ERRATUM

A mistake occurred in the title of the contribution "Reconstruction of the diet in Wadi Qitna, Egyptian Nubia", published in Anthropologie XXXVI/3, p. 267, where " Sudanese Nubia" was erroneously mentioned instead of the correct " Egyptian Nubia ".
The correct title should therefore run "Reconstruction of the diet in Wadi Qitna, Egyptian Nubia". Václav Smrčka presents his apologies on behalf of the authors of the contribution.

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RECONSTRUCTION OF THE DIET IN WADI QITNA, SUDANESE NUBIA

ABSTRACT: Chemical analysis of the elements in skeletal remains shows which sources of elements were predominant in the diet of a certain population. The cemetery of Wadi Qitna situated on the left bank of the Nile, 65 km south of Asuan can serve as an example of unsuitable diet which led even to premature osteoporosis. The cemetery was used for burials from the half of the third century to the fifth century A.D. In this burial ground we have found significantly lower concentration of strontium in the proximal parts of the femurs in the individuals approximately of the age of 30. Reduction was also found in zinc and copper. Both male and female parts of the population were affected by the lower concentration. These conditions could be brought about by unleavened bread containing a large quantity of phytates which can combine with some elements so much that they are not usable any more, thus reducing considerably their effective concentration in the diet. This kind of bread is typical for Egyptian and Nubian villages. Remains of this bread of rough-ground flour were found also in the graves. The development of premature osteoporosis could be also caused by geophagy. At the same time also such parasites as a hookworm, ankylostomiasis and schizostomiasis could play a part in the loss of the elements.

KEY WORDS: Sudanese Nubia – Premature osteoporosis – Diet – Bones – Trace elements

INTRODUCTION

The cemetery of Wadi Quitna is situated on the bank of the Nile, 65 km south of Asuan. The cemetery was used for burials from the half of the third century to the fifth century A.D.

At the cemetery in Wadi Qitna the remains of 558 people were found in 456 graves, however, a large part of the skeletons were in fragments (Strouhal 1971). From the skeletons deposited in the Náprstek Museum in Prague, 64 samples were taken from 36 individuals for the study of reconstruction of the diet. 21 femurs (10 male and 11 female) and 29 tibias (17 male and 12 female) were examined. In terms of age representation there were only juvenile or adult individuals (*Table 1*).

Reconstruction of the diet is based on the relative contents of certain elements in the bones, changing according to the predominant components in the diet of every individual, taking into account the possible changes of their contents after burial.

MATERIALS AND METHODS

Sampling

The samples were taken by surgical forceps (Liston and Luer) and at the same time cancellous bone and compact bone were taken. In the samples upper parts and the central parts of the femur (shaft) and tibia were represented.

Chemical analysis

The elements Ca, Sr, Na, K, Li were determined with flame emission spectroscopy after dissolving the sample in nitric acid. The elements Co, Ti, Ag, Zn, Cu, V, Ni, Cr, Pb and Mn were determined using the method of emission

TABLE 1. Age distribution of skeletal materials used for reconstruction.

	Infans I+II 0–14	Juvenis 15–20	Adultus 20–40	Maturus 40–60	Senilis over 60	Undetermined	Total
Male	–	2	12	3	–	–	17
Female	–	3	11	3	–	–	17
Undetermined	–	–	–	–	–	2	2
Total	–	5	23	6	–	2	36

spectroscopy with alternating current arched after the mineralization of the sample. The limits of detection for individual elements are given in *Table 2*.

TABLE 2. Parameters of analytical methods.

Element	Flamme emission spectroscopy: Limits of detection µg/g dry weight	Standard deviation (SD) %
Ca	0.1	3.5
Sr	0.06	2.8
Na	0.05	2.6
K	0.08	2.1
Li	0.01	2.0

Element	Emission spectroscopy alternating arched current: Limits of detection µg/g mineralized weight	Standard deviation (SD) %
Co	0.5	9.5
Ti	0.04	12
Ag	0.006	8.0
Zn	9.4	14
Cu	0.035	7.3
V	0.03	7.7
Ni	0.08	6.8
Cr	0.05	9.0
Pb	0.2	8.4
Mn	1.0	9.6

Limits of detection and standard deviation (SD) determined from the numbers measured N =10. The limits of detection determined according to criteria 3^{s}m. The values of standard deviation valid for the concentrations of elements 10× the concentration of detection limits.

