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The impact of maternal overweight on hair essential trace element and mineral content in pregnant women and their children

Anatoly V. Skalny^{1,2,3}, Alexey A. Tinkov^{1,2,3}, Tatiana G. Bohan⁴, Marina B. Shabalovskaya⁴, Olga Terekhina⁴, Svetlana B. Leshchinskaia⁴, Lyubov A. Agarkova⁵, Svetlana V. Notova^{6,7}, Margarita G. Skalnaya^{2,3}, Yulia Kovas^{4,8}

¹ Yaroslavl State University, Yaroslavl, Russia

² Peoples' Friendship University of Russia (RUDN University), Moscow, Russia

³ IM Sechenov First Moscow State Medical University, Moscow, Russia

⁴ Laboratory for Cognitive Investigations and Behavioural Genetics, Tomsk State University, Tomsk, Russia

⁵ Research Institute of Obstetrics, Gynecology and Perinatology, Tomsk National Research Medical Center of the Russian Academy of Sciences. Tomsk, Russia

⁶ Federal Scientific Center of Biological Systems and Agrotechnologies of the Russian Academy of Sciences, Orenburg, Russia

⁷ Orenburg State University, Orenburg, Russia

⁸ Goldsmiths, University of London, London, UK

Corresponding author

Alexey A. Tinkov, MD, PhD

tinkov.a.a@gmail.com

+79619378198

Abstract

The aim of the present study was to investigate hair essential trace elements and mineral levels in 105 pregnant normal-weight (control) and 55 overweight and obese women in the third trimester of pregnancy, as well as in their children at the age of 9 months. The hair essential trace elements and mineral levels were assessed using inductively-coupled plasma mass-spectrometry. Overweight pregnant women had significantly reduced Cr (-24%; $p = 0.047$) and Zn (-13%; $p = 0.008$) content, as well as elevated hair Na and K levels as compared to the controls. Children from overweight and obese mothers had lower hair Mo (-18%; $p = 0.017$), Se (-8%; $p = 0.043$), and V (-24%; $p = 0.028$) levels, as well as elevated Sr content (19%; $p = 0.025$). Correlation analysis revealed a significant relationship between maternal and child hair levels of Co ($r = 0.170$; $p=0.038$), Cu ($r = 0.513$; $p<0.001$), Mn ($r = 0.240$; $p=0.003$), and Na ($r = 0.181$; $p=0.027$) in the whole sample. Pre-pregnancy maternal body mass index (BMI) positively correlated with maternal hair K ($r = 0.336$; $p<0.001$) and Na ($r = 0.212$; $p=0.008$), and negatively correlated with V ($r = -0.204$; $p=0.011$) and Zn ($r = -0.162$; $p=0.045$) levels. The results indicate that impaired trace element and mineral metabolism may play a role in the link between maternal obesity, complications of pregnancy and child's postnatal development. Hypothetically, dietary improvement may be used as a tool to reduce these risks. However, further experimental and clinical studies are required to investigate the relationship between obesity and trace element metabolism in pregnancy.

Key words: maternal obesity; chromium; vanadium; zinc; pregnancy.

Introduction

Essential trace elements and minerals play a significant role in male [1,2] and female [3,4] reproductive health. Specifically, in females variations of zinc and copper [5], as well as selenium [6] are related to menstrual cycle. Impaired trace element metabolism may be involved in polycystic ovarian syndrome pathogenesis [7].

Adequate nutritional status of trace elements and minerals is also required for normal embryogenesis and pregnancy [8,9]. Particularly, in view of the role of selenium in pregnancy [10], altered Se metabolism may be associated with adverse pregnancy outcomes [11], including higher risk of gestational diabetes [12] and pre-eclampsia [13]. Adequate selenium status and selenoprotein metabolism is also essential for fetal development [14]. In addition, selenium may also play a protective role against hazardous environmental pollutants in pregnancy [15].

Zinc also plays a crucial role in pregnancy, as well as prenatal and postnatal development [16]. Poor maternal Zn status is associated with reduced linear growth and psycho-motor development in children [17], although the existing data are inconsistent [18]. The results of a meta-analysis demonstrate that Zn supplementation may reduce the rate of preterm birth [19].

1 Other trace elements and minerals including copper, magnesium [20], iron [21], calcium [22], also play a role in
2 normal pregnancy and fetal development. A significant relationship has been demonstrated between trace element
3 status and risk of infertility [23], as well as pre-eclampsia [24] and other adverse outcomes [25]. It has been also
4 noted that altered trace element status may be also involved in pathogenesis of postpartum depression [26].

