Elements alteration in scalp hair of young obese Saudi females

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ABSTRACT

The aim of the present work is to investigate the levels of trace and macro elements including copper (Cu), magnesium (Mg), iodine (I), sodium (Na), potassium (K), cadmium (Cd), chromium (Cr), manganese (Mn), selenium (Se), calcium (Ca), zinc (Zn), iron (Fe) and lead (Pb) in hair sample of young Saudi females with or without obesity. This cross-sectional study was conducted between 2018 and 2019 among 75 young Saudi females aged ≥20 years. In this study, obese (n = 30) and non-obese (n = 45) participants. The hair samples of participants were analysed by inductively coupled plasma atomic emission spectrometer after samples underwent wet acid digestion method. The obtained data revealed a significantly higher level of Ca, K, Na, Pb and Mg and lower Mn, Cr and Zn levels in hair amongst the obese group when compared to the non-obese group participants. The results of the present study have demonstrated the changes in elemental content in the hair of young obese Saudi females. Although obesity poses a risk for element imbalances, the general etiopathogenesis of obesity and/or its related metabolic disorders may be at least partially mediated by altered trace and macro elements.

1. Introduction

Obesity (OB) is a major challenge worldwide and is related to the incidence of many health disorders, such as diabetes, metabolic syndrome, respiratory and cardiovascular diseases and malignancies (Palmer & Toth, 2019).

The prevalence of OB is increasing in Saudi Arabia, especially in females and is considered among the highest in the world (Saad Salman, 2016). According to a 2010 World Health Organization (WHO) report, the prevalence of OB in Saudi Arabia among females aged between 15 and 100 years was 36% (World Health Organization, 2010). A recent study found that half of the Saudi females were physically inactive (Alhakbany et al., 2018).

There is a growing recognition of the impact of lifestyle changes and economic growth on the prevalence of OB. The alteration in levels of some trace elements and metals has been confirmed to be associated with OB (Demerdash, 2015; Grün & Blumberg, 2006). Essential trace elements are very important for maintaining normal body metabolic pathways. There is evidence that exposure to high concentrations of toxic elements can affect cell membranes and functions, leading to an impairment of many cellular functions involving deoxyribonucleic acid, the signalling system, transporters and enzymes. At the same time, a deficiency of essential elements may compromise overall health (Calderon Guzmán, Juárez Olguín, Osnaya Brizuela, Hernández García, & Lindoro Silva, 2019). Females are at a greater risk of developing micronutrient deficiencies and are more vulnerable to toxic metal exposure than males (Berglund et al., 2011).

Several studies regarding the association between trace and macro elements in hair and, OB are anecdotal and may require further investigation (Campbell, 2001; Choi, Ko, Kim, & Moon, 2019; Yerlikaya, Toker, & Aribas, 2013).

Hair elements analysis is relatively accurate in the evaluation of nutritional status for metabolic disorders and environmental exposure. Besides, it is convenient in the collection, storage and transport as well as analysis due to the high concentration of the elements in the hair (Chojnacka, Zielińska, Górecka, Dobrzański, & Górecki, 2010; Nasli-Esfahani, Faridbod, Larijani, Ganjali, & Norouzi, 2011; Park, Shin, & Kim, 2007).

While in blood, minerals undergo continuous homeostatic changes which do not reflect long-term metabolic changes (Razagui & Ghribi, 2005), the concentration of trace and macro elements in hair samples, represents their mean concentration in the
body for a longer period of time compared to the body fluid compartments (Momen, Khalid, Elsheikh, & Ali, 2015; Rahman et al., 2009). This could serve as a good indicator of any disturbance in homeostasis and in identifying the risk factors leading to the development of metabolic complications.

In Saudi Arabia, few studies have been performed in order to investigate the trace and macro element alterations in scalp hair samples of females. Fatani et al. (2016) conducted a study on estimation of five element concentrations (Fe, Zn, Se, Cu and Mn) and found a significant reduction in Fe, Mn and increased levels of Se and Cu in the hair of obese Saudi women (Fatani, Saleh, Adly, & Abdulkhaliq, 2016).

The relationship between OB and elemental composition in hair is very complicated, as OB and its complications can promote the metabolic alteration of trace element concentrations (Skalnaya & Demidov, 2007). Despite the few reports showing altered hair element status in OB (Skalnaya et al., 2018), the evaluation and clinical importance of elemental analysis in OB seem to be heterogeneous (Padilla, Elobeid, Ruden, & Allison, 2010). Therefore, the aim of this present study was to investigate trace (Cu, I, Cd, Cr, Mn, Se, Zn, Fe and Pb) and macro (Mg, Na, K and Ca) elements alterations in hair samples of young obese Saudi females.