Mathematical analysis

Basic statistical characteristics were calculated during the entire summary of results and conclusive evidence of differences between the calculated averages of the concentration of elements in the upper, central and lower parts of the femur and tibia were tested by dispersion analysis. The relationship of the contents of certain elements to age and sex was also assessed by contingency tables comparing the concentration numbers with the critical values according to Fischer's exact test.

Interpretation of the results

For the interpretation of results it was necessary to designate the distribution of elements in individual parts of the long bones, to compare the concentration of individual elements in the same part in relation to age and sex, and to compare the content of elements in bones with the content in the soil as well as with the composition of elements in the produce and remains of other food materials found in the Wadi Qitna graves.

The basis of evaluation of the state of the diet became the comparison of elements strontium, zinc and lead to calcium, in which the relationship of the contents to the eating conditions is adequately demonstrated and they are relatively stable in the skeletons and the surrounding soil. The contents of sodium and copper are also significantly important. The other elements primarily served as indicators of contamination of the bone by the surroundings.

RESULTS

Distribution of the elements in femurs and tibias

The average contents of the designated elements in the upper, central and lower parts of the femurs and tibias are presented in *Tables 3, 4, 5, 6, 7, 8*.

Statistically significant (with 95% reliability) is the increased concentration of Ca and Sr in the central parts of diaphysis of the tibia in comparison to the proximal epiphysis, where on the contrary there was a higher concentration of the elements Co, Ti, Cu, V, Ni, Pb.

The Relationship of element concentration to age and sex

No significant difference in calcium was found. However, in strontium a significant difference of concentration was recorded in the age group 25–35 in comparison to other age groups and at the same time a significant difference between the sexes (*Figure 1*). The contents of Sr were thus related to age and sex (*Figure 3*). In copper no relationship between age and sex was determined. Unlike European population data for the 1st–4th centuries A.D. (Smrčka *et al.* 1988, 1989) there was a markedly higher concentration of sodium in the femurs and tibias of skeletons in Wadi Qitna. The content levels of Na reached up to 25 mg.g^{-1}of the bone (*Figure 7*).

In the compact bone of the central part of the femurs and tibias the concentration of lead was 1.0–1.4 µg.g^{-1} of the bone, in the proximal head 2.08–2.5 µg.g^{-1} of the bone (*Tables 3, 6*). In Sudanese Nubia for the time period 1–750 A.D. the amount of lead in 1 g of bone, most likely temporal, was established as 1.2 µg (Nielsen *et al.* 1986).

5,000 years ago, less than 0.9 µg.g^{-1} was found in the compact bones and pulp dentin of Nubians. 4,500 years

TABLE 3. Femurs – elements (µg/g dry weight) Wadi Qitna.

Element	Upper end Mean (n = 2)	S	Central part of the shaft Mean (n = 1)	S	Lower end Mean (n = 7)	S
Ca	252 000	51 000	306 000	0	258 000	33 000
Sr	140	62	.151	0	134	37
Na	3 000	5 100	24 000	0	12 100	1 350
K	560	363	1 060	0	490	311
Co	8.46	4	0	9.3	7.4	
Ti	10.6	6.5	9	0	10	10.3
Ag	0.03	0.04	0.01	0	0.04	0.03
Zn	149	53	120	0	137	14
Cu	23	14	25	0	27	10
V	2	2.3	0.1	0	0.7	1
Ni	1.9	2	0.3	0	2	1.8
Cr	1.5	1.2	0.3	0	0.81	0.78
Pb	2.08	0.88	1	0	2.1	1.5
Mn	25	12	23	0	27	14

TABLE 4. Male femurs – elements (µg/g dry weight) Wadi Qitna.