5 Essential elements have also been linked to obesity, which itself negatively affects female reproductive system and
6 pregnancy. For example, a study of 287,213 pregnancies demonstrated the association between obesity and
7 gestational diabetes, pre-eclampsia, intrauterine death and other adverse pregnancy outcomes [27]. In addition,
8 obese women are characterized by a higher rate of placental vascular lesions [28]. Research has demonstrated links
9 between obesity pathogenesis and metabolism of iron [29], zinc [30], magnesium [31], as well as other essential
10 elements. Correspondingly, multiple studies have demonstrated altered trace element and mineral levels in hair [32,
11 33], blood [34, 35], and urine [36] of obese patients.

12 Given the role of metal-ligand homeostasis both in obesity and reproduction, as well as the adverse effects of
13 maternal obesity on pregnancy and fetal development, it is hypothesized that altered trace element and mineral
14 metabolism play a role in the link between obesity and pregnancy complications and outcomes. The existing data are
15 insufficient to test this hypothesis [17, 24, 37]. Therefore, the present study aims to address this issue by evaluating
16 hair essential trace elements and mineral levels in pregnant non-overweight and overweight women and their
17 children at the age of 9 months.

18 **Materials and methods**

19 *Participants*

20 A total of 159 mother-children pairs, living in the Siberian Federal District of the Russian Federation, were involved
21 in the present study. The present study was performed in agreement with the principles of the Declaration of
22 Helsinki and its later amendments. The protocol of the study was approved by the Ethics Committee for
23 Interdisciplinary Investigations (Tomsk State University, Russia). All women participated in the investigation on a
24 voluntary basis and were informed about the objectives and procedures of the study. The women signed informed
25 consent for their own and their children's participation. Hair sampling procedures involving children were
26 performed in the presence of one of the parents.

27 *Measures*

28 Pre-pregnancy body mass index (BMI) was assessed using a standard formula: $BMI = \text{weight (kg)} / \text{height}^2 (\text{m}^2)$.
29 Based on BMI values, all women were divided into two groups: normal-weight controls ($n = 104$; $BMI = 18 - 25$)
30 and overweight ($n = 55$; $BMI > 25$).

31 Demographic information, obstetric anamnesis, as well as information about the pregnancy were recorded for all
32 women (Table 1). Prenatal monitoring of fetal condition (Table 2) was performed regularly in agreement with the
33 program of prenatal screening (Ministry of Health of the Russian Federation, No. 572n). Specifically, chronic fetal
34 hypoxia was assessed using doppler ultrasonography. Blood serum levels of human chorionic gonadotropin (hCG)
35 and pregnancy-associated plasma protein (PaPP) as markers of eclampsia and adverse pregnancy outcome [38, 39]
36 were assessed in the first trimester of pregnancy using enzyme-linked immunosorbent assay (ELISA). Threatened
37 miscarriage (ICD-10: O20.0), being characterized by vaginal bleeding and increased risk of premature delivery [40]
38 was registered regularly (each trimester). At delivery, newborn health status information including body weight,
39 height, head and chest circumference, as well as Apgar 1 and 5 scores was recorded by neonatologist in the delivery
40 room (Table 3).

41 *Hair sampling and preparation*

42 Maternal hair sampling was performed in the third trimester of pregnancy, whereas hair from their children were
43 collected at the age of 9 months. 9-month-old children were examined in order to investigate the impact of maternal
44 overweight and obesity not only during gestation, but also at breastfeeding. Proximal parts of hair samples were
45 collected from 3 sites of the occipital region using ethanol-precleaned stainless steel scissors in a quantity of 0.05–
46 0.1 g. All examinees have washed their hair in the morning before sampling using usual commercial shampoos.
47 Earlier data demonstrate that commercial shampoos not enriched with trace elements (zinc, selenium) do not affect
48 hair trace element levels [41].

