

DETERMINING LEVELS OF MINERAL CONSUMPTION FROM FOODSTUFF SOURCES IN THE DAILY DIETS OF ADOLESCENT STUDENTS LIVING IN KAMIEŃ POMORSKI. A PILOT STUDY

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ABSTRACT

Background. In recent years, changes to adolescent life style and nutrition are becoming increasingly apparent. One of the ways in which this can be observed, is in an unbalanced daily intake of dietary minerals, where some intakes are in excess whilst others are deficient. Normal growth and development can thereby become adversely affected.

Objective. To determine daily dietary intake levels of calcium, magnesium, phosphorus, sodium, potassium, iron, zinc and copper together from their various foodstuff sources in the daily diet of a defined group of adolescents.

Material and methods. Subjects were adolescents aged 16-19 years attending the technical college at the Polish town of Kamień Pomorski; being under the jurisdiction of the Western Pomeranian Province (voivodship). The study tool was a survey of food that had been consumed within the last 24 hours, from which the amounts of mineral elements in any given menu, so chosen, could thus be estimated.

Results. Average daily potassium intakes were found to be generally low; less than 2350 mg and 1800 mg respectively for girls and boys compared to recommended values. This was coupled with high sodium intakes, where respectively, girls and boys exceeded recommended values by 2.1 and 2.8 times. Excess intakes of phosphorus, iron and copper were also observed in boys; respectively 500 mg, 4 mg and 2 mg. Some subjects showed insufficient intakes of calcium and magnesium i.e. 63%-80% below EAR (Estimated Average Requirements). The main source of calcium was found to be ripe cheeses, milk and fermented beverages. In both groups the main dietary sources of magnesium, sodium, iron and copper were bread. Girls diets showed that phosphorus and zinc mostly came from eating ripe cheeses and poultry, whereas potatoes were the main source of potassium. The boy's daily dietary intakes demonstrated that phosphorus and zinc originated from eating bread and potatoes. Significantly lower amounts of phosphorus, sodium, iron and zinc were however consumed by girls compared to boys.

Conclusions. The mineral content of the subjects' daily diet was found to be substantially unbalanced.

Key words: *nutrition, adolescents, minerals, consumption, daily diets*

STRESZCZENIE

Wprowadzenie. Od pewnego czasu obserwuje się zmiany w stylu życia i sposobie żywienia młodzieży. Wyraża się to m.in. niewłaściwym zbilansowaniem całodziennych racji pokarmowych (crp) w odniesieniu do składników mineralnych. Niektóre spożywane są w nadmiarze, natomiast inne w niedostatecznej ilości. Fakt ten może mieć negatywny wpływ na przebieg procesów wzrostowo-rozwojowych.

Cel. Celem badań była ocena wielkości spożycia wapnia, magnezu, fosforu, sodu, potasu, żelaza, cynku i miedzi i ich źródeł w całodziennych racjach pokarmowych młodzieży.

Material i metody. Badania wykonano w grupie młodzieży uczącej się w Kamieniu Pomorskim (województwo zachodniopomorskie), w wieku 16-19 lat. Do badań wykorzystano metodę wywiadu o spożyciu z ostatnich 24 godzin. Zawartość pierwiastków w jadłospisach określono metodą obliczeniową.

Wyniki. Na podstawie uzyskanych wyników stwierdzono zbyt niskie spożycie potasu (u dziewcząt średnio o 2350 mg a u chłopców o 1800 mg mniejsze od zaleceń) a nadmierne – sodu (u dziewcząt przekroczenie ilości zalecanej 2,1 razy, u chłopców – 2,8 razy). Pewne nadmiary występowały również w przypadku fosforu, żelaza i miedzi, w grupie chłopców (kolejno, średnio o 500 mg, 4 mg i 2 mg). U części osób podaż wapnia i magnezu była niewystarczająca (63%-80% osób ze spożyciem poniżej poziomu EAR). Głównym źródłem wapnia w żywieniu ankietowanej młodzieży były sery podpuszczkowe dojrzewające oraz mleko i napoje fermentowane. W obu grupach uczniów pieczywo dostarczało największych ilości magnezu, sodu, żelaza i miedzi. W jadłospisach dziewcząt fosfor i cynk pochodziły w przewadze z serów dojrzewających

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oraz mięsa i drobiu a potas z ziemniaków. W crp chłopców najwięcej fosforu i cynku dostarczały pieczywo i ziemniaki. Dziewczęta spożywały istotnie mniej fosforu, sodu, żelaza i cynku niż chłopcy.

Wnioski. Całodzienne racje pokarmowe badanej młodzieży były niewłaściwie zbilansowane pod względem zawartości większości analizowanych pierwiastków.