Element	Upper end Mean (n = 9)	S	Central part of the shaft Mean (n = 1)	S	Lower end Mean (n = 4)	S
Ca	264 000	49 200	306 000	0	239 000	31 100
Sr	167	81	151	0	124	48
Na	12 100	3 370	24 000	0	11 500	1 290
K	470	210	1 060	0	560	370
Co	7.7	4.6	4	0	8.5	3.8
Ti	10.8	6	9	0	8.1	7.3
Ag	0.02	0.01	0.01	0	0.03	0.02
Zn	152	42	120	0	127	5
Cu	24	13	25	0	33.5	6.8
V	1.8	2.3	0.1	0	0.37	0.05
Ni	7.1	2	0.3	0	2.8	1.8
Cr	1.39	0.9	0.3	0	0.58	0.3
Pb	2.08	0.75	1	0	2.5	1.8
Mn	26.9	9.7	23	0	23	11.5

TABLE 5. Female femurs – elements (µg/g dry weight) Wadi Qitna.

Element	Upper end Mean (n = 11)	S	Central part of the shaft Mean (n = 0)	S	Lower end Mean (n = 2)	S
Ca	241 000	52 300	0	0	282 000	24 700
Sr	119	29	0	0	154	2
Na	13 700	6 240	0	0	13 500	700
K	640	450	0	0	540	71
Co	9	7	0	0	14	14.1
Ti	11	7	0	0	17.5	17.7
Ag	0.04	0.06	0	0	0.06	0.04
Zn	146	62	0	0	155	7
Cu	22	15	0	0	23.5	5
V	2.1	2.5	0	0	1.7	1.8
Ni	1.7	2	0	0	1.4	1.6
Cr	1.6	1.5	0	0	1.4	1.6
Pb	2.1	1	0	0	2	1.2

TABLE 6. Tibias – elements (µg/g dry weight) Wadi Qitna.

Element	Upper end Mean (n = 25)	S	Central part of the shaft Mean (n = 8)	S	Lower end Mean (n = 3)	S
Ca	247 000	38 200	300 000	28 700	268 000	37 400
Sr	135	53	178	38	165	61
Na	13 100	3 300	16 100	4 600	14 700	5 690
K	660	464	400	322	530	272
Co	12.6	8.1	6.9	2.5	18	23
Ti	12.7	8.3	5.4	4.2	5.8	8
Ag	0.06	0.09	0.02	0.01	0.03	0.03
Zn	155	40	131	67	130	26
Cu	23	11	13.9	7.7	29	14
V	1.7	2.1	0.26	0.12	1.8	2.8
Ni	1.6	1.3	0.51	0.62	1.1	1.6
Cr	1.3	1.1	0.8	1.1	0.9	1.1
Pb	2.5	1	1.4	1	1.7	1.5
Mn	29	11.6	22	15	34	18

TABLE 7. Male tibias – elements (µg/g dry weight) Wadi Qitna.

Element	Upper end Mean (n = 14)	S	Central part of the shaft Mean (n = 4)	S	Lower end Mean (n = 1)	S
Ca	253 000	37 000	298 000	35 100	311 000	0
Sr	130	54	172	26	232	0
Na	13 000	3 000	17 800	6 240	21 000	0
K	640	480	520	450	840	0
Co	15.3	7.7	8	2.3	6	0
Ti	13.4	9.5	3	4	2	0
Ag	0.07	0.11	0.01	0.006	0.02	0
Zn	156	35	122	90	100	0
Cu	24	12.7	9.2	4.5	20	0
V	1.8	2.6	0.18	0.05	0.2	0
Ni	1.6	1.2	0.3	0.16	0.2	0
Cr	1.1	1	0.28	0.35	0.2	0
Pb	2.4	1.2	1.52	1.53	0.8	0
Mn	32	12	17	11	22	0

TABLE 8. Female tibias – elements (µg/g dry weight) Wadi Qitna.

