DIFFERENT TRENDS OF CR, FE AND ZN CONTENTS IN HAIR BETWEEN OBESE, OVERWEIGHT AND NORMAL-WEIGHT MEN

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SUMMARY

Objectives: Overweight and obesity are risk factors for many diseases, nutrition leading to these phenomena is not only a question of disbalance between energy intake and expenditure, but also the presence of micronutrients. In our study, we focused on measuring residues of chromium, zinc and iron in the hair of men with different BMI.

Methods: Hair samples and anthropometric questionnaires were collected from 45 males. Numbers of subjects and age structure were comparable between the three BMI groups. The determination of metal levels was performed by inductively coupled plasma mass spectrometry after mineralization of the hair.

Results: The hair of obese men contained significantly higher chromium (0.096 μg/g vs. 0.045 μg/g, $p = 0.0039$) and iron (9.42 μg/g vs. 5.84 μg/g, $p = 0.0009$) concentrations than that of overweight men, but no significant difference between the normal-weight group and the obese group were found. The concentration of zinc was lower in obese subjects compared to overweight subjects (183.5 μg/g vs. 206.2 μg/g, $p = 0.038$). Also, statistically significant correlations between chromium and iron concentrations in hair and BMI were found ($r = 0.307$, $p = 0.040$, $r = 0.360$, $p = 0.015$, respectively). According to our results, age did not significantly affect chromium, iron and zinc concentrations in hair.

Conclusion: Consistent with some published studies, we have found that obese men have higher chromium and iron concentrations and lower zinc concentrations in hair.

Key words: hair, chromium, iron, zinc, obesity

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INTRODUCTION

Hair analysis has proven to be a useful tool for human biomonitoring in terms of both essential and toxic elements (1, 2). The contents of elements in hair may, on one hand, reflect the exposure to environmental pollutants, and on the other hand, be linked to metabolic parameters (2, 3). It has been shown that metabolic disorders (such as obesity-induced hyperinsulinemia) are manifested by mineral disbalance of e.g., chromium (Cr), iron (Fe) and zinc (Zn) (4–6).

The aim of the study was to assess the hair content of the three above-mentioned elements and examine differences between three groups of men classified according to their BMI: normal weight, overweight, and obese.

Chromium in trivalent state is an essential trace element that plays a key role in the regulation of glucose (as a mediator of the insulin signal in insulin-dependent tissues) and its possible effect on weight reduction is also explored. An insufficient amount of this element can lead to many physiological disorders such as elevated blood levels of glucose, insulin, cholesterol, and triacylglycerols, and reduced HDL cholesterol levels, which increase the risk of type 2 diabetes mellitus and cardiovascular disease (5, 7–9).

Zinc is an essential micronutrient that plays a key role in adipose tissue metabolism (zinc stimulates lipogenesis and glucose uptake in isolated adipocytes) and in the synthesis and action of insulin (7, 9, 10). Zinc deficiency might affect glucose metabolism, leading to development of metabolic disorders including insulin resistance and impaired glucose tolerance (11).

The most common deficiency with respect to essential micronutrients is iron deficiency, which is very common among overweight and obese children and adolescents (7). Iron is involved in electron transfer in the mitochondria and oxygen transport through bonds with myoglobin and haemoglobin (12). Iron deficiency and anaemia may lead to fatigue and a consequent decrease in physical activity associated with further weight gain. In addition, deficiency of iron might disrupt the mitochondrial activity of the respiratory chain, thereby reducing exercise capacity and increasing insulin resistance (13).

Recent studies suggest that obese people have more frequent occurrences of iron (13, 14), zinc (15, 16) and chromium deficiency (7, 17, 18), and therefore it may be beneficial to provide these individuals with these essential trace elements in the form of supplements (17–19). In obesity, the potentially beneficial roles of essential minerals and trace elements might be related to their insulin-sensitizing effects (zinc, chromium) or antioxidant properties (selenium, magnesium) (3, 20, 21). Other studies suggest that a higher BMI is associated with increased chromium (5, 22) and iron (23) contents and decreased zinc (3, 5, 12) content in hair, while some studies (24) point out that many of these elements have antagonistic effects.

