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Minerals in the diet of adolescents aged 15

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ABSTRACT

Introduction. Studies which focus on the supply of minerals in the diet of adolescents show that the diet is deficient in such macroelements as calcium and magnesium and such microelements as copper, zinc, iodine and iron. Inadequate supply of minerals may increase the risk of development of diet related diseases at a mature age.

Material and Methods. The questionnaire on the consumption of food products consumed every day for the period of 7 days was filled in by the person conducting the survey. The needs for minerals were defined individually for every child with reference to recommended dietary allowance.

Results. The norm of daily sodium intake among 15-year-old adolescents was exceeded in all tested groups, however, in the group of boys sodium intake was at a higher level than in the group of girls. Potassium intake in the group of both girls and boys did not reach the recommended daily value, whereas the recommended daily consumption of manganese was exceeded twice. In all tested subjects, the ratio of calcium to phosphorus was very low. In the group of girls who are underweight, daily consumption of iron did not cover 50% of the demand.

Conclusions. Inadequate supply of minerals recorded in all tested 15-year old subjects, regardless of their BMI, may lead to developmental disorders and diet related diseases at a mature age.

Keywords: children, food, nutrition, malnutrition, minerals.

Introduction

Minerals, in addition to basic nutrients, play an important role in the diet of children, adolescents and adults. Adequate supply of nutrients conditions proper development of the human organism [1]. Research on nutrition of adolescents shows that their diet is characterised by many errors, especially related to the nutritional and energetic value of meals and to the content of minerals in the diet [2]. Proper nutrition in the period of adolescence is particularly important as it conditions the predisposition to learn at school at the same time having impact on the occurrence of diseases at a later age. The main errors in nutrition of adolescents include unbalanced nutrient consumption, too high supply of fats and sugars and too low consumption of complex carbohydrates, fibre, calcium, magnesium, iron and certain vitamins [3]. Another important problem concerning the diet of adolescents aged 13–15 is too high consumption of sodium which leads to cardiovascular diseases in adolescence and at a later age may be the cause of strokes [4]. Excessive consumption of manganese also has adverse effects on human organism as it may lead to the development of dementia, schizophrenia or exacerbate

symptoms of Parkinson's disease, its deficiency may destabilize DNA and decrease the synthesis of proteins [5].

Studies which focus on the supply of minerals in the diet of adolescents show that the diet is deficient in such macroelements as calcium and magnesium and such microelements as copper, zinc, iodine and iron [3]. Iodine deficiency in diet may lead to the occurrence of mental retardation and inhibit growth of the organism. Deficiency in some minerals may be associated with the occurrence of excessive body weight [5]. Inadequate supply of minerals may increase the risk of development of diet related diseases at a mature age [6].

Aim

The aim of the study was to assess daily intake of selected minerals depending on BMI value in the diet of selected adolescents aged 15.

Research subjects and method

The study was conducted in the Spring of 2017 in a representative middle school in the city of Bielsko-Biała. All third grade students were included in the study.

Participation in the study was voluntary. In total 133 students aged 15 (57 girls and 76 boys) were included in the study. Measurement of body mass and height of all of the students was taken and the BM value, classified in accordance with WHO and US Department of Health and Human Services and U.S. Department of Agriculture was calculated. BMI below 5 percentile — underweight, BMI between 5 and 85 percentile — appropriate body mass, overweight — BMI between 85–95 percentile and obesity — BMI value above 95 percentile [7, 8].

The questionnaire on the consumption of food products consumed every day for the period of 7 days was filled in by the person conducting the survey. In order to determine the amount of minerals consumed, the size of the portion was verified with the use of „The Album of Photographs of Food Products and Dishes" [9] and the DIETA FAO programme containing information about 1067 typical food products. A detailed description of the study was included in earlier publications. The needs for minerals were defined individually for every child with reference to recommended dietary allowance. Obtained mean intake values were compared with nutrition standards for people with moderate physical activity defined by the United States Department of Agriculture as well as with *Normy żywienia dla populacji polskiej (Nutrition Standards for Polish Population)* [8, 10].

The analysis was performed with the following software: PQStat 1.6.4; PSPP 0.10.4; MS Office 2013 (RS for Excel), "R". The analyzed variables were measured on nominal and quantity scales. Materiality level p in all analyzes was < 0.05. Normality of the variable distribution was verified using Shapiro-Wilk's test. If variables were other than normal, the nonparametric Kruskal-Wallis test was used. For qualitative variables the $\chi 2$ test was applied and – in the case of failure to meet its objectives – the exact Fisher's test.