Element	Upper end Mean (n = 10)	S	Central part of the shaft Mean (n = 4)	S	Lower end Mean (n = 1)	S
Ca	241 000	41 600	303 000	26 100	253 000	0
Sr	146	53	185	50	148	0
Na	12 700	3 480	14 500	1 900	13 000	0
K	670	490	294	63	380	0
Co	9.9	8	5.8	2.4	45	0
Ti	12.3	7.1	7.8	3.2	15	0
Ag	0.05	0.09	0.03	0.015	0.06	0
Zn	152	50	140	46	150	0
Cu	23.4	8.9	18.5	7.9	22	0
V	1.54	1.53	0.35	0.1	5	0
Ni	1.7	1.5	0.72	0.86	3	0
Cr	1.7	1.2	1.38	1.36	2.1	0
Pb	2.7	0.7	1.2	0.2	3.5	0
Mn	27	11	28	18.5	55	0

later the lead content increased up to 10×, meaning a shift in proportion Pb/Ca from 90.10^{-8} to 900.10^{-8} (Ericson 1979). In the observed skeletal materials there was an average ratio of Pb/Ca 877.10^{-8}, the contents are thus in correspondence with the results of both authors.

The range of elements in the soil and remaining food materials

Table 9 presents the contents of the elements in the soil fixed from dissolved soil up to 1 M HNO_3 from the surroundings of the skeletons in Wadi Qitna. *Table 10* presents the entire contents of the elements in the remains of produce and food materials from the graves.

Fragments of bread (P 3096) contained noticeably larger amounts of sodium than grain. Also from the ratio of Na/K and the content of chloride ions, it is possible to deduce that this dough was intentionally salted. This was also suggested by comparisons with bread samples from the Egyptian Der El Mendina (18th–20th dynasty) and bread dough today (*Table 11*).

DISCUSSION

Chemical analyses of bones from Wadi Qitna indicate that in the femurs and tibias this population has lower amounts of elements which make up the basic building components

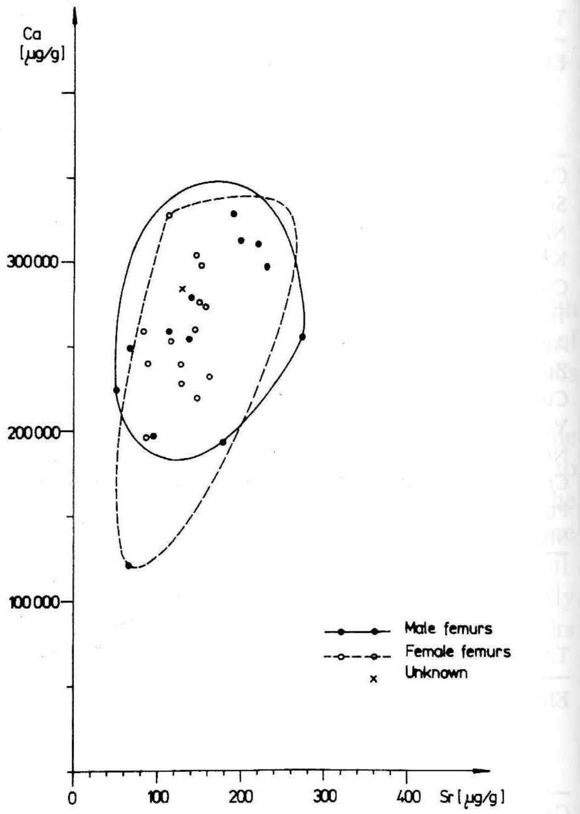

FIGURE 1. Concentration of Ca and Sr in male and female femurs (in micrograms/g bone).

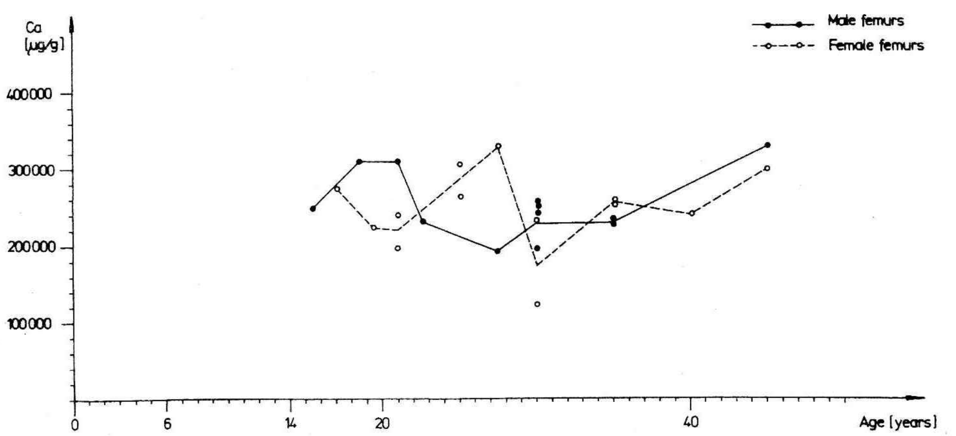

FIGURE 2. Concentration of Ca in male and female femurs in relation to age.