49 In the laboratory the obtained hair samples were washed with acetone and rinsed three times with deionized water
50 ($18 \text{ M}\Omega \cdot \text{cm}$) from DVS-M/1HA-1(2)-L electric distiller (Mediana-Filter, Podolsk, Russia). Washed hair samples
51 were dried on air at 60°C to a stable weight. Microwave degradation of hair samples (50 mg) was performed in the
52

1 presence of concentrated HNO₃ (Sigma-Aldrich Co., St. Louis, MO, USA) in Teflon tubes using Berghof SW-4
2 DAP-40 (microwave frequency, 2.46 GHz; power, 1450 W) microwave system (Berghof Products + Instruments
3 GmbH, 72800 Eningen, Germany) at 170–180°C for 20 minutes. The obtained solutions were adjusted to 15 ml with
4 distilled deionized water and transferred into polypropylene test tubes for further analysis.

5 *Hair analysis and quality control*

6 The levels of essential trace elements (Co, Cr, Cu, Fe, I, Mn, Mo, Se, Si, Sr, V, and Zn) and minerals (Ca, K, Mg,
7 Na, P) were established using inductively-coupled plasma mass-spectrometry in dynamic reaction cell mode (ICP-
8 DRC-MS) at NexION 300D (PerkinElmer Inc., Shelton, CT, USA) equipped with 7-port FAST valve and ESI SC-2
9 DX4 autosampler (Elemental Scientific Inc., Omaha, NE, USA). The system was calibrated via external calibration
10 using standard solutions containing 0.5, 5, 10 and 50 µg/l of the studied elements prepared from Universal Data
11 Acquisition Standards Kit (PerkinElmer Inc.). Internal online standardization was performed using 10 µg/l yttrium-
12 89 and rhodium-103 solutions prepared from Yttrium (Y) and Rhodium (Rh) Pure Single-Element Standard
13 (PerkinElmer Inc. Shelton, CT, USA) on a matrix containing 8% 1-butanol (Merck KGaA, Gernsheim, Germany),
14 0.8% Triton X-100 (Sigma-Aldrich Co., St. Louis, MO, USA), 0.02% tetramethylammonium hydroxide (Alfa
15 Aesar, Ward Hill, MA, USA) and 0.02% ethylenediaminetetraacetic acid (Sigma-Aldrich Co., St. Louis, MO, USA).
16 Laboratory quality control was performed twice a day (before and after a set of analysis) using GBW09101 human
17 hair certified reference material (Shanghai Institute of Nuclear Research, Shanghai, China). The recovery rates for
18 the studied trace elements and minerals varied from 92% to 111%. The laboratory is also a participant of the
19 Occupational and Environmental Laboratory Medicine External Quality Assessment Schemes (OELM EQAS).
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22 *Statistical analysis*

23 Statistical analyses were performed using Statistica 10.0 (Statsoft, Tulsa, OK, USA). Data distribution was assessed
24 using Shapiro-Wilk test. As data on hair trace element and mineral levels were characterized by non-Gaussian
25 distribution, median and 25–75 percentile boundaries (interquartile range, IQR) were used as descriptive statistics.
26 Demographic and anthropometric data from both mothers and their children were normally distributed, therefore
27 mean and standard deviation (SD) were used for data expression. Significance of group differences was assessed
28 using the non-parametric Mann-Whitney U test for paired-group comparisons and one-way ANOVA. False
29 Discovery Rate (FRD) adjustment for p-value was applied due to multiple comparisons. Correlation analysis was
30 performed using Spearman's rank correlation coefficient. The level of significance of $p < 0.05$ was used for all
31 statistical analyses.
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35 **Results**

36 The data demonstrate that pregnant women in the overweight group had 34% higher values of pre-pregnancy body
37 weight and of BMI, as compared to the control group (Table 1). Women in the overweight group also had earlier age
38 of menarche and first sex. No significant group differences were found in age, pre-pregnancy body height, as well as
39 other parameters.
40

41 The results of prenatal monitoring of fetal health (Table 2) indicate that the risk of spontaneous abortion
42 (miscarriage) in the first trimester was more likely in overweight and obese women. However, no significant group
43 differences in relation to the risk of miscarriage in the second and third trimesters was observed. The rate of chronic
44 fetal hypoxia as assessed by Doppler studies was similar for the two groups. The circulating levels of PaPP and hCG
45 in blood of overweight women were significantly lower than those in the control group by 33% and 41%,
46 respectively.
47

48 Assessment of children's health at delivery (Table 3) did not reveal any significant group differences. Pregnancy
49 duration, as well as the rate of Cesarean section, were similar in the two groups.
50