MATERIALS AND METHODS

All subjects were asked to complete a questionnaire on their age, height, weight, waist circumference, education, diet and dietary supplements, diseases, and smoking habits. Exclusion criteria were the use of mineral supplements, coloured hair, smoking, presence of chronic diseases such as type 2 diabetes mellitus, or history of disorders affecting food intake or absorption. The sample comprised 45 males aged 21–85 years. Subjects were divided into three groups – normal-weight men (BMI 18.5–24.9 kg/m^2, n = 14), overweight men (BMI 25–29.9 kg/m^2, n = 16), and obese men (BMI ≥30 kg/m^2, n = 15). The criterion for dividing the groups was the body mass index (BMI). In clinical practice, obesity is classified by BMI calculated as the ratio of human body weight to squared height. Normal weight is defined as a BMI in the range 18.5–24.9 kg/m^2, overweight as a BMI in the range 25–29.9 kg/m^2, and obesity as a BMI equal to or greater than 30 kg/m^2 (25). Although this approach is common in clinical practice, it neglects the possible effect of an excess of muscle mass. Therefore, in some cases, e.g. bodybuilders, BMI can be misleading. However, no such cases were observed in this study.

No significant age difference between the three groups was found using One-way ANOVA.

All participants signed informed consent and the study protocol was approved by the Ethics Committee of the Faculty of Medicine at Masaryk University in Brno.

Hair Mineral Analysis

Hair samples were cut from the suboccipital zone of the head using ceramic scissors to avoid sample contamination. To limit the potential influence of external effects, the hair was cut close to the head at a maximum distance of 5 cm from the scalp and washed with acetone, p.a., three times with demineralized water, and again with acetone (26). The hair was immersed in each solution for 10 minutes to eliminate sweat, dirt, and pollutants from the external environment. After these procedures, the hair was dried in a laboratory oven at 50 °C for 60 minutes.

With respect to mineralization, samples (app. 50 mg of hair) were mixed with 1 mL of concentrated HNO_3 (Merck, p.a.) in polypropylene tubes and the mixtures were left to react at 70 °C for 2 hours in a block heater (Stuart SBH 200D/3). A few drops of 30% H_2O_2 (Merck, p.a.) were added during the digestion to enhance mineralization processes. After cooling, the mixtures were diluted with deionized water up to a volume of 9.7 mL (18.2 MΩ · cm-1, Simplicity 185, Millipore). The contents of Cr, Fe and Zn were determined by means of inductively coupled plasma mass spectrometry (Agilent 7700x ICP-MS, Agilent Technologies). The methodology was validated by the analysis of duplicated hair samples spiked with known amounts of Cr, Fe, and Zn before and after mineralization. Spiking recoveries were found to be 105 ± 3% and 105 ± 2%, respectively.

Statistical Analysis

The obtained data were statistically analysed by means of STATISTICA 12. Using the Shapiro-Wilk test, it was found that the distribution of the data differed significantly from the normal one. Therefore, nonparametric tests were used for further analysis. The Mann-Whitney U test and the Kruskal-Wallis test were used to compare the contents of selected elements within individual groups. The nonparametric Spearman's correlation coefficient was used to determine the relationship between the observed continuous parameters. All tests were evaluated at a significance level of $p < 0.05$.

RESULTS

The concentration of chromium, iron and zinc in male hair are shown in Table 1. In this study population, the median concentrations of chromium in the hair of men in the normal-weight, overweight, and obese groups were 0.047 µg/g, 0.045 µg/g, and 0.096 µg/g, respectively, with an overall median concentration of 0.053 µg/g. The median concentrations of iron in the hair of men in the normal-weight, overweight, and obese groups were 6.16 µg/g, 5.84 µg/g, and 9.42 µg/g, respectively, with an overall median concentration of 6.26 µg/g. The Kruskal-Wallis test revealed significant differences between medians of chromium and iron contents between the groups ($p = 0.011$, $p = 0.007$, respectively). Since the spread of chromium and iron contents was relatively wide in the normal-weight group, no statistically significant difference was observed in the other groups. However, the shift in the content of both elements was significant from the overweight group towards the obese group (Table 1).

The median zinc concentration in the hair of all tested men was 201.8 µg/g. The difference in zinc concentrations between groups was statistically significant (Kruskal-Wallis test, $p = 0.042$). The obese group exhibited significantly lower concentrations of zinc than the overweight group (Table 1). The median zinc concentration for the normal-weight group reached 201.1 µg/g and was insignificantly higher than the median for the obese group.

Correlations between the variables were also analysed. The Spearman's correlation coefficient showed statistically significant correlations between BMI and chromium and iron concentrations in hair ($r = 0.307$, $p = 0.040$, $r = 0.360$, $p = 0.015$, respectively). In contrast, no statistically significant correlation was found between BMI and zinc concentration in hair. A strong positive correlation was found between chromium and iron concentration in hair ($r = 0.683$, $p < 0.001$). No age dependency was found for chromium, iron or zinc levels.