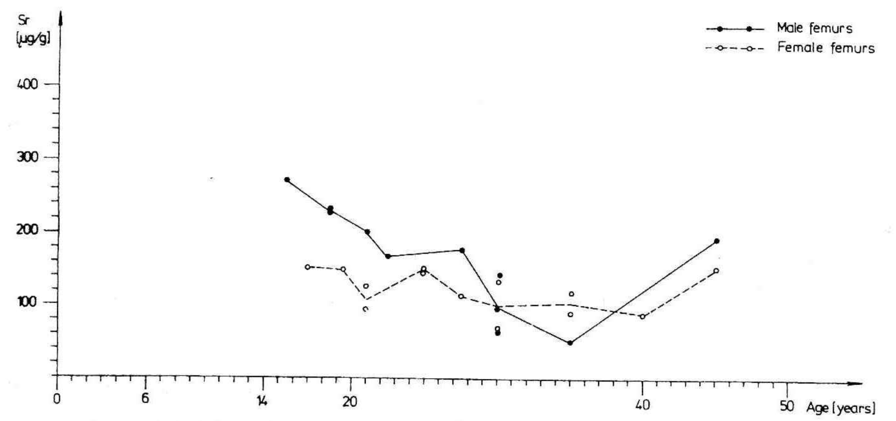

FIGURE 3. Concentration of Sr in male and female femurs in relation to age.

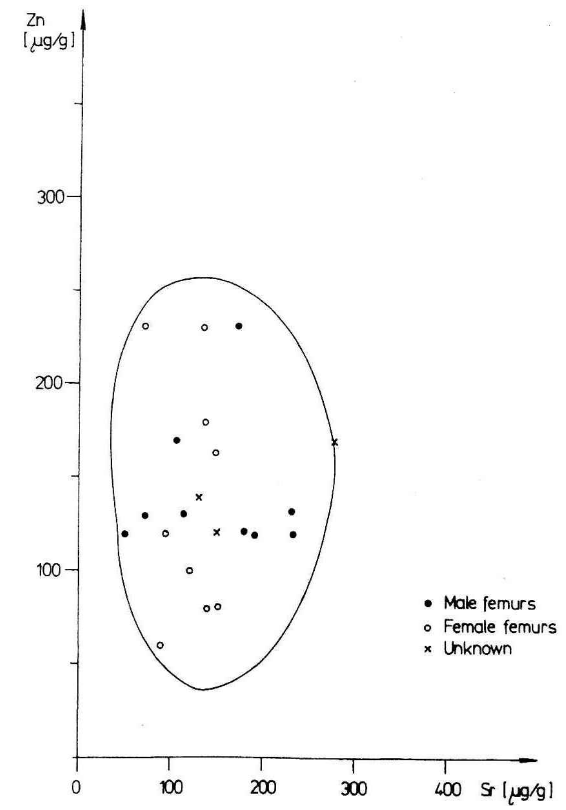

FIGURE 4. Concentration of Zn and Sr in male and female femurs (in micrograms/g bone).

of the bone. Lower concentration of elements is most significant around the age of 30. Thinning of bones is part of the osteoporotic change which was recorded in European populations in the 1st–4th centuries A.D. (Smrčka *et al.* 1988, 1989, 1994) only to occur at a later age. Thus, in Wadi Qitna there was premature osteoporosis. Premature osteoporosis was proved histologically in Sudanese Nubia in group X (Martin *et al.* 1984, 1985). Its occurrence was explained primarily by Nubian women´s frequent pregnancies during their thirties. Nevertheless, the process affected men as well and it is therefore necessary to look for other factors influencing the development and build of Nubian skeletons.

