The Content of Fluoride, Calcium and Magnesium in the Hair of Young Men of the Bantu Language Group from Tanzania Versus Social Conditioning

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Abstract The present study aimed at analysing the content of fluorine (F), calcium (Ca) and magnesium (Mg) in the hair of young male students ($n=52$) of a secondary school in Mafinga in Tanzania (Africa) who participated in anthropological examinations. Ca and Mg concentrations were determined using atomic absorption spectrophotometer while F levels using a potentiometric method. F in the hair of boys from older group (≥16 years old; $n=24$) was significantly higher than in the younger group (<16 years old; $n=28$) versus Ca and Mg levels. High carbohydrate diet was predominant—mainly based on corn or bean and meat served once a week, with few fruit and raw vegetables. Collective catering in the dormitory reflected habits and culinary preferences at home. The lack of balanced diet, with majority of the nutritional energy supplied by easily accessible and cheap carbohydrates, was reflected in dietary deficiencies, characterised, among others, by visible skin conditions and tooth decay.

Keywords Fluoride · Calcium · Magnesium · Hair · Bantu

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Introduction

The analysis of the content of chemical elements in hair is an important tool in toxicological and ecological examinations and recently is the most studied biomarkers [1–4]. Due to simplicity and non-invasive character of sampling, it is an alternative for blood, urine and biopsy material analyses. The latter method is most likely the most reliable one, but in some communities, it evokes doubts of ethical nature and cannot be used commonly. This is particularly important when examining hardly accessible environments, with black populations living in their indigenous environments being treated like such ones. The content of chemical elements in hair is determined, among others, by diet, sex, age, race and individual organism's requirement for them as well as by socio-economic conditions [5–8]. Also, the content of chemical elements in drinking water, geographical location and environmental pollution connected with civilisational progress and population are of importance [6]. Chemical elements are being permanently incorporated into hair structure over the whole time of their growth and the same they characterise the mineral state of organism during the last few or several months. The concentration of mineral elements in hair correlates with their content in the whole human organism, thus their content in hair can be a good indicator of organism saturation with them [9]. In literature, papers concerning the content of chemical elements in organisms of black populations living in their indigenous environments are not numerous. In particular, there are no reports referring to hardly accessible environments, like the Tanzania's region examined by us. In many countries of Africa, there is no infrastructure for collecting statistical information or social consent for performing regular biosocial examinations. Current data and information referring to biological development, body constitution, nutrition and family structure

could be a valuable source of information on transformations in African communities. The present study aimed at analysing the content of chemical elements fluoride (F), calcium (Ca) and magnesium (Mg) in easily available biological media like hair.

Material and Methods

Examinated Group

Material for analysis of the concentration of F, Ca and Mg in hair collected in October 2005 and March 2006 came from young male ($n = 52$) students of secondary school in Mafinga, Iringa District in Tanzania. The hair probes were collected from the nape of the neck. The students participated in anthropological examinations carried out in October 2005, during which information was collected, among others, on their tribal descent and permanent residence. Due to the broad age range of subjects (12.93–18.75), they were separated into two age groups: a younger group <16 years old ($n = 28$) and an older group ≥16 years old ($n = 24$). They had been staying in the place where examination was carried out for a period of a few or several months only. For the study period, they had been accommodated in a dormitory and took advantage of day-long sustenance.

Analysis of the Element Contents in Hair

Ca and Mg Determination Hair samples were obtained from students who did not have coloured or treated hair. Initially, the hair was cleaned out in ultrasonic bath for 1 h and next washed twice using acetone and dried overnight in laminar flow hood at 25 °C. Thereafter, probes were digested using mixture of 1 mL of 65 % HNO_3 and 1 mL of 70 % $HClO_4$, dried once again (48 h/25 °C), mineralized (30 min/BM-1S/II microwave mineraliser, Plazmotronika, Wrocław, Poland) and dried under nitrogen. For calcium and magnesium determination, hair sample was dissolved in 1 ml of concentrated 65 % HNO_3. From this basic solution, 10 μl was taken to plastic test tubes and added 5 ml H_2O. Calcium and magnesium concentrations were determined using atomic absorption spectrophotometer (AAS) 9100X PHILIPS. The apparatus was calibrated using standard solutions. The calibration curve was drawn automatically by the computer coupled with the apparatus. The determinations were performed in an air–acetylene flame for the relevant lamps at the following wavelengths: Ca—422.7 nm (with an added 0.5 % lanthanum buffer solution) and Mg—285.2 nm (with an added 0.1 % lanthanum or strontium as a buffer solution).

F Determination For fluoride determination hair sample was dissolved in 1 ml of 2 M perchloric acid (1 h/95 °C). From the resultant solution, 0.5 ml was poured into polyethylene cups,

to which 2.5 ml of TISAB II (total ionic strength adjustment buffer) buffer solution and 2 ml 1 M sodium citrate were added. Fluoride contents were determined with a potentiometric method, using Thermo Orion ion-selective electrode (The Thermo Scientific, USA). The electrode was calibrated using standard solutions.