51 The data demonstrate that overweight status was associated with altered hair trace element and mineral levels in
52 pregnancy (Table 4). Specifically, hair Cr and Zn levels were significantly reduced in overweight women, as
53 compared to the women with normal weight by 24% and 13%, respectively. In contrast, hair K and Na content was
54 severely elevated, being higher than the respective values in the control group by 104% and 55%. It is also notable
55 that hair Fe levels in the overweight group were 26% lower than the control values, with marginal significance.
56

57 Differences were observed in the level of several hair trace elements and minerals in children of overweight vs. non-
58 overweight mothers (Table 5). In particular, hair Mo, Se, and V content in children from overweight women was
59 18%, 8%, and 24% lower as compared to the respective control values. In contrast, hair Sr in this group of children
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exceeded the control levels by 19%. No significant group differences in hair Cr, Zn, K, and Na content were revealed.

Correlation analysis was performed to investigate the association between maternal and children's hair trace elements and minerals (Table 6). In the full cohort (non-overweight and overweight groups combined), a significant correlation was observed between maternal and child hair levels for the following elements: Co ($p = 0.038$), Cu ($p < 0.001$), Mn ($p = 0.003$), and Na ($p = 0.027$). In the control group of mother-child pairs, a significant correlation was observed for only hair Mn ($p = 0.005$). In contrast, in the overweight group, significant correlations between mothers and children were revealed for Co ($p < 0.001$), Cu ($p < 0.001$), I ($p = 0.002$), and Na ($p = 0.006$).

Correlation analysis also demonstrated the association of hair trace element and mineral content with BMI values in women (Table 7). In the full cohort of women, BMI directly correlated with hair K ($p < 0.001$) and Na ($p = 0.008$) content. In contrast, hair V ($p = 0.011$) and Zn ($p = 0.045$) were inversely associated with BMI values. Similarly to the total sample, BMI was inversely related to hair V ($p = 0.016$) and Zn ($p = 0.029$) levels in the normal weight group. In the overweight group, only hair Fe ($p = 0.007$) and Si ($p = 0.049$) correlated with BMI values. No significant associations between maternal BMI and hair trace elements in children's hair were observed.

Discussion

The results of this study showed no significant association between maternal overweight status and adverse outcomes in pregnancy and offspring at 9 months. Nevertheless, overweight status was related to both maternal and offspring hair essential trace element and mineral content. The only adverse parameters that differed between study groups were reduced hCG and PaPP levels, as well as significantly increased risk of spontaneous abortion in the first trimester in the overweight group as compared to the controls. The observed decrease in hCG levels in pregnant overweight women is in agreement with the earlier data [42]. The observed association may be related to the interplay between adipokines and hCG [42, 43]. Lower PaPP-A [38] and h-CG [39] levels were associated with increased risk of preeclampsia and premature delivery.

The obtained data on hair trace elements in overweight pregnant women are in agreement with the existing studies. Hair Zn levels were found to be reduced in overweight women. Several studies have demonstrated that obese individuals are characterized by reduced hair, as well as urinary [44] and serum/plasma [45] zinc levels. Plasma zinc was found to be reduced in pregnant underweight, overweight, obese women [46]. Moreover, Zn status is also associated with metabolic profile in obese patients [47] and experimental animals [48]. Zn supplementation was shown to be effective in improving metabolic health in obesity [49]. The association between low Zn stores, its protective effect, and obesity may be mediated by antioxidant and anti-inflammatory effects of zinc, as well as by its role in regulation of adipogenic signals [30].

Pregnancy is associated with modulation of Zn kinetics including increased Zn absorption and reduced loss in order to provide fetus with sufficient levels of the nutrient [50]. Although data on the association between Zn and pregnancy complications are rather contradictory [51], the existing studies demonstrate the role of altered Zn metabolism on prenatal and postnatal development [16]. Particularly, the association between Zn deficiency and fetal growth restriction [52] and neural tube defects [53] has been revealed. The underlying mechanisms may involve altered regulation of transcription factors in fetal brain [54]. In addition, the results of meta-analysis demonstrated that Zn supplementation may reduce preterm birth [55].

Chromium content was also decreased in overweight women as compared to controls. Low Cr status in overweight/obese patients may be associated with the intake of refined foods especially those enriched with sugars that contain low levels of Cr and increase its excretion [56]. Diet-induced obesity was shown to result in reduced hair and adipose tissue chromium levels in experimental animals, being also associated with metabolic parameters [57]. Moreover, multiple studies have considered chromium as the potential tool for metabolic improvement in obesity and diabetes [56].

