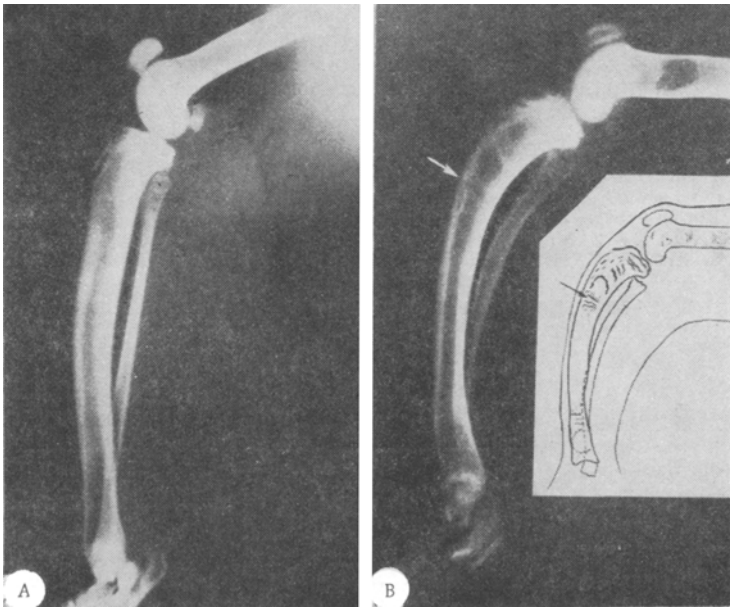

Fig. 3. X ray of region of knee joint and leg of baboon No. 8084 (normal for comparison; A) and x ray of region of knee joint and leg of baboon No. 8093 (B): against the background of osteoporosis the bone structure is reorganized, large and irgularly shaped cystic areas of rarefaction are present, the bone trabeculae in some places run transversely; residual phenomena of Looser's transformation zone are visible at the border between the proximal and middle thirds of the tibia (arrow), saber deformity of the leg bones; soft tissues are less well developed than in the control monkey.

For example, in males Nos. 5987 and 6710, which were adults when the experiment began, no pathological changes were found in the bones despite the fact that they received an excess of NaCl for 2.5 years and that one kidney had first been removed from one of these monkeys. In male No. 8109, which was in late adolescence when the experiment began, and underwent preliminary left nephrectomy, 1.5 years after the beginning of the experiment, changes were found in the skeletal system consisting of moderately severe osteoporosis, generalized hypotrophy of the skeleton, and slight deformation of the proximal ends of the humeri and in the region of the knee joints.

The severest changes in the skeletal bones were found in the group of monkeys aged under one year (2-11 months) when the experiment began. Within this group differences were found between monkeys with intact kidneys and those subjected to unilateral nephrectomy. For instance, in female No. 8103 and males Nos. 8093 and 8061, from which the left kidney had been removed and which received an excess of NaCl for 3 years apart from a small intermission, the changes in the bones were very severe. They consisted of well-marked generalized hypotrophy of the skeleton, deformation (crushing) of the vertebral bodies, especially in the lumbar region, the appearance of Schmorl's nodules – penetration of the nucleus pulposus of the intervertebral disk into the cancellous bone of the vertebral body (Fig. 2), reorganization of the bony structure of the limbs, a well-marked saber deformity of the limb bones, and the appearance of Looser's transformations in the femora (Fig. 3).

In three other monkeys (female No. 10343 and males No.s 10391 and 9344), who were less than one year old when the experiment began but whose kidneys were intact, and who received an excess of NaCl for 2.5 years (No. 9344) and 1.5 years (the other two) respectively, the changes in the bones were much less severe. Their osteoporosis was only moderate in degree, no compression of the vertebral bodies was apparent, and the deformation of the limb bones, although present, was slight.

It is clear from this description that the greatest changes following NaCl loading were observed in the bones of growing monkeys, and of these, in particular, those who had undergone unilateral nephrectomy. However, the zone of growth of the bones was not affected and delay of growth could not be attributed to changes in it .

If the results are compared with the general state, the development, and the external appearance of the animals, it will be concluded that these changes in the bones and the delay of growth are due to disturbances of mineral metabolism and tissue nutrition.

The dystrophic changes in the bones, especially their curvature, occurred mainly in those parts of the skeleton (spine and limbs) which are exposed to the greatest physical load during movements. These changes are perhaps due to an increase in the deposition of sodium in the bones, for the results of estimulation of the sodium concentration in the plasma and certain tissues, and also the presence of periodic edema of the limbs in the monkeys, were evidence of sodium retention in the body, and the bone tissue is evidently no exception.

However, the incorporation of sodium into bone tissue can occur only in the growing animal. Investigations with radioactive sodium have shown that much of it is fixed by bone in the growing organism [3]. The adult organism evidently differs by having certain mechanisms for preventing the incorporation of sodium into bone tissue.

Definite relations between the different salts are known to exist in the living body. Introduction of certain substances (lead, bismuth, phosphorus, strontium, fluorine, etc.) into the human body gives rise to pathological changes in the skeletal system [1, 2]. Accumulation of an excess of sodium in the bones can probably lead to unfavorable changes in other mineral components also. Evidently for these reasons no changes were found in the skeletal system of the two adult monkeys, while in the young adolescents the changes were severe, especially if one kidney had first been removed and, consequently, excretion of sodium from the body was still more impaired.

A detailed analysis of the mechanism of the bone changes discovered during prolonged administration of an excess of NaCl calls for further study with the inclusion of an investigation of the state of the hormonal and other types of metabolism during this form of overloading.

In presenting this paper, the authors wish to draw attention to the fact that pathological changes may appear in the skeletal system of growing animals receiving a high intake of NaCl.

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