Ethical Consideration

The study was approved by the Ethics Committee of the University of Bielsko-Biala (No: RNN/10/2017) which is in accordance with the Declaration of Helsinki. All participants gave their informed consent to taking part in the research, participation in this study was voluntary and anonymity of participants was preserved.

Adolescents participating in the study were divided into groups according to gender and BMI values. Among boys the groups were as follows: BMI below 5th percentile, BMI between 5th and 85th percentile and BMI between 85th and 95th percentile. Among girls the groups were as follows: BMI below 5th percentile, BMI between 5th and 85th percentile and BMI above 95th percentile (**Table 1**).

Results

In the tested group of 15-year-olds 68.4% (n = 39) of girls and 65.8% (n = 50) of boys had correct BMI value. In 8.8% (n = 5) of girls cases of obesity were recorded and in 15.8% (n = 12) of boys - cases of overweight. Cases of underweight were more frequently observed in the analyzed group of young people. Underweight occurred in a similar number of girls (n = 13) and boys (n = 14) (**Table 1**).

The analysis of the intake of selected minerals demonstrated that in all groups of girls and boys, regardless the BMI value, there were cases of both shortage and excessive intake of minerals (**Table 2** and **3**).

Table 1. Presentation of the studied groups of boys and girls

Percentile BMI	Below 5		Percentile 5-85		Percentile 85-95		Above 95		Total	
	n	%	n	%	n	%	n	%	n	%
Boys	14	18.4%	50	65.8%	12	15.8%	-	-	76	100%
Girls	13	22.8%	39	68.4%	-	-	5	8.8%	57	100%
Total	27	20.3%	89	66.9%	12	9%	5	3.8%	133	100%

In all groups of boys excessive intake of zinc (12.28–16.4 mg) and manganese (4.68–5.55 mg) as well as insufficient intake of magnesium (297–370 mg) and potassium (2054–3436 mg) was recorded. In the case of sodium the recommended daily intake was exceeded more than three times and amounted to 4475–5303 mg.

In all groups of boys daily intake of phosphorus exceeded daily demand and amounted to 1334–1654 mg, while daily intake of calcium amounted to 535–828 mg and covered only 41–64% of the daily demand (**Table 2**). An important element in nutrition is maintaining a proper ratio of calcium to phosphorus. The ratio of daily intake of calcium to phosphorus in the group of boys with underweight was 0.5:1, in the group of boys with normal body weight it was 0.4:1 and in the group of boys with overweight the ratio was 0.37:1. Statistically significant differences were observed in the intake of minerals between the group of boys with various BMI values. In the group of boys with underweight the intake of potassium, calcium, magnesium and manganese did not cover the recommended daily intake, yet, in spite of this, it was the highest compared to the group of boys with normal weight and overweight – the differences were statistically significant. In all groups of boys the recommended daily intake of manganese was more than double and the difference in the intake between the group of boys with underweight and the group of boys with overweight was statistically significant. In the analyzed groups of boys the intake of iron covered daily demand, in the case of iodine intake daily demand was covered in the diet of boys with normal body weight (**Table 2**).

In all groups of girls an excessive intake of zinc (9.55–11.14 mg) and manganese (3.52–3.85) and insufficient intake of potassium (2513–2621 mg) and magnesium (239.23–258.06 mg) were reported. The intake of sodium (2309–3655 mg) in the group of girls exceeded daily demand, however, it was not as high as in the group of boys (**Table 2** and **3**).

Table 2. Illustration of the median and IQR of daily consumption of selected minerals in the tested groups of boys divided according to the BMI value