DISCUSSION

Numerous studies aimed to resolve the relationship between obesity and chromium, zinc and iron disbalance have led to conflicting results. Positive correlation between hair chromium content and BMI observed in the present study was evidenced by

Table 1. Metal concentrations in hair of men in normal-weight, overweight and obese groups (in micrograms per gram)

Parameter	Normal weight (n = 14)	Overweight (n = 16)	Obese (n = 15)	p-value
Age (years) – mean (SD)	42.1 (20.9)	46.9 (16.9)	51.1 (11.2)	–
BMI (kg/m^2) – mean (SD)	22.8 (1.4)	27.4 (1.3)	34.1 (3.7)	
Chromium (percentiles)				
5th	0.028	0.028	0.036	–
25th	0.032	0.034	0.067	–
50th (median)	0.047	0.045#	0.096#	0.0039*
75th	0.076	0.053	0.175	–
95th	0.209	0.140	0.239	–
Iron (percentiles)				
5th	4.75	4.90	5.72	–
25th	5.52	5.40	8.12	–
50th (median)	6.16	5.84#	9.42#	0.0009*
75th	9.22	6.42	12.34	–
95th	17.05	11.45	40.16	–
Zinc (percentiles)				
5th	161	176	137	–
25th	174	198	165	–
50th (median)	201	206#	183#	0.038*
75th	229	238	202	–
95th	245	399	237	–

#Median test (overweight vs. obese); *statistically significant, $p < 0.05$

former research conducted on pubic hair (5) and scalp hair (22). In contrast, other authors observed no such dependence (4, 27). Higher chromium concentrations in hair of obese individuals may be associated with the fact that metabolic disorders which accompany obesity may lead to increased chromium excretion from the body via excretory pathways (28, 29).

Content of iron in the hair samples follows similar pattern as that observed for chromium, i.e., that hair of obese subjects contained more iron than that of normal-weight and significantly more than that of overweight subjects. Król et al. (30) reported that obese patients with type 2 diabetes mellitus had significantly higher concentrations of iron in hair as well as a higher dietary iron intake than the control group. Such elevated iron concentrations in hair in diabetic and obese subjects were assumed to be caused by increased inflammatory changes typical for type 2 diabetes mellitus or differences in dietary iron intake. Nevertheless, other attempts to reveal a relationship between BMI and hair iron resulted in observation of negative (24) or no correlation (3, 27).

In contrast to trends observed for chromium and iron, no correlation between hair zinc content and BMI was detected. In some studies, lower zinc content in hair of subjects with excessive weight was observed (3, 5, 33) and this phenomenon was attributed to the fact that both zinc deficiency and imbalance play a role in the pathogenesis of obesity and type 2 diabetes. Kruskal-Wallis showed a lower concentration of zinc in the obese group in this study, the trend of the whole group's dependence of zinc concentration on BMI was not statistically significant. Similar findings were made by Hong et al. (22) and Lee et al. (27), who failed to find a significant correlation between zinc concentration and BMI.

Although the hair concentration of some metals (especially those accumulative and toxic ones such as cadmium or lead) has been often associated with age (17, 22, 29, 32, 33), no such dependence was observed in this study.

CONCLUSION

The findings of this pilot study confirm some of the trends reported by previous research focused on the relationship between BMI and the content of chromium, iron and zinc in hair. Concentrations of chromium and iron in the hair of obese subjects were significantly higher compared to overweight men. Conversely, concentrations of zinc in the hair of obese subjects were lower than those in overweight subjects. However, no dependence was confirmed between chromium, iron or zinc concentration and age. Further research on the topic is required to help clarify the exact causes of this understudied phenomenon.