Słowa kluczowe: żywienie, młodzież, składniki mineralne, spożycie, całodzienne racje pokarmowe

INTRODUCTION

In order to ensure that adolescent development proceeds in a manner conducive to health, adequate nutrition and energy intake are necessary which includes having an appropriate intake of minerals. The latter falls into the category of exogenous elements that need to be supplied on a daily basis via the diet. These constitute some of the basic cellular building blocks, they form important elements of cells, body fluids, enzymes, hormones, are involved in oxygen transport, regulating nervous and muscular excitatory states and in maintaining water-electrolyte homeostasis and acid-base balance. A dietary mineral deficiency in adolescents leads to abnormal development and health disorders. In addition, it constitutes some of the risk factors for the early appearance of the so called diseases of civilisation (e.g. diabetes, hypertension, osteoporosis etc) [3, 13, 20, 23, 29]. There are many reasons for shortcomings found in the diet of adolescents, some of which are as follows: inadequate knowledge about nutrition, socio-economic status, the toll exacted from a day's schedule and after school activities, eating fads, advertising, stress, pre-formed eating habits and food preferences as well as the influence of peers [29]. In terms of fulfilling adequate dietary requirements, it is thus important that mineral intakes and their sources are taken into account.

The study aims were to determine whether dietary intake levels of the chosen minerals, as well as their sources, were sufficiently adequate for the normal/standard dietary requirements of adolescents receiving technical education in a typical town of north western Poland.

MATERIAL AND METHODS

Studies were carried out during winter (December 2010 - January 2011) on volunteer students attending technical college and studying nutrition/dietetics at the town of Kamień Pomorski, (Western Pomeranian Province). There were 72 subjects (45 girls and 27 boys) aged 16-19 years. Subjects were interviewed to assess their daily diet (menu) with the aid of a specially designed photograph album [27], allowing the amounts of food consumed to be determined. Data so

obtained, enabled the calorific value of the daily diet to be estimated together with its content of protein, fat, carbohydrates, calcium, magnesium, phosphorus, sodium, potassium, iron, zinc and copper. Calculations were performed via the 'Dieta 4D' computer programme designed at the Warsaw Food and Nutrition Institute (IŻŻ). Results were compared to the recommended daily allowances for human nutrition [12]. A group of 17 basic foodstuffs providing key mineral elements to the diet were also defined.

The χ^2 and *Kolgomorov-Smirnoff* tests showed that the intake data were not normally distributed within the boy and girl groupings. Thus, in this instance, the non-parametric *Mann-Whitney U* test was used to assess the significance of differences between them. The statistical package used was the STATISTICA 10 (Statsoft 2011) programme [26]. A probability level of $p < 0.05$ was adopted as showing significant differences.

RESULTS

At 62.5% females formed the majority in the subject group reflecting the college's educational profile. The contents of the daily diet was varied and are shown in Tables 1 and 2. The mean dietary calorific value and intakes of fat and carbohydrates were found to be inadequate (Table 1). The calorific intake deficiencies were around 990 kcal for girls and 1340 kcal for boys compared to recommendations. Mean protein intakes were however somewhat excessive, especially in boys where the RDI (Recommended Daily Intake) were exceeded by about 30 g. Girls' daily diets had lower calorific values, protein content, fats and carbohydrates than boys (Table 1).

Mineral intakes were rather high in sodium; girls and boys being respectively 2.1 and 2.8 times the recommended values as shown in Table 2. Excesses in phosphorus, iron and copper intakes were also observed in boys, respectively; over 500 mg, 4 mg and 2 mg. Bread was found to be the main source of sodium of 23.7% - 34.9% (Tables 3 and 4), followed in descending order in girls by cold meats, meat and poultry, whilst in boys by cold meats and potatoes. Milk and dairy products were the main source of phosphorus in the boys' daily diet, whilst bread was the main source of iron and copper in all subjects; respectively 20.7% - 28.3% and 20.0% -

Table 1. The energy value and intakes of fat and carbohydrates in the daily diets of pupil subjects

Dietary component	Girls (n=45)					Boys (n=27)				
	Median	Minimum	Maximum	25% Quartile	75% Quartile	Median	Minimum	Maximum	25% Quartile	75% Quartile
Calories (kcal)*	1455.3	804.3	4271.7	1116.3	2016.6	1886.4	661.4	6355.2	1604.3	3086.1
Protein (g)*	63.8	26.1	191.8	50.8	89.0	85.1	28.1	261.9	67.7	127.7
Fats (g)*	57.7	13.3	159.3	32.7	85.2	93.9	25.9	258.7	53.9	145.4
Carbohydrate (g)*	215.1	87.5	544.8	139.9	287.0	284.4	86.5	799.7	182.5	352.0

* statistically significant between genders (p<0.05)

Table 2. The mineral composition of the daily diets in pupil subjects

Mineral component (mg)	Girls (n=45)					Boys (n=27)				
	Median	Minimum	Maximum	25% Quartile	75% Quartile	Median	Minimum	Maximum	25% Quartile	75% Quartile
Calcium	755.9	106.3	2795.6	452.4	1011.5	885.7	222.6	4649.3	446.4	1255.4
Magnesium	221.4	91.1	501.7	156.4	305.3	287.4	107.8	719.0	174.2	382.1
Phosphorus *	1031.2	358.0	2946.3	837.9	1422.4	1347.6	569.5	4408.1	972.0	1983.5
Sodium *	3233.1	1434.9	6178.2	2749.7	4181.3	4235.6	1273.0	8637.3	3320.0	6660.0
Potassium	2344.4	891.1	5501.5	1645.3	3097.6	2884.4	1048.1	8757.4	1879.6	4219.7
Iron *	8.0	2.6	40.8	6.4	9.8	11.4	2.6	32.0	7.1	16.7
Zinc *	7.9	2.8	16.3	5.7	10.5	11.3	3.3	25.9	8.8	14.6
Copper	0.9	0.3	2.4	0.6	1.1	1.0	0.3	3.3	0.7	1.6