Factors influencing the elemental composition of skeletons in Wadi Qitna

Changes in the elemental composition of skeletons in Wadi Qitna are most significant in Ca, Sr, Zn, Cu in the sense of an average lower concentration and a higher concentration of Na. There is a definite increase in the content of Ca and Sr in compact bone, while there is a sodium increase in cancellous bone (Klepinger 1984). Zn and Cu predominate in cancellous bone, are commonly with Fe as parts of blood-forming organs and directly influence the production of blood.

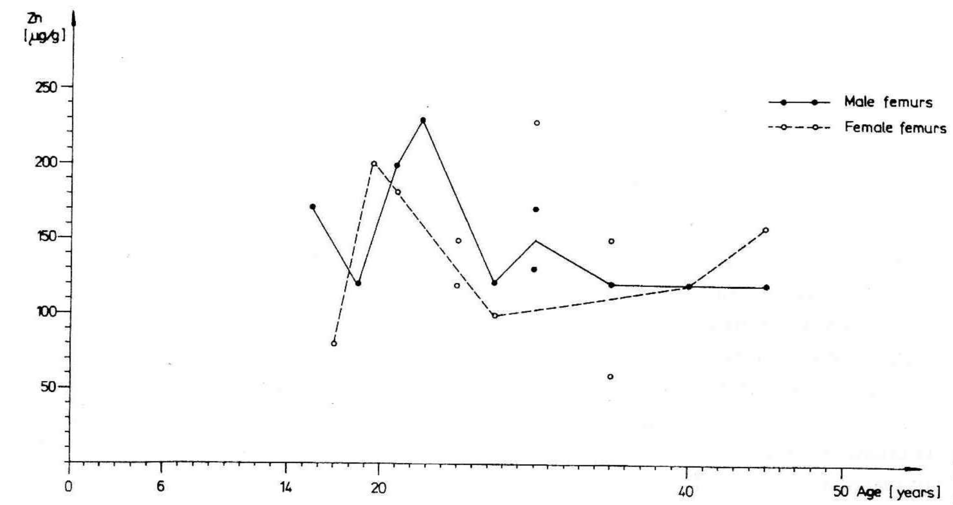

FIGURE 5. Concentration of Zn in male and female femurs in relation to age.

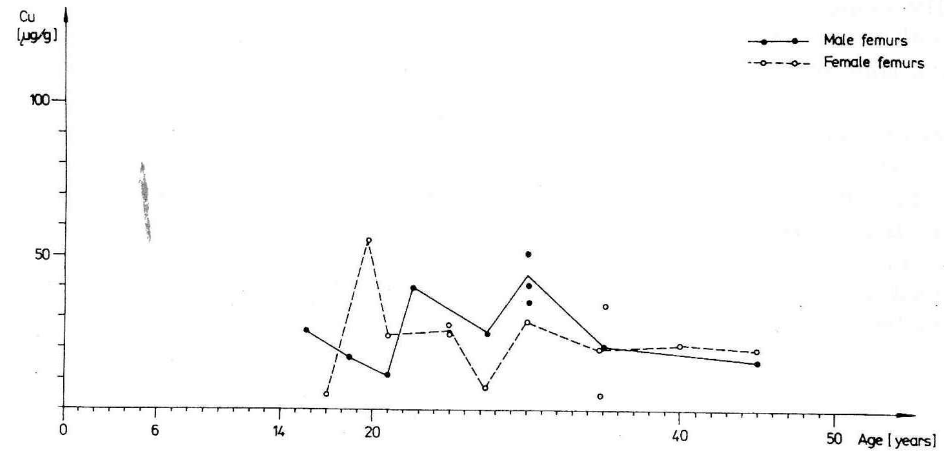

FIGURE 6. Concentration of Cu in male and female femurs in relation to age.

TABLE 9. Element composition of soil in Wadi Qitna (µg element / g soil).