Conflicts of Interests

None declared

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REFERENCES

1. Černá M, Krsková A, Cejchanová M, Spěváčková V. Human biomonitoring in the Czech Republic: an overview. Int J Hyg Environ Health. 2012;215(2):109-19.
2. Beneš B, Sladká J, Speváčková V, Šmíd J. Determination of normal concentration levels of Cd, Cr, Cu, Hg, Pb, Se and Zn in hair of the child population in the Czech Republic. Cent Eur J Public Health. 2003;11(4):184-6.
3. Skalnaya MG, Skalny AV, Grabeklis AR, Serebryansky EP, Demidov VA, Tinkov AA. Hair trace elements in overweight and obese adults in association with metabolic parameters. Biol Trace Elem Res. 2018;186(1):12–20.
4. Kim HN, Song SW. Concentrations of chromium, selenium, and copper in the hair of viscerally obese adults are associated with insulin resistance. Biol Trace Elem Res. 2014;158(2):152-7.
5. Wiechuła D, Loska K, Ungier D, Fischer A. Chromium, zinc and magnesium concentrations in the pubic hair of obese and overweight women. Biol Trace Elem Res. 2012;148(1):18-24.
6. Banach W, Nitschke K, Krajewska N, Mongiałło W, Matuszak O, Muszyński J, et al. The association between excess body mass and disturbances in somatic mineral levels. Int J Mol Sci. 2020;21(19):7306. doi: 10.3390/ijms21197306.
7. Kaidar-Person O, Person B, Szomstein S, Rosenthal R. Nutritional deficiencies in morbidly obese patients: a new form of malnutrition? Part B: minerals. Obes Surg. 2008;18(8):1028-34.
8. Suksomboon N, Poolsup N, Yuwanakorn A. Systematic review and meta-analysis of the efficacy and safety of chromium supplementation in diabetes. J Clin Pharm Ther. 2014;39(3):292-306.
9. Lapik IA, Galchenko AV, Gapparova KM. Micronutrient status in obese patients: a narrative review. Obes Med. 2020;18:100224. doi: 10.1016/j.obmed.2020.100224.
10. Fukunaka A, Fujitani Y. Role of zinc homeostasis in the pathogenesis of diabetes and obesity. Int J Mol Sci. 2018;19(2):476. doi: 10.3390/ijms19020476.
11. Ennes Dourado Ferro F, de Sousa Lima VB, Mello Soares NR, Franciscato Cozzolino SM, do Nascimento Marreiro D. Biomarkers of metabolic syndrome and its relationship with the zinc nutritional status in obese women. Nutr Hosp. 2011;26(3):650-4.
12. Fatani SH, Saleh SAK, Adly HM, Abdulkhaliq AA. Trace element alterations in the hair of diabetic and obese women. Biol Trace Elem Res. 2016;174(1):32-9.
13. Aigner E, Feldman A, Datz C. Obesity as an emerging risk factor for iron deficiency. Nutrients. 2014;6(9):3587-600.
14. Nikonorov AA, Skalnaya MG, Tinkov AA, Skalny AV. Mutual interaction between iron homeostasis and obesity pathogenesis. J Trace Elem Med Biol. 2015;30:207-14.
15. Marreiro DDN, Fisberg M, Cozzolino SMF. Zinc nutritional status in obese children and adolescents. Biol Trace Elem Res. 2002;86(2):107-22.
16. Olechnowicz J, Tinkov A, Skalny A, Suliburska J. Zinc status is associated with inflammation, oxidative stress, lipid, and glucose metabolism. J Physiol Sci. 2018;68(1):19-31.
17. Tofiq DI, Ismael PA, Hasan HG. Estimation of serum chromium levels in obesity. Middle East J Intern Med. 2012;5(5):3-9.
18. Lima KVG, Lima RPA, Gonçalves MCR, Faintuch J, Morais LC, Asciutti LS, et al. High frequency of serum chromium deficiency and association of chromium with triglyceride and cholesterol concentrations in patients awaiting bariatric surgery. Obes Surg. 2014;24(5):771-6.
19. Cruz KJ, Morais JB, de Oliveira AR, Severo JS, Marreiro DD. The effect of zinc supplementation on insulin resistance in obese subjects: a systematic review. Biol Trace Elem Res. 2017;176(2):239-43.
20. Belin RJ, He K. Magnesium physiology and pathogenic mechanisms that contribute to the development of the metabolic syndrome. Magnes Res. 2007;20(2):107-29.
21. Wiernsperger N, Rapin J. Trace elements in glucometabolic disorders: an update. Diabetol Metab Syndr. 2010;2:70. doi: 10.1186/1758-5996-2-70.
22. Hong SR, Lee SM, Lim NR, Chung HW, Ahn HS. Association between hair mineral and age, BMI and nutrient intakes among Korean female adults. Nutr Res Pract. 2009;3(3):212-9.
23. Bae YK, Cho MS. Analysis of hair tissue mineral contents according to body mass index. Korean J Food Nutr. 2008;21(2):256-62.
24. Wang CT, Chang WT, Zeng WF, Lin CH. Concentrations of calcium, copper, iron, magnesium, potassium, sodium and zinc in adult female hair with different body mass indexes in Taiwan. Clin Chem Lab Med. 2005;43(4):389-93.
25. Bagchi D, Preuss HG, editors. Obesity: epidemiology, pathophysiology, and prevention. 2nd ed. Boca Raton: CRC Press; 2012.
26. Spěváčková V, Knotková J. Elemental analysis of clinical materials - application of electrothermal atomic absorption spectrometry. Chem Listy. 1998;(92):287-93. (In Czech.)
27. Lee YA, Kim SH, Kim HN, Song SW. Are there differences in hair mineral concentrations between metabolically healthy and unhealthy obese adults? Biol Trace Elem Res. 2020;193(2):311-8.

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