Statistical Analysis

The results were analysed statistically using the software package Statistica 6.1. Arithmetical mean and the standard deviation (SD) were found for each of the studied parameters. The distribution of results for individual variables was obtained with the Shapiro–Wilk W test. As most of the distributions deviated from the normal Gaussian distribution, nonparametric tests were used for further analyses. Correlations between the changes of the parameters were examined with the Spearman's rank correlation coefficient. To assess the differences between the studied groups, the non-parametric Mann–Whitney test was used. The level of significance was $p \leq 0.05$.

Results

Mean contents of the analysed chemical elements in the hair of Bantu language group males are presented in Figs. 1, 2 and 3.

Fluoride content in the hair of boys from older group was 49 % higher than in younger group, and the difference was statistically significant ($p < 0.006$) (Fig. 1).

On the other hand, higher Ca content (about 4 %) was found in the hair samples from the younger group, but there were no statistically significant differences (Fig. 2).

Similar results were noted for Mg content in the hair samples. Despite the higher magnesium content in the hair of a younger group of around 14 % compared with the older one, the difference was not statistically significant (Fig. 3).

Spearman's test showed the occurrence of dependence between the concentrations of the examined elements in the hair. The content of fluoride was negatively correlated with the concentration of Ca in older group ($R_s = -0.36$, $p = 0.002$). Additional age positively correlated with the body mass index (BMI=kg/m^2) in both examined groups ($R_s = 0.44$, $p = 0.001$ for younger group and $R_s = 0.44$, $p = 0.004$ for older group) and the highly negative with Mg content in samples from older group ($R_s = -0.39$, $p = 0.01$).

BMI was calculated for the subjects showing that out of 50 men participating in the study, 19 % was characterised by mediocre nutrition (BMI≤18.49). No statistically significant correlations were found between BMI and the analysed chemical elements.
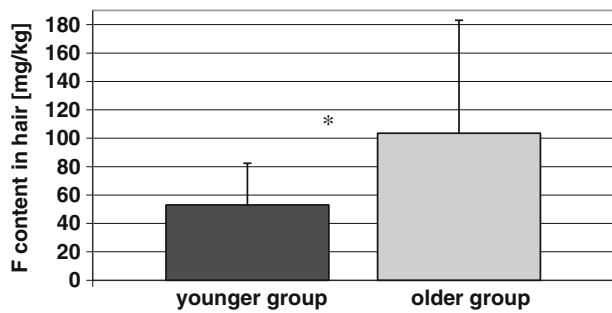
Fig. 1 The content of F [milligrams per kilogram dry mass] in the hair of Bantu language group males. *p <0.006 (significant difference between groups)

Fig. 3 The content of Mg [grams per kilogram dry mass] in the hair of Bantu language group males. *ns* no significant difference between groups

Socio-economic studies revealed a high percentage of parents with higher education (59.6 % of fathers and 42.3 % of mothers); nevertheless, only 15.4 % of subjects confirmed that they are satisfied with financial status of their families (Table 1).

Discussion

Population studies in Africa are seriously hindered by socio-economic factors and their consequences. The living conditions determine the supply of minerals in the daily diet, and the diet affects the mineral content in the body [6]. Intake of elements in humans can occur through food, water and incidental consumption of soils. Children may take up elements from the food they eat, ingestion of soil while playing or the water they drink [10]. An important role is played by socio-cultural factors and living conditions which determine nutrition in terms of quantity and quality. The last two factors seem to be directly responsible for the levels of individual minerals in the human body [11].

Element concentrations in hair were correlated to food and soil in element-specific patterns [10]. Levels of elements in humans have conventionally been determined through the analysis of biological samples including hair [9] because of their
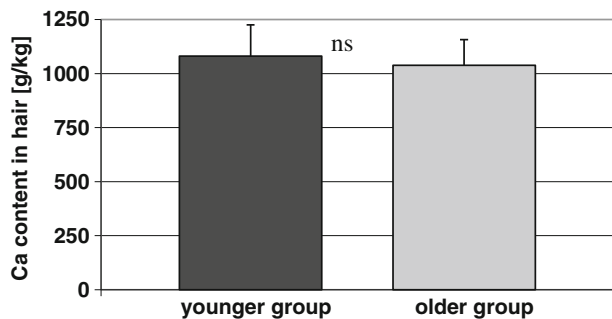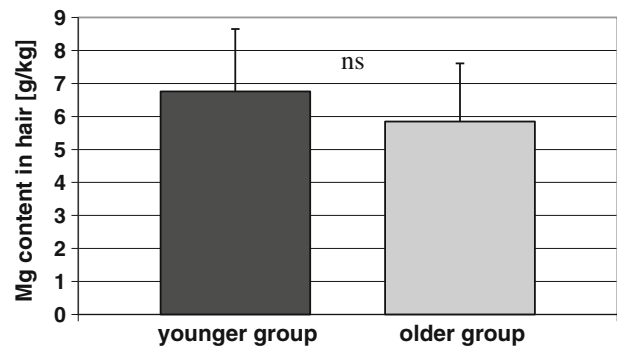
easy to store and because the concentration in hair has been established to reflect external exposure levels, and this material is a good indicator for certain elements to which people have been exposed during the previous 2 to 18 months [9].