Studied variable and unit	Group A BMI below 5 percentile Median (IQR)	Group B BMI 5-85 percentile Median (IQR)	Group C BMI 85 – 95 percentile Median (IQR)	Statistical significance	Recommended dietary allowance RDA
Sodium (mg)	4810.60 (3230.23–6390.98)	4475.19 (4119.64–5852.99)	5303.81 (4208.61–5303.81)	No	1500 mg
Potassium (mg)	3436.92 (3138.54–3735.31)	3344.34 (2616.90–4013.62)	2054.57 (2054.57–2632.53)	Yes A and C; B and C	4700 mg
Calcium (mg)	828.89 (696.40–961.38)	571.85 (496.66–1000.80)	535.91 (295.33–535.91)	Yes A and C; B and C	1300 mg
Phosphorus (mg)	1654.42 (1493.79 - 1815.05)	1334.76 (1244.87–1628.39)	1437.65 (1098.53–1437.65)	Yes A and B; A and C	1250 mg
Magnesium (mg)	370.96 (318.64–423.27)	326.57 (271.06–359.97)	297.67 (272.268–297.67)	Yes A and C; B and C	410 mg
Iron (mg)	12.51 (11.34–13.68)	13.75 (13.67–16.44)	13.59 (11.60–13.59)	No	12 mg
Zinc (mg)	14.907 (13.22–16.59)	12.28 (11.35–14.06)	16.40 (12.61–16.4)	Yes A and B; B and C	11 mg
Copper (mg)	1.28 (1.12–1.44)	1.23 (1.20–1.83)	1.04 (1.04–1.05)	Yes A and C	0.9 mg
Manganese (mg)	5.55 (4.13–6.98)	5.09 (3.51–6.45)	4.68 (3.80–4.68)	Yes A and C	2.2 mg
Iodine (µg)	138.94 (111.19–166.68)	154.29 (126.75–212.74)	147.56 (122.83–147.56)	No	150 µg

(mg – milligram, µg – microgram)

Table 3. Illustration of the median and IQR of daily consumption of selected minerals in the tested groups of girls divided according to the BMI value

Studied variable and unit	Group D BMI below 5 percentile Median (IQR)	Group E BMI 5–85 percentile Median (IQR)	Group F BMI above 95 percentile Median (IQR)	Statistical significance	Recommended dietary allowance RDA
Sodium (mg)	2309.58 (2309.58–3135.59)	3655.49 (3135.59–4801.52)	3655.49 (3065.79–4209.75)	Yes D and E; D and F	1500 mg
Potassium (mg)	2621.74 (2513.62–2621.74)	2550.24 (2513.62–2586.86)	2513.62 (2365.10–2857.76)	No	4700 mg
Calcium (mg)	656.68 (623.34–656.68)	499.19 (499.19–623.34)	574.34 (496.38–627.02)	Yes D and E	1300 mg
Phosphorus (mg)	993.06 (993.06–1106.25)	1121.33 (1106.25–1376.99)	1106.25 (1043.12–1294.75)	Yes D and E; D and F	1250 mg
Magnesium (mg)	258.06 (239.23–258.06)	254.72 (239.23–311.45)	239.23 (214.93–279.89)	No	360 mg
Iron (mg)	7.16 (5.89–7.16)	22.00 (5.89–26.71)	14.05 (6.730–22.00)	Yes D and E; D and F	15 mg
Zinc (mg)	9.55 (5.11–9.55)	10.690 (5.11–10.69)	11.14 (5.85–11.36)	Yes D and F	9 mg
Copper (mg)	1.15 (0.80–1.15)	0.89 (0.80–1.01)	0.88 (0.82–0.96)	Yes D and E; D and F	0.9 mg
Manganese (mg)	3.85 (1.96–3.85)	3.52 (1.96–3.52)	3.66 (2.32–4.22)	Yes D and E	1.6 mg
Iodine (µg)	89.27 (89.27–218.47)	104.33 (104.339–218.47)	168.82 (50.67–216.35)	No	150 µg

(mg – milligram, µg – microgram)

In the group of girls with underweight and girls with normal body weight insufficient intake of iodine (89.27–104.33 µg) was observed. Daily intake of phosphorus (993–1121 mg) as well as of calcium (499–656 mg) did not cover the daily demand. However, in the case of calcium intake the demand was not covered even in 50% (**Table 3**). Among girls the most beneficial ratio of calcium to phosphorus (0.66:1) in the diet was observed in the group of girls with underweight. In the group of girls with normal body weight the ratio of calcium to phosphorus was 0.44:1, whereas in the group of girls with obesity 0.52:1.

In a group of girls with underweight very low iron intake (7.16 mg) was observed, it did not cover even 50% of the recommended daily intake. Statistically significant differences in the intake of minerals between the particular groups of girls were demonstrated. They included unfavourable differences concerning phosphorus and iron intake in the group of girls with underweight. In other cases of statistically significant differences minerals intake in the group of girls with underweight was the highest compared to the other groups of girls (**Table 3**). Manganese intake in the group of girls exceeded the recommended daily intake, but it was not at such a high level as in the group of boys (**Table 2** and **3**).