Co	Ti	Ag	Zn	Cu	V	Ni	Cr	Pb	Mn	Ca	Sr	Na	K	Li
27	40	0.2	400	75	8	10	4.5	3.5	300	40 000	59	11000	1900	1.5

Elemental composition of skeletons could influence:
1) The amount of a certain element in food.
2) The differences of element transfer from the digestive tract to the organism.
3) Excessive elimination and loss of elements from the organism.
4) The surroundings of the buried skeletons at the cemetery.

The amount of elements in food

The circulation of elements in the biosphere from minerals through plants or animals to humans is a very complex process in which the local balance given by the geochemical composition of the atmosphere is disrupted, in both the long term and short term, by the transfer of elements between heterogeneous localities and changes in the composition of the environment affecting the state and development of the biosphere. There is a possibility of local accumulation or deficiency of certain elements, which, when these elements are lacking, practically affect in a negative way the physical condition of living organisms tied to the given locality.

There are regions in the Amur region of Russia, North Korea and China with a deficiency of calcium (Hamilton 1979). In these regions Urov Disease endemically appears which is characterized by a stiffening of joints, inhibition of movement and an effect on the function of epiphyses and cartilage. In these regions strontium was concentrated in the soil and found its way into the plants and animals in place of calcium. Children between the ages of 11–15 were affected the most.

In England the relationship between the strontium content in bones and the geochemical proportions was determined. The greatest content of Sr in bones was found in southeastern and northwestern England, where minerals of the cretaceous and limestone variety were found (Hamilton 1989).

The deficiency of zinc in humans is characterized by a loss of appetite, growth retardation, hypogonadism, skin changes, and poor wound healing. The studies from the Middle East prove that patients with severe growth retardation and hypogonadism have significant zinc deficiencies (Prasad 1966).

Copper acts as a catalyzator of enzymes, and is related to the development of bones and the production of pigments and hemoglobin. In the case of copper deficiencies hypochromatic microcytarnic anemia sets in. Only about 30% of Cu is absorbed in the upper part of the small intestine and finds its way into the blood. The absorption of copper is prevented by zinc, cadmium and iron (Underwood 1977, Hejda 1985).

From the content of the mentioned elements in the Wadi Qitna soil and the plants accessible, it is possible to conclude that there could not have been a deficiency of these elements in food (*Tables 9, 10*). The consumption of salted bread most likely ensured the intake of sodium.

TABLE 10. Element composition of produce and food remains in Wadi Qitna (µg element/g organic tissue).

Element	Grain of six row barley P 3084	Fruit of palm Medemia argum P 3094	Fragments of bread P 3096
Na	280	800	1 320
Pb	5.6	3.5	14
Cr	1.8	3.5	5
Ni	0.5	2.5	2
Fe	120	450	210
Mo	7	5	8
Sn	4	7.5	92
V	2.3	15	7
Ca	162	800	200
Mn	32	140	65
Zn	93	1000	450
Ag	0.2	0.8	0.8
Cu	4.6	5	6
Ti	69	250	120
Co	2.3	25	12

TABLE 11. Analysis of bread samples.

Sample	Na	K	Cl	Na/K
Dér el Medína, Upper Egypt, 18th–20th Dynasty				
P 1624	2.6	5.2	–	0.50
P 1625a	2.4	5.8	6.4	0.41
P 1625b	2.9	5.4	8.4	0.54
P 16256a	2.8	5.9	7.4	0.47
P 1626b	3.1	6.1	8.4	0.51
P 1627	5.7	5.3	9.9	1.08
P 1628	7.1	5.9	11.4	1.20
Wadi Qitna				
P 3096	2.7	4.0	4.8	0.68
Current products				
Bread	6.7	3.2	12.9	2.09
Flour	0.1	2.3	2.6	0.043

All values of Na, K and Cl are given in mg/g dry matter.

Differences of element transfer from the digestive tract to the organism

This can be caused either by the poor absorption through the intestinal wall or the retention of elements in the intestines by certain components of the diet.

In the case of calcium, absorption is influenced by parathormone and vitamin D. There was certainly a sufficiency of this vitamin in Nubians.

