Journal of Trace Elements in Medicine and Biology xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Trace Elements in Medicine and Biology

journal homepage: www.elsevier.com/locate/jtemb

Biochemistry

Hair biomonitoring and health status of a general population exposed to Nickel

Eleni Sazakli, Michalis Leotsinidis*

Lab of Public Health, Medical School, University of Patras, University Campus, Patras, GR-26504, Greece

ARTICLE INFO

Article history:
Received 12 September 2016
Received in revised form 10 January 2017
Accepted 4 February 2017

Keywords:
Nickel
Metals in human hair
Oral exposure
Biochemical alterations

ABSTRACT

An epidemiological cross-sectional study was conducted in a Greek population, being orally exposed to Ni via food consumption, in order to investigate possible health effects and to evaluate hair Ni concentration as a biomarker of exposure.

The study population consisted of 139 men and 155 women, aged 25–69. Socio-demographics, lifestyle, dietary habits, occupational and medical history data were recorded through a personal interview. Hematological and biochemical examinations were conducted in blood specimens. Metals – Ni, Cr, Cd, Pb, Hg, Cu and Zn – were determined in hair samples. Women were characterized by higher Ni and Cu hair concentrations, while men by higher Cr and Hg. Factors affecting hair metal concentrations were identified to be dietary habits, consumption of local crops, occupation and smoking.

Hair element content in the study population was comparable to the "reference ranges" reported in Europe, except for Ni, found higher in a fraction of our population. Men in the upper quartile of hair Ni distribution are at higher risk for abnormal high cholesterol, LDL, albumin and calcium, with odds ratios (OR) varying between 3.5 and 6.2. Accordingly, high hair Ni content in women is associated with abnormal glucose (OR = 3.9), triglycerides (OR = 3.1) and low abnormal sodium (OR = 4.3).

The study provides evidence of the suitability of hair analysis in assessing environmental exposure to Ni and supports the use of hair Ni content as a valuable and relatively inexpensive tool of biomonitoring, to identify people at risk for certain biochemical alterations.

1. Introduction

Oral exposure to Ni via food consumption and to Cr(VI) via drinking water of a population in an area of central Greece has been recently brought to light [1–6]. Geological investigations proved that Ni and Cr are mainly of natural, lithogenic origin [1–3]. Health outcomes due to Cr exposure have been recently assessed in this population [6]. However, effects of exposure to Ni have not been investigated so far, even though vegetables in the area contain at least two times more Ni [4,5] than the corresponding crops examined throughout Europe [7].

Health effects of oral exposure to Ni include contact dermatitis and systemic gastrointestinal, hematological, neurological and immune disorders [7]. These effects are mediated by non-specific interactions of Ni with macromolecules, leading to inflammation, oxidative stress, cell proliferation, and cell death [8]. The most prevalent (up to 15%) effect of Ni is an allergic skin reaction, frequently remaining undiagnosed [7].

Exposure to environmental contaminants can be assessed at the individual level through hair analysis [9,10]. It reflects both past and ongoing exposure and requires a non-invasive sampling [9–11]. Among its disadvantages are the high variability and the possible external contamination which can be eliminated by following an appropriate washing procedure [10].

Several studies focus on defining standardized baseline hair concentration levels, based on measurements on unexposed healthy subjects, denoted as "reference ranges" [9,12–14]. It has been suggested each country to establish its own reference values, separately for men and women [9,12,13], given that factors, e.g. gender, ethnicity, lifestyle, diet, influence hair concentration [14,15].

The aims of the present epidemiological study are to investigate possible health consequences due to oral Ni exposure and to evaluate Ni hair content as a biomarker of exposure. Additionally, hair levels of some other trace elements are assessed.

* Corresponding author.
E-mail addresses: elsazak@upatras.gr (E. Sazakli), micleon@upatras.gr (M. Leotsinidis).

http://dx.doi.org/10.1016/j.jtemb.2017.02.001
0946-672X/

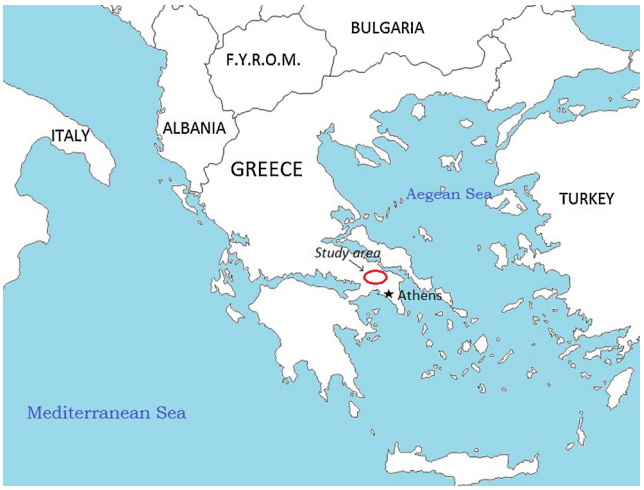

Fig. 1. Map of Greece, indicating the study area.

2. Material and methods

2.1. Study area and study population

The study area is located in Central Greece, around the Asopos River basin (Fig. 1). The area is characterized of intense agricultural activity, mainly in its western part, while in its eastern part an industrial area has been developed during the last 40 years.