Discussion

A diet which is properly balanced in terms of nutrition and energy, with particular emphasis on minerals, is an element ensuring proper physical and mental development of children and adolescents [2]. Both excess and shortage of minerals can adversely affect health.

Studies by Wielgos et al. assessing the coverage of minerals demand in Polish adolescents in the region of Lesser Poland demonstrated that sodium intake norm was exceeded 6 times both in the group of boys and girls. After being converted to salt, the obtained results amounted to 6.8 g for girls and 7.9 g for boys. The sodium came mostly from sodium chloride contained in bread, salty snacks and meat preparations [6]. American research on a group of adolescents aged 2–18 demonstrated that daily intake of sodium increased with age, and in the group of 12- to 18-year-old adolescents it amounted to 3545 ± 79 mg per day [4]. The norm of intake was exceeded more than three times. Such an amount of sodium corresponds to 9 grammes of salt.

In the authors' own research similar average daily sodium intake in all analyzed groups of boys (regardless of the BMI value) was observed. In the group of girls sodium intake was not at such

a high level as in the group of boys, however, it also exceeded the recommended daily intake. The lowest daily intake of sodium was reported in the group of girls with underweight (2309 mg), and this difference, compared to a group of girls with normal weight and with obesity, was statistically significant. Higher intake of sodium connected with higher weight values was reported by Haidong et al. leading research on a group of adolescents aged 14–18 in the State of Georgia [11]. According to Grimes et al., higher sodium intake causes intense thirst which contributes to increased consumption of sugar-sweetened beverages (SSBs) connected with the occurrence of overweight [4]. Consumption of sweetened beverages every day increases the risk of overweight by more than 60% compared to consumption of sweetened beverages once a week [12].

Epidemiological studies proved that high intake of sodium is associated with an increased risk of cardiovascular diseases and in particular with the occurrence of arterial hypertension. High intake of sodium combined with low intake of potassium may contribute to the occurrence of elevated values of blood pressure. Low intake of potassium initiates mechanisms leading to its retention in the organism, with simultaneous retention of sodium. Due to water retention sodium leads to an increase in the amount of circulating blood and to increased blood pressure. A diet rich in potassium is related to the occurrence of lower blood pressure [3, 13].

The analysis of the authors' own materials demonstrated that average daily consumption of potassium in the group of both girls and boys did not reach the recommended daily value of 4700 mg. Similar results were achieved by Italian researchers – estimated average daily intake of potassium among children aged 2–18 was lower than the recommended in more than 96% of boys and 98% of girls [14]. Maintenance of proper values of blood pressure is also dependent on the proper amount of consumed calcium. Calcium plays a major role in muscle contractility and vascular tension. Calcium is an important element of the skeleton structure. Adolescence is a period during which peak bone mass is achieved. Achieving high peak bone mass in this period to a large extent prevents osteopenia and osteoporosis in old age. To achieve a proper bone mass phosphorus is also necessary. An inadequate ratio of calcium to phosphorus in the diet, which in the case of children should be at least 1.2:1, results in impaired bone transformation [3, 15].

Examining the consumption of calcium in Polish girls aged 13–15, Czeczuk et al determined that despite an increased content of this element in the diet, its supply is still low [16]. Wang at al demonstrated that the percentage of insufficient consumption of calcium is still very high (> 96%) [17].

Authors own research demonstrated that average daily consumption of calcium in the group of girls (656 mg) and boys (828 mg) with underweight was statistically higher than in the other groups of adolescents, nonetheless, it did not satisfy the daily demand of 1300 mg. An improper ratio of calcium to phosphorus was also observed. The most appropriate ratio was noted in the analysed groups with underweight - which was 0.5:1 for boys, and 0.66:1 for girls. An improper ratio of calcium to phosphorus is connected with the risk of resorptive mechanisms in bones [3, 15].

The recommended daily consumption was not achieved in the studied group in the case of iron. Iron consumption by girls did not even satisfy 50% of the demand. Studies by Wang at al conducted on the group of Chinese adolescents aged 4–17 demonstrated that consumption of minerals increases with age. Consumption of iron was changing over time and in the group of boys aged 14–17 the percentage related to inadequate intake of iron significantly increased, however, an increase up to 30.8% in the percentage was observed in girls. The symptoms occurring in girls, caused by decreased consumption of iron, are additionally strengthened during menstruation. Low consumption of iron, even in the absence of anaemia, results in slower growth, lower immunity to infections, reduced cognitive abilities and in hormonal imbalance. The associated overall fatigue impairs efficiency of learning [18].