Data on the potential role of chromium and its deficiency in pregnancy and its complications are limited. However, it has been demonstrated that reduced chromium levels are associated with gestational diabetes [58], which may be at least partially associated with increased chromium loss [59]. The existing data on the impact of maternal chromium deficiency on fetal development are also insufficient. Particularly, experimental studies demonstrated that maternal chromium restriction results in increased body adiposity in the offspring [60] through modulation of methylation status of hepatic genes involved in insulin signaling [61].

The present findings of higher hair Na and K levels in overweight pregnant women are in agreement with our earlier data demonstrating increased hair Na and K levels in both obese postmenopausal women [62] and high-fat-fed animals [63]. The underlying mechanism of the observed alterations may involve modulation of mineralocorticoid

secretion in obesity [64]. It has been also demonstrated that dietary intake as well as urinary Na levels were associated with increased adiposity [65]. Conversely, potassium intake was proposed to be effective in reduction of the obesity risk [66].

The results of the present study also found links between maternal overweight status and trace element status of children, although the changes were not similar to those in their mothers. Data on prenatal programming of trace element status by maternal obesity are limited. However, earlier studies demonstrated the impact of maternal overweight and obesity in pregnancy on placental nutrient transport [67]. Impaired trace element metabolism may be associated with modulation of hepatic metallothionein expression in the offspring [68]. Specifically, umbilical vein Zn levels were found to be altered in the obese group of maternal-fetal pairs [69].

In a recent study it has been revealed that children from obese women are characterized by reduced hair Mo, Se, Sr, and V levels. Earlier data by [70] demonstrated a negative correlation between maternal body mass and amniotic fluid V and Sr levels ($r = -0.31$), however the correlation did not reach significance [70]. We propose that the reduced levels of these trace elements in offspring hair may be at least partially associated with impaired processing of these elements during pregnancy in obese women. The physiological effect of vanadium is mainly related to its insulin mimetic effects being beneficial in both diabetes and obesity [71]. Correspondingly, obese children were characterized by significantly reduced serum vanadium levels [72]. Strontium is also shown to play a significant role in improvement of insulin sensitivity, as well as in bone physiology [73]. In turn, selenium is essential for various functions due to its role in selenoproteins. Particularly, selenium plays a significant role in brain development, mediating the immune-thyroid interplay [74]. Selenium also has an impact on glycemic control [75] although high Se exposure may disrupt insulin signaling through modulation of redox environment [76]. Molybdenum deficiency, although being rather rare in humans, is also known to be associated with brain dysfunction [77]. The observed findings of impaired metabolism of vanadium, selenium, and strontium all playing a role in carbohydrate metabolism in children of obese women are in agreement with the experimental observation of insulin resistance in adult offspring from obese ewes [78].

Limitations

The present study has a number of limitations that should be addressed in further studies. First, nutritional intake of trace elements and minerals was not assessed in pregnant women. Monitoring of maternal diet could indicate whether the observed changes in hair trace elements and mineral content are associated with insufficient dietary intake or increased excretion of the elements. Second, data on serum and urine levels of the studied elements would be beneficial in order to elucidate the mechanisms of the observed group differences. Third, in this study, analysis of hair was performed in children at 9 months. This allowed to investigate the impact of maternal weight not only during gestation, but also breastfeeding. However, the absence of hair analysis at delivery precludes disentangling effects of prenatal environment and breast feeding from potential influence of postnatal environmental factors. Finally, the sample size was relatively small and unequal for the two groups. As the study is ongoing, in the future we plan to replicate and extend our findings in a bigger sample.

Conclusions

The results demonstrated that maternal overweight status is associated with impaired hair trace element and mineral content in both mothers and their children. Specifically, overweight pregnant women were characterized by significantly reduced Cr and Zn content alongside elevated hair Na and K levels. Their children had lower Mo, Se, and V levels, and increased Sr content in hair, as compared to the control values. It is possible that impaired trace element and mineral metabolism provides an additional link between maternal overweight and complications of pregnancy and postnatal development. Hypothetically, dietary improvement may be used as a tool to reduce these risks. However, further experimental and clinical studies are required to investigate the complex relationship between weight and trace element metabolism in pregnancy.

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Compliance with Ethical Standards

The present study was performed in agreement with the principles of the Declaration of Helsinki and its later amendments. The protocol of the study was approved by the Ethics Committee for Interdisciplinary Investigations (Tomsk State University, Russia) (project No. 8.1.11.2018). All women participated in the investigation on a

voluntary basis and were informed about the objectives and procedures of the study. The women signed informed consent for their own and their children's participation. Hair sampling procedures involving children were performed in the presence of one of the parents.