2. Materials and methods

2.1. Participant characteristics

A cross-sectional study was conducted between July 2018 and March 2019 at Imam Abdulrahman Bin Faisal University in Saudi Arabia among young Saudi female students with naturally coloured hair who were non-smokers and healthy (not in care for chronic disease or cancer). Exclusion criteria included current pregnancy and a history of taking a mineral supplement for the past 3 months (Blażewicz et al., 2017).

Participants were divided into two groups: non-obese (NOBG) participants (n = 45, body mass index [BMI] = 18.5–25 kg/m²) and obese (OBG) participants (n = 30, BMI > 30 kg/m²) (Alkahtani, Elkilany, & Alhariri, 2015). Written informed consent was given by all participants in accordance with the Helsinki Declaration, and the study’s protocol was reviewed and approved by the Internal Review Board at Imam Abdulrahman Bin Faisal University (IRB-2018-01-028).

2.2. Reagents and sample preparation procedure

Hair specimens (approximately 100 mg) were collected from the nape of the neck (less than 3 cm from the scalp) by using stainless steel scissors and stored at 25 °C until digestion and analysis. A total of 5 mg of hair was obtained and washed in acetone and Triton-X 100 (Merck, Darmstadt, Germany), and then the sample dilution procedure was carried out in accordance with the method described by Ishak and colleagues in 2015 (Ishak, Rosli, Mohamed, & Ismail, 2015).

Subsequently, hair samples were subjected to microwave degradation (Speedwave Four, Berghof Products, Germany) in the presence of H₂O₂ and HNO₃ (Sigma-Aldrich Co., USA) for 20 min at 180 °C [22].

2.3. Determination of elements contents in hair samples

The quantitative analyses of the trace and macro elements (Cu, Mg, I, Na, K, Cd, Cr, Mn, Se, Ca, Zn, Fe and Pb) were carried out with simultaneous ICP atomic emission spectrometer (ICPE-9800, Shimadzu Corporation, Japan) according to the technical procedure described by Blażewicz et al. (2017).

2.4. Statistical analysis

Data were analysed using IBM SPSS version 25. The normality distribution was assessed using the Shapiro–Wilk test, and the differences between groups were tested using the Mann–Whitney U test. Data will be presented as mean values ± SEM. The Bonferroni’s test was used to adjust for multiple comparisons with levels of trace and macro elements representing the dependent variable and the factor “groups” (1 = NOBG, 0 = OBG) being the independent variable. Statistical significance was set at p < 0.05.

3. Results

3.1. Participant characteristics

A total of 75 participants were recruited for the study; 45 were in NOBG, and 30 were in OBG. The mean age of the participants in NOBG was...
Table 1. Contents of trace and macro elements (mg/kg) in hair of OBG vs. NOBG.

| Group | Mean ± SEM (mg/kg) | p value |
|-------|-------------------|---------|
| Ca*** | NOBG 178.3 ± 17   | <0.001  |
|       | OBG 294.1 ± 25    |         |
| Cd**  | NOBG 0.83 ± 0.02  | 0.340   |
|       | OBG 0.51 ± 0.01   |         |
| Cr*   | NOBG 0.20 ± 0.02  | 0.126   |
|       | OBG 0.16 ± 0.01   |         |
| Cu**  | NOBG 36.1 ± 11    | 0.601   |
|       | OBG 22.2 ± 2      |         |
| Fe**  | NOBG 44.3 ± 4     | 0.364   |
|       | OBG 46.9 ± 7      |         |
| I**   | NOBG 5.4 ± 1      | 0.287   |
|       | OBG 6.7 ± 2       |         |
| K***  | NOBG 152.2 ± 11   | <0.001  |
|       | OBG 258 ± 20      |         |
| Mg*** | NOBG 29.6 ± 1     | <0.001  |
|       | OBG 83.9 ± 9      |         |
| Mn*** | NOBG 0.85 ± 0.07  | <0.001  |
|       | OBG 0.50 ± 0.05   |         |
| Na*** | NOBG 71.9 ± 5     | <0.001  |
|       | OBG 209.4 ± 19    |         |
| Pb**  | NOBG 0.47 ± 0.05  | 0.006   |
|       | OBG 1.15 ± 0.04   |         |
| Se**  | NOBG 0.13 ± 0.01  | 0.174   |
|       | OBG 0.10 ± 0.01   |         |
| Zn*** | NOBG 51.8 ± 4     | 0.011   |
|       | OBG 38.2 ± 7      |         |

Significant results at p < 0.05 are highlighted in bold, and those remaining significant after the Bonferroni’s test correction for multiple tests are indicated with asterisks.