Polish studies which were carried out on high school students from the region of Mazovia divided into two age groups (16–18 years old and 19 years old) showed that sodium intake exceeded the Estimated Average Requirement (EAR), at the same time, insufficient consumption of calcium, potassium and iron was observed. Insufficient iron intake was reported in the case of the group of 19-year-old adolescents, in the younger group (16–18 years old) daily intake of iron covered the EAR, which was 8 mg [2]. In the authors' own research the recom-

mended daily intake of iron was defined according to RDA which is 12 mg for boys and 15 mg for girls. If compared to the EAR level, iron intake in the tested group would cover the recommended consumption in the authors' own research. In the case of sodium, calcium and potassium comparison of EAR and RDA values did not show such large differences as in the case of iron.

Magnesium deficiency significantly affects development and, at the same time, leads to aggravation of ADHD (Attention Deficit-Hyperactivity Disorder) symptoms in children. It is believed that insufficient intake of magnesium plays an important role in etiology of cardiovascular diseases, diabetes and thyroid diseases [19].

According to the authors' own research, consumption of magnesium in the group of boys was at a higher level than in the group of girls, however, it did not cover the daily demand in any of the tested groups. In the group of girls with underweight and normal body weight, insufficient intake of iodine was also recorded. Reduced intake of iodine might be caused by reduction of salt intake, however, this was not observed in the tested groups as the sodium intake norm in both tested groups of girls was exceeded.

Iodine is essential for proper functioning of thyroid and synthesis of hormones influencing proper growth and development of the body. Insufficient consumption of iodine results in development of thyromegaly, which is connected with the occurrence of hypothyroidism. Iodine deficiency in children may lead to inhibition of growth and mental development as well as to cretinism [20].

Research conducted in Australia revealed that iodine deficiency concerned 14.8% of adolescents aged 14–18. Despite introduced mandatory iodine fortification of salt used in bread there are differences in the consumption of iodine in the diet, which is caused, inter alia, by insufficient consumption of bread [21]. In Poland, owing to the Minister of Health Decree of 1997, an obligation to iodize salt for direct consumption was introduced. This obligation does not apply to salt used in food processing.

American studies conducted among adolescents aged 13–19, which were to determine the relation between the concentration of minerals in blood and the occurrence of obesity, demonstrated that an increase in manganese concentration in blood was related to obesity in the tested adolescents [5]. According to the authors' own research, the recommended daily intake of manganese in the group of boys, regardless of the BMI value, was exceeded more than twice. In the group of girls the recommended daily intake of manganese was also exceeded more than twice in all tested groups. It should be noted, however, that recommended daily intake of manganese in the group of boys is 2.2 mg and is higher than in girls (1.6. mg). Consumption of manganese was statistically much higher in the group of adolescents with BMI which was an indication of overweight, than it was in the other groups. The current state of knowledge does not allow to demonstrate a link between the consumption of manganese, an increase in its concentration in blood and the occurrence of overweight. Nonetheless, manganese is known to play an important role in the metabolism of carbohydrates, proteins and lipids [5].

There exists a correlation between the consequences associated with deficiency and excess of minerals and the occurrence of metabolic disorders. The risk related to deficiency in minerals increases with consumption of highly processed food. In addition, the risk is even higher due to insufficient knowledge about the right choice of nutrients and balancing diet.

Summary

The norm of daily sodium intake among 15-year-old adolescents was exceeded in all tested groups, however, in the group of boys sodium intake was at a higher level than in the group of girls. Potassium intake in the group of both girls and boys did not reach the recommended daily value, whereas the recommended daily consumption of manganese was exceeded twice. In all tested subjects, regardless the BMI value, the ratio of calcium to phosphorus was very low. In the group of girls who are underweight, daily consumption of iron did not cover 50% of the demand, whereas in the group of girls with underweight and appropriate body weight a relatively low consumption of iodine was recorded.

Conclusions

1. Inadequate supply of minerals recorded in all tested 15-year old subjects, regardless of their

BMI, may lead to developmental disorders and diet related diseases.
2. Existing nutrition errors in the diet of adolescents point to the need to introduce educational programmes about rational nutrition addressed both at adolescents as well as their caregivers. .

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Conflict of interest statement
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