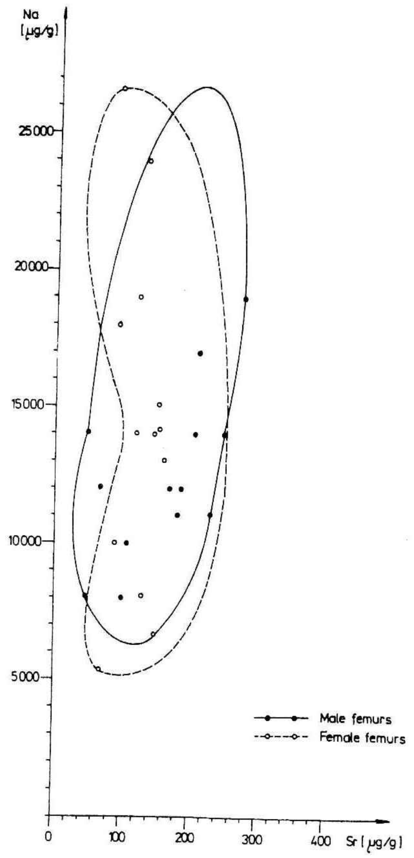

FIGURE 7. Concentration of Na and Sr in male and female femurs (in micrograms/g bone).

Elements such as Ca, Zn, Cu, Fe, Mn and Mg, however, could be sustained by food containing large amounts of dietary fiber and large amounts of dietary phytates (salts of inositolphosphoric acid), as was found in the unleavened bread tanok (lavosh, shepherd´s bread) of Iranian villages. It has been established that rising and fermentation are more important determinants of the concentration of dietary phytates in bread than the degree of grinding flour (Reinhold 1972). Dietary fiber is found to a greater degree on the surface of the grain and therefore a greater amount is found in wholemeal flour (Hejda 1985).

The corn in Sudanese Nubia made up the basic part of the food supply, according to the findings of ears of barley and whole wheat bread in Wadi Qitna (Němečková 1973) and the findings of wheat and barley in the intestinal contents at the Qustul cemetery (Batrawi 1935 in: Strouhal 1984). Ethnographic findings from Egypt and regions of the Middle East confirm that bread makes up 50–80 percent of the village diet (Waslien 1976).

Excessive elimination and loss of elements from the organism

The loss of elements regarding the Wadi Qitna population mainly concerns zinc because of its accumulation in the fetus during the frequent pregnancies of Nubian women. Great blood loss and thus the loss of Zn, Cu and Fe can be caused by parasites which cannot be determined from the bone analysis. Among the parasites in question there are especially amebiasis, schistosomiasis and ancylostomiasis (hookworm). The blood loss can even be increased by secondary lesions caused by parasites in the liver and kidneys. It is known that in Egypt almost every village inhabitant has one or more types of parasites and typhoid and hepatitis carriers make up a significant percentage of the village population (Waslien 1976).

Lower concentration of Cu, Fe and Zn, influenced by blood loss and the one-sided diet, could develop into the onset of anemia and thus *cribra orbitalia*. These occur more often in children since they are more sensitive to changes in conditions. At the cemetery in Wadi Qitna few skeletons of children were preserved so this conclusion cannot be confirmed in the given locality. The frequent occurrence of *cribra orbitalia* was reported at other Nubian cemeteries (Martin *et al.* 1984).

The surroundings of the buried skeletons at cemeteries

A higher concentration of sodium in skeletons at Wadi Qitna could possibly be caused by the contamination of the surroundings and the minimal erosion of sodium from the bones. Because these greater values do not occur in other alkaline metals, their relationship to the diet is highly probable (Jambor 1988). The insignificant influence of the surroundings, including rain and underground water, on the bone materials is supported by the findings of organic remains (bread, grains, fruits of palms and seeds of grass) in the graves.

CONCLUSION

A lower concentration of strontium and zinc was determined by the analysis of elements in the femurs and tibias of men and women around the age of 30 at the cemetery in Wadi Qitna in Egyptian Nubia. In addition, concentration of Sr was also dependent on the sex, while the dependence of Zn on the sex was not determined. Higher concentration of sodium was found both in the femurs and tibias.

It is possible to explain the origin of these changes by the ingestion of foods with higher contents of dietary phytates and plant fibers, especially in the form of salted bread. At the same time blood loss could have been caused by the influence of parasites.

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