Conflict of interest

The authors declare no conflict of interest

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Table 1. Demographic and obstetric characteristics of the examined women with normal and excessive body mass index

Parameter	Normal weight (n = 104)	Overweight (n = 55)	P value
Age, years	32.5±4.0	33.0±5.3	0.151
Pre-pregnancy height, cm	166.0±5.7	166.0±5.8	0.972
Pre-pregnancy weight, kg	58.0±6.3	77.5±11.2	< 0.001 *
Pre-pregnancy BMI	21.0±1.7	28.1±3.7	< 0.001 *
Age of menarche, years	13.2±1.3	12.6±1.2	0.014 *
Age of first sex, years	18.7±2.5	17.9±2.0	0.043 *
Use of Fe supplements, %	43%	35%	0.288
Special diet	13%	24%	0.118
First pregnancy	44%	25%	0.021 *
Number of pregnancies	2.3±1.5	2.5±1.2	0.235
Planned pregnancy	85%	91%	0.268
Anemia	61%	53%	0.481
Thyroid pathology	19%	39%	0.839
Data expressed as mean ± SD or % (% is indicative of the respective number of women with particular characteristics from the total number of women in the group); * Significant difference at p < 0.05.			

Table 2. Prenatal monitoring of fetal condition in normal weight and overweight pregnant women

Parameter	Normal weight mothers (n = 104)	Overweight mothers (n = 55)	P value
Chronic hypoxia	10%	16%	0.568
Risk of spontaneous abortion			
I trimester	27%	49%	0.043 *
II trimester	33%	37%	0.700
III trimester	26%	29%	0.804
Whole pregnancy	13%	31%	0.121
PaPP, IU/L	3.361 (2.203 - 4.829)	2.258 (1.048 - 4.317)	0.012 *
hCG, IU/L	59.5 (37.6 - 78.2)	35.0 (20.4 - 55.4)	0.004 *
Data expressed as Median (IQR) or % (% is indicative of the respective number of women with particular characteristics from the total number of women in the group); * Significant difference at $p < 0.05$.			

Table 3. Children's health at delivery in relation to maternal body mass index

Parameter	Normal weight mothers (n = 104)	Overweight mothers (n = 55)	P value
Gender, F/M (%)	46/54	64/36	0.115
Pregnancy duration, wk	39.2±1.6	38.9±2.5	0.825
Cesarean section	38%	49%	0.316
Apgar score 1, pts	8.2±0.5	8.1±0.6	0.375
Apgar score 5, pts	9.0±0.6	8.8±0.6	0.265
Body weight, g	3349.1±535.8	3261.5±898.7	0.954
Height, cm	52.3±2.8	52.5±4.3	0.319
Head circumference, cm	34.3±1.5	34.3±2.4	0.714
Chest circumference, cm	33.6±2.0	33.8±3.0	0.388
Data expressed as mean ± SD or % (% is indicative of the respective number of women with particular characteristics from the total number of women in the group); * Significant difference at p < 0.05.			

Table 4. Hair essential trace element and electrolyte levels in normal weight and overweight women ($\mu\text{g/g}$)

Element	Normal weight mothers (n = 104)	Overweight mothers (n = 55)	P value
Ca	1947.9 (1143.6-3222.0)	1561.2 (813.0-2631.4)	0.193
Co	0.019 (0.009-0.056)	0.015 (0.009-0.028)	0.151
Cr	0.098 (0.052-0.166)	0.074 (0.043-0.118)	0.047 *
Cu	13.66 (11.05-21.75)	14.99 (11.25-24.45)	0.333
Fe	16.85 (9.07-32.94)	12.44 (9.08-21.17)	0.079
I	0.307 (0.193-0.514)	0.323 (0.215-0.482)	0.739
K	92.2 (44.2-190.3)	188.1 (106.0-573.4)	< 0.001 *
Mg	113.2 (75.2-198.9)	99.2 (59.3-221.5)	0.608
Mn	0.919 (0.468-1.704)	0.767 (0.558-1.39)	0.994
Mo	0.022 (0.016-0.027)	0.021 (0.016-0.03)	0.921
Na	73.3 (43.2-133)	113.8 (70.1-267.4)	0.002 *
P	162.3 (146.2-178)	164 (148.5-200.9)	0.256
Se	0.423 (0.328-0.483)	0.376 (0.261-0.486)	0.255
Si	32.6 (19.71-45.46)	26.36 (16.06-39.18)	0.141
Sr	6.937 (4.089-11.518)	6.393 (3.097-11.205)	0.645
V	0.010 (0.005-0.024)	0.007 (0.005-0.014)	0.177
Zn	229.2 (190.7-303.6)	198.2 (152.0-246.0)	0.008 *
Data expressed as Median (IQR); * Significant difference at $p < 0.05$.			