*p = 0.03, **p = 0.04, ***p = 0.05.

20.5 ± 1.6 years and 21.3 ± 1.8 years among participants enrolled in OBG. The mean BMI (kg/m²) of the participants in NOBG and OBG was 22.8 and 35.4, respectively (Figure 1).

3.2. Trace and macro element analysis

Table 1 provides the results of the studied elements. The mean content of the following elements was significantly higher in the hair of participants enrolled in OBG as compared to those in NOBG: Ca (p < 0.001), K (p < 0.001), Mg (p < 0.001), Na (p < 0.001) and Pb (p < 0.01). Following Bonferroni correction for multiple testing, differences remained significant for Ca (p = 0.05), K (p = 0.04), Mg (p = 0.05) and Na (p = 0.05).

In contrast, Mn (p < 0.001) and Zn (p = 0.01) levels were significantly lower in the hair of participants in OBG as compared to those in the NOBG. Following Bonferroni correction, significant results were observed for Mn (p = 0.05), Zn (p = 0.05) and Cr (p = 0.03).

The levels of other elements that were studied, i.e., (Cd, Co, Cu, Fe, I and Se), did not have any significant difference between NOBG and OBG.

4. Discussion

The present study demonstrates a marked increase in levels of Ca, K, Na, Mg and Pb and decrease in levels of Mn and Zn in hair of young obese Saudi females. After Bonferroni correction, the levels of Ca, K, Na and Mg were found elevated in hair of participants enrolled in OBG while Mn, Zn and Cr were decreased.

The observed increase in Ca levels in hair sample from OBG is similar to the findings of previous studies with other studies (Chojnacka et al., 2010; Kwiecień, Samołotńska, Puczkowski, Waśko, & Blicharski, 2019). Many abnormalities in Ca homeostasis have been reported in people with OB. Earlier studies proposed some explanations for this metabolic disturbance. This included the physiologic adaptation to the need for more bone mass to support increased weight, volumetric dilution, sequestration of vitamin D in adipose tissue (Drincic, Armas, Van Diest, & Heaney, 2012) and secondary hyperparathyroidism (Golzarand, Hollis, Mirmiran, Wagner, & Shab-Bidar, 2018; Hamoui, Anthone, & Crookes, 2004).

High blood Ca is initiated by activation of bone resorption process triggered by the activation of osteoclasts, i.e., “calcium-resorbing bone cells”, in response to secondary hyperparathyroidism. This results in a number of manifestations, such as neuromuscular effects, muscle weakness, fatigue, confusion, impaired concentration (Harvey, 2015). In addition, cardiovascular involvement namely “vascular calcification, hypertension, cardiac arrhythmias”, etc. could occur (Choi et al., 2019). Further, renal effects “polyuria, polydipsia, dehydration, nephrolithiasis” may be observed. Moreover, gastrointestinal manifestations such as “abdominal, pain, constipation, nausea, anorexia, rarely peptic ulcer disease or pancreatitis” and osteoporosis of cortical bone could occur (Otsuka, Ohno, & Oshima, 2018).

The observed increase in Na in hair sample of OBG participants is consistent with findings from previous research (Kwiecień et al., 2019). A possible explanation could be the imbalance in the hormonal mechanism of Na homeostasis, which contributes to the development of hypernatremia and hypertension in obese individuals (Alonso-Galicia, Brands, Zappe, & Hall, 1996; Kwiecień et al., 2019; Stocker, Kinsman, & Sved, 2017). This is of clinical importance because high Na levels cause hypertension, which is considered as the leading risk for premature death worldwide (Nalini et al., 2018; Thuesen et al., 2015).