Anthropological studies enabled to collect information related with student's nutrition, concerning not only the quality but also the quantity of consumed meals. With regard to the school where this study was conducted, a carbohydrate-rich diet was routine (based mainly on corn or bean, with meat served once a week). This diet included few fruits and raw vegetables. Collective catering in the dormitory reflected habits and culinary preferences, which young people observed at their home environment. However, the analysis focusing on the BMI index did not reveal significant differences between the studied groups. Despite reporting 19 % cases of malnutrition, many alumni "compensated" their body mass deficits after living in the facility for several months. Nonetheless, lack of a balanced diet, and above all, the fact that majority of the supplied nutritional energy was covered by easily accessible and cheap carbohydrates (59.4 % of the total supplied nutritional energy), and the fact that the diet contained no fruits and raw vegetables was reflected in dietary deficiencies, characterised among others by visible skin conditions and tooth decay.

It is common knowledge that in order to perform several physiological functions, human organism simultaneously requires large amounts of macroelements, such as magnesium and calcium, and small concentrations of trace elements, for example fluorine [12]. Based on the analysis related with the content of trace elements in hair conducted in both studied youth groups, the researchers did not observed drastic Ca and Mg deficiencies; nevertheless, the younger group revealed significantly lower F content in hair. It is difficult to comprehensively compare the obtained results with these obtained by other authors since studies on the content of elements in hair conducted among black populations (including people from Bantu language group) residing in home environment are a rarity, and what is more, noteworthy differentiation between studied environments makes it impossible to compare obtained results [13–15].

Fig. 2 The content of Ca [grams per kilogram dry mass] in the hair of Bantu language group males. *ns* no significant difference between groups

Table 1 Results of socio-economic data for the whole materials and analysed age groups

Socio-economic information	Total (n=52)		Age group <16 (n=28)		Age group ≥16 (n=24)	
Question	n	%	n	%	n	%
Self-estimation of material situation of family						
Very good	8	15.4	6	21.4	2	8.3
Rather good	6	11.5	4	14.3	2	8.3
Average	36	69.2	18	64.3	18	75.1
Rather bad	–	–	–	–	–	–
Very bad	–	–	–	–	–	–
NA	2	3.9	–	–	2	8.3
Education status (mother)						
None or primary	3	5.8	1	3.6	2	8.3
Secondary school	27	51.9	14	50.0	13	54.2
Higher	22	42.3	13	46.4	9	37.5
NA	–	–	–	–	–	–
Education status (father)						
None or primary	–	–	–	–	–	–
Secondary school	20	38.5	6	21.4	14	58.3
Higher	31	59.6	22	78.6	9	37.5
NA	1	1.9	–	–	1	4.2

NA not available

Fluorine is enumerated among trace elements playing a crucial biological role [16]. It is present in all human tissues; however, its greatest concentration can be observed in bones and teeth [17, 18], where it constitutes a part of fluorapatites and hence stimulates both bone hardness and resilience [17, 19] as well as enamel solubility in teeth [19–21]. As far as our study is concerned, we observed a considerable difference in hair fluoride content between studied groups, which may reflect the concentration of this element in the organism. Since the physiological role played by fluorine is mainly related with bone tissue mineralization processes, its lowered content within the group of younger boys may cause disorders related with binding calcium, magnesium and phosphorus in bones, next to abnormalities relating teeth formation and enamel weakening [18, 20–22] in quickly developing organisms. These assumptions seem to confirm our observations associated with noticeably increased tooth decay among younger children. Increased magnesium content in hair reported in this group is yet another additional factor that may intensify the above-mentioned phenomena. Apart from the fact that magnesium participates in multiple important physiological functions [23], this element also activates enzymes taking part in synthesis, resorption and reconstruction of the bone tissue [23, 24]. However, its high concentration in hard tissues may stabilise the amorphic (immature) form of hydroxyapatite [25] and hence lead to rapid initiation and development of tooth decay and decreased bone hardness [25]. Calcium is an element, which plays two significant roles in human organism. When located in bones, it stands as a supporting structure of human skeleton, whereas when ionised in extracellular and intracellular fluid, it plays a notable biological role [26] and that is why its blood concentration is very precisely regulated and maintained on an appropriate level, at the expense of other tissues, for example bones [27]. The study did not reveal significant differences between the studied groups as far as calcium content in hair is concerned, which might probably result from the fact that in case of decreased supply of this element with food, its blood concentration was supplemented by mobilising the calcium stored in bones.

Despite quite high education, considering conditions of edification related with more expanded knowledge on health and the role played by macro- and microelements in proper development of the human organism, nutritional habits and in particular the economic situation constituted dominating factors influencing the diet selected at family home as well as in the place where boys enrolled in the study were taught, and all this posed considerable influence on concentrations of these elements in human organism. Population studies in Africa are seriously hindered by socio-economic factors and their consequences. The living conditions determine the supply of minerals in the daily diet, and the diet affects the mineral content in the body [6].

Conflict of Interest The authors declare that they have no conflicts of interest.

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