The study population was randomly selected and stratified in non-overlapping sex and age strata, to obtain a representative sample. To participate in the study, an individual had to be between 25 and 69 years old and permanent resident of the area for at least the last seven consecutive years. All participants signed a written informed consent. The study was approved by the Ethics Committee of the University of Patras and the principles of the Declaration of Helsinki were followed. Overall, 139 men and 155 women were recruited. Details about the characteristics of the study population are given in Table 1.

2.2. Questionnaire and medical examination

Each participant had a meeting with a general practitioner and a health visitor, members of the research team, in the local health center. The practitioner filled in a specially-designed questionnaire, through personal interview, to collect information on: demographic characteristics (age, sex, residential history, marital status, educational level, working and economical status); medical history (morbidities, hereditary diseases); lifestyle (physical activity, smoking, coffee and alcohol consumption), while weekly consumption frequencies of major food groups, *i.e.*, meat, fish, vegetables, legumes, dairy products, sweets and fruits, were assessed by a 7-day food frequency questionnaire. A specific question was also included to characterize the frequency of consuming local crops as "exclusively", "usually", "seldom" or "never". Moreover, a physical examination was conducted to record weight, height, systolic and diastolic blood pressure of each subject.

2.3. Collection and analysis of biological samples

The health visitor collected blood and hair samples from the participants. A full blood count was conducted in whole blood samples, while typical biochemical parameters were determined in serum samples.

Samples of head hair (0.5–1.0 g) were cut with stainless steel scissors from the scalp of the occipital region and up to a distance of 2 cm, placed into metal-free plastic containers and transferred to the laboratory of Public Health for analysis. The samples were immersed in acetone for 20 min, washed twice with MilliQ water (18.2 MΩ cm), and then with 0.1% SDS solution in an ultrasonic bath for 15 min. A second 15-min ultrasonic bath followed in MilliQ water, and then the samples were filtered, washed once again with MilliQ water and left overnight at 60 °C for drying. Approximately 0.2 g hair sample, accurately weighted, were digested with 7 mL supra-pure 65% HNO_3 by using a microwave-assisted closed wet digestion (Ethos Touch). The obtained solutions were diluted to a final volume of 10 mL with MilliQ water.

Atomic absorption spectrometry (AAS) was employed in graphite mode for the determination of Ni, Cr, Cd, Pb and Cu, in flame mode in the case of Zn, while Hg was determined via cold vapor AAS (Shimadzu AA-6300 system, equipped with autosampler ASC-6100, graphite furnace GFA-EX7i and Hydride Vapor Generator HVG-1). Calibration was performed via standard solutions subjected to the same digestion procedure. Detection limits were calculated to be 0.03 μg/g for Cr, 0.05 μg/g for Ni and Pb, 0.006 μg/g for Cd, 0.10 μg/g for Cu, 0.35 μg/g for Zn and 0.06 μg/g for Hg.

Precision was estimated at 5–7% by replicate measurements on 30 hair samples. Recovery of known trace element amounts added to the hair samples before wet digestion varied from 85% to 109%. The quality assurance of metal analyses was further checked by using one certified reference material, the IAEA-436 biota sample, and one Proficiency Test in biota sample (MA-MED POL TM), both provided by IAEA's Marine Environment Studies Laboratories (MESL). The determined values did not differ more than 5% from the certified ones (Table A1, in Appendix).

2.4. Statistical analysis

For descriptive purposes, median and percentiles of the metal content in hair were calculated. Mann-Whitney *U* test was employed for group comparisons. Linear regression models were constructed to evaluate the effect of various variables on the levels of hair metals. The independent variables were log-transformed in order to meet the assumption of linear regression for the residuals to be normally distributed. Principal component analysis was performed to investigate the relationship between metals. Finally, subjects were classified according to their Ni content in hair into two groups and according to their values in each hematological and biochemical parameter into two or three groups. These cut-off values were given by the laboratory where the blood analyses were conducted and are presented, along with details about the population distribution, in Table A2 (in Appendix). The associations of groups of subjects with normal and "out of normal" values, regarding certain hematological or biochemical parameters, with Ni hair levels were assessed via multinomial logistic regression models. Factors with $p \leq 0.100$ were kept in the models. The statistical significance level was set at $a = 0.05$. Statistical analysis was performed by IBM SPSS v.21 statistical software (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Hair metals' concentrations

The results of hair metal analyses are presented in Table 2.

Hair levels of Ni, Cr, Hg and Cu were sex-related, as the Mann-Whitney *U* test revealed. In detail, women were characterized by significantly higher hair Ni ($p = 0.007$) and Cu ($p < 0.001$) content in comparison to men, while the opposite was the case for Cr ($p = 0.002$) and Hg ($p < 0.001$). No significant differences were observed in Cd ($p = 0.717$), Pb ($p = 0.324$), and Zn ($p = 0.543$) hair levels between men and women.

Please cite this article in press as: E. Sazakli, M. Leotsinidis, Hair biomonitoring and health status of a general population exposed to Nickel, J Trace Elem Med Biol (2017), http://dx.doi.org/10.1016/j.jtemb.2017.02.001