Table 5. Essential trace elements and minerals in hair of children of normal weight and overweight women ($\mu\text{g/g}$)

Element	Normal weight mothers (n = 104)	Overweight mothers (n = 55)	P value
Ca	324.4 (239.5-438.7)	341.0 (259.7-565.0)	0.233
Co	0.009 (0.006-0.017)	0.008 (0.005-0.014)	0.337
Cr	0.182 (0.125-0.302)	0.152 (0.105-0.263)	0.242
Cu	10.43 (7.97-12.90)	9.922 (8.019-12.740)	0.800
Fe	13.95 (10.02-20.13)	13.73 (9.34-18.34)	0.596
I	0.804 (0.449-1.390)	0.605 (0.430-1.036)	0.176
K	869.5 (349.7-1644.4)	687.4 (330.4-1691.4)	0.815
Mg	19.43 (15.41-28.39)	23.15 (17.49-29.47)	0.101
Mn	0.319 (0.226-0.475)	0.334 (0.242-0.524)	0.689
Mo	0.050 (0.033-0.066)	0.041 (0.026-0.055)	0.017 *
Na	275.8 (133.2-627.3)	334.4 (135.0-703.0)	0.366
P	160.2 (131.0-185.9)	158.0 (135.8-176.0)	0.794
Se	0.469 (0.400-0.540)	0.433 (0.368-0.483)	0.043 *
Si	25.05 (14.65-51.43)	30.46 (18.44-59.00)	0.410
Sr	0.800 (0.565-1.187)	0.955 (0.734-1.629)	0.025 *
V	0.021 (0.012-0.055)	0.016 (0.007-0.040)	0.028 *
Zn	67.22 (43.84-111.86)	84.03 (51.62-118.99)	0.219
Data expressed as Median (IQR); * Significant difference at $p < 0.05$.			

Table 6. Correlation between maternal and children's hair trace elements and minerals

Element	General cohort (n = 159)	Normal weight (n = 104)	Overweight (n = 55)
Ca	-0.086	-0.095	-0.255
Co	0.171 *	0.110	0.745 *
Cr	-0.048	-0.064	-0.071
Cu	0.514 *	0.084	0.803 *
Fe	-0.082	-0.107	0.019
I	0.121	0.072	0.431 *
K	0.049	0.045	0.048
Mg	-0.109	-0.089	-0.176
Mn	0.241 *	0.279 *	0.303 *
Mo	-0.020	-0.025	-0.003
Na	0.180 *	-0.003	0.435 *
P	-0.056	-0.006	-0.141
Se	-0.026	-0.077	0.052
Si	0.036	0.061	0.009
Sr	-0.079	-0.083	-0.145
V	0.088	0.071	0.160
Zn	0.006	-0.007	0.089
Data expressed as correlation coefficient (r); * - correlation is significant at p < 0.05			

Table 6. Correlation between maternal hair trace element and mineral content and pre-pregnancy BMI values

Element	General cohort (n = 159)	Normal weight (n = 104)	Overweight (n = 55)
Ca	0.006	-0.012	0.167
Co	0.040	0.093	0.173
Cr	-0.143	-0.188	0.095
Cu	0.021	-0.085	0.067
Fe	-0.097	-0.083	0.376 *
I	-0.080	-0.014	-0.071
K	0.336 *	0.056	0.068
Mg	0.073	0.019	0.154
Mn	-0.003	-0.080	0.158
Mo	-0.021	0.075	0.122
Na	0.212 *	-0.015	0.090
P	0.131	0.127	-0.076
Se	-0.092	-0.050	0.018
Si	-0.025	-0.103	0.277 *
Sr	-0.065	-0.083	0.171
V	-0.204 *	-0.237 *	-0.105
Zn	-0.162 *	-0.215 *	0.044

Data expressed as correlation coefficient (r); * - correlation is significant at $p < 0.05$