Our results are consistent with those from other reports indicating elevated concentrations of K in hair sample of adult females with higher (Wang, Chang, Zeng, & Lin, 2005). Previous study indicated that the mean nutrient adequacy ratio for K is significantly higher among Saudi females (ALFaris, Al-Tamimi, Al-Jobair, & Al-Shwaiyat, 2015). It is well known that natural diets, which consist of unprocessed foods, contain a high percentage of K (Karppanen, Karppanen, & Mervaala, 2005). Date palm is a very important fruit and a major food item.
source in Saudi Arabia. It contains a high percentage of carbohydrates (calories) and K compared to most fresh fruits (Al-Farsi & Lee, 2008). Additionally, data palm consumption, being higher among obese Saudi females (Alqahtani et al., 2017).

Pb is a heavy metal widely used in lead-acid battery industries and gasoline (Wang, Chen, et al., 2016). Pb poisoning is one of the most common exposures that can lead to a functional and neuro-psychological decline in humans, with neurological dysfunction in attention, language, memory, intelligence, executive functioning, mood, processing speed, motor and visuospatial skills (Mason, Harp, & Han, 2014). Moreover, it may cause endocrine disturbance on the hypothalamic-pituitary-adrenal axis associated with late-onset puberty (Hauser et al., 2008), thus causing high stress-related cortisol levels (Rossi-George, Virgolini, Weston, & Cory-Slechta, 2009). High bone turnover is also related to high blood Pb (Beier et al., 2015). Interestingly, some studies have investigated the relationship of early Pb exposure with, BMI and Diabetes. They reported that Pb exposure caused prolonged and persistent hyperglycaemia (Tyrrell, Hafida, Stemmer, Adhami, & Leff, 2017). Scientific evidence has confirmed that DNA methylation changes of some metabolic process-related genes were accompanied by both type 2 diabetes and OB (Kirchner et al., 2016). In our research, Pb in hair samples was observed significantly higher among participants of OBG, which was in accordance with another research (Wang, Chen, et al., 2016).

Zn is a metalloenzyme that has many important physiological roles for humans, such as synthesis, release and storage of insulin (Dubey, Thakur, & Chattopadhyay, 2020). Zn deficiency can lead to several health disorders including hair loss, impotence, depressed immunity, stunted growth, diarrhoea, skin lesions, eye affection and impaired appetite (Blazewicz et al., 2017). The results of this study have shown a significant reduction of Zn concentration in the hair of females in OBG. This finding is in agreement with other studies conducted on hair samples of obese patients (Chen, Lin, & Cheng, 1988; Fatani et al., 2016). Dysregulation of Zn homeostasis can play an important role in the pathogenesis of both OB and type 2 diabetes (Dubey et al., 2020; Fukunaka & Fujitani, 2018). It remains unclear as to whether Zn deficiency is merely a consequence or causes the disease. However, several recent evidences explain the significant relationship between changes in Zn homeostasis and risk of type 2 diabetes and/or pancreatic beta cells (Fukunaka & Fujitani, 2018; Maret, 2017; Rutter et al., 2016).

The observation of lower hair Mn content in OBG is inconsistent with some studies concerning the Mn concentration in the samples of hair (Kim & Song, 2014). Mn plays an important role in metabolisms of lipids, carbohydrates and, maintenance of insulin synthesis and secretion. Importantly, Mn reduces the mitochondrial oxidative stress. Therefore, Mn may have a protective effect against the occurrence of metabolic diseases, including OB, type 2 diabetes mellitus, insulin resistance, hyperlipidaemia, hepatic steatosis, non-alcoholic fatty liver disease and atherosclerosis (Li & Yang, 2018). A clinical study reported a significant association between serum Mn and pre-diabetes and diabetic state (Wang, Zhang, et al., 2016).

Cr is known to promote fat loss (Vincent, 2003). The observed decrease in hair Cr levels in OBG was in agreement with other previous observation (Kim & Song, 2014). However, epidemiological studies have led to a debate on whether Cr levels are associated with OB or not (Campbell, 2001).

In the current study, no significant differences were found in the levels of Cd, Cu, Fe, I and Se in hair samples between the two studied groups. However, these findings could be influenced by the size of the studied sample (Gupta, 2015).

5. Conclusion

Our results showed a lower concentration of Zn, Cr and Mn and marked increase of Ca, K, Na, Mg and Pb levels in hair samples of young obese Saudi females. The obese Saudi females may be at a greater risk of developing an imbalance of trace and macro elements, that may play a significant role in the development of pathogenesis of OB or/and related metabolic risk factors. Further prospective researches rather than cross-sectional studies are warranted to explain the relationship between OB and trace elements dynamics with lifestyle information and environmental pollution.

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