* statistically significant between genders (p<0.05)

Table 3. Percentage share of foodstuffs contributing to the mean daily dietary intakes of minerals in female pupil subjects

Foodstuff	Calcium	Magnesium	Phosphorus	Sodium	Potassium	Iron	Zinc	Copper
Bread	3.6	17.4	10.5	23.7	13.2	20.7	17.2	20.0
Flour and pasta	0.1	0.6	0.4	1.5	0.4	0.7	0.5	0.4
Cereals, rice and breakfast cereal	1.6	9.6	4.7	10.5	3.7	11.2	7.1	8.0
Potatoes	0.7	12.4	5.6	12.2	22.1	6.6	4.0	10.7
Vegetables	2.7	4.0	2.1	1.9	8.4	5.8	3.7	6.7
Pulses	-	-	-	1.0	-	-	-	-
Fruit	3.2	8.0	1.9	2.1	11.5	5.9	2.0	12.0
Milk and fermented beverages	29.1	9.8	13.9	3.7	10.0	3.3	6.0	5.3
Cream cheese	2.0	1.3	3.8	1.0	1.4	0.8	2.0	0.9
Ripe cheese	43.8	5.5	19.8	9.4	2.1	3.4	11.3	2.7
Poultry	3.8	17.4	18.8	13.2	15.5	19.1	26.3	12.0
Cold meats	1.5	5.3	10.3	17.6	6.9	9.4	11.0	12.0
Fish	-	-	-	-	-	-	-	-
Eggs	1.0	0.9	2.9	0.7	0.7	4.1	3.6	0.9
Animal fat	0.8	0.4	0.6	0.1	0.3	0.2	0.3	0.8
Vegetable fat	-	-	-	0.1	-	-	-	0.1
Sugar and sweets	6.0	7.5	4.5	3.7	3.7	8.9	4.9	8.0

26.7%. Smaller sources of iron were also provided by meat and poultry, whilst for copper these were meat and meat products for girls and potatoes for boys.

In boys, dietary zinc mostly originated from bread at 26.2% but from meat and poultry for girls 26.3%. All subjects showed somewhat low potassium intakes with girls averaging about 2350 mg less than AI values (Adequate Intake), and boys 1800 mg less; the main source of potassium being potatoes (22.1% - 27.6 %). Many subjects, (63% - 80%), showed low intakes of magnesium and calcium that were below the EAR (Tables 2 and 5). Dietary calcium was mostly derived from milk and dairy products (29.1% - 43.8%), and magnesium

from bread, potatoes, meat and poultry (17.4% - 27%) (Tables 3 and 4). Girls consumed significantly less phosphorus, sodium, iron and zinc than boys (Table 2).

DISCUSSION

The importance of assessing nutrition in adolescents are widely recognised from many reasons. For example, inappropriate daily diets can lead to disorders in the rate of development and worsening health in later adult life. Monitoring nutrition can become socially significant, particularly in areas of high unemployment where nutritional

Table 4. Percentage share of foodstuffs contributing to the mean daily dietary intakes of minerals in male pupil subjects

Foodstuff	Calcium	Magnesium	Phosphorus	Sodium	Potassium	Iron	Zinc	Copper
Bread	5.5	27.0	19.2	34.9	12.2	28.3	26.1	26.7
Flour and pasta	1.0	1.1	1.2	1.3	1.1	1.3	1.0	1.2
Cereals, rice and breakfast cereal	0.4	2.7	2.5	4.7	1.3	3.0	2.6	2.7
Potatoes	1.1	17.5	8.2	17.5	27.6	8.9	5.7	16.2
Vegetables	2.7	3.1	1.5	0.9	5.3	4.7	2.3	6.7
Pulses	-	-	-	-	-	-	-	-
Fruit	2.5	7.4	1.9	0.1	16.3	5.4	2.4	8.1
Milk and fermented beverages	29.3	10.8	14.6	2.8	10.9	2.7	6.9	5.4
Cream cheese	4.6	1.4	6.8	0.5	2.0	0.7	3.4	2.7
Ripe cheese	36.4	3.8	13.8	7.5	0.9	2.7	8.6	2.7
Poultry	1.0	5.0	4.6	2.0	3.6	13.1	15.6	6.7
Cold meats	2.7	5.8	10.0	19.4	7.4	9.3	12.0	6.7
Fish	0.1	1.1	1.0	1.3	1.1	0.6	0.4	0.4
Eggs	2.0	1.7	5.4	2.2	1.5	7.2	5.7	1.3
Animal fat	1.6	0.5	0.7	0.1	0.6	0.4	0.4	0.9
Vegetable fat	-	-	-	0.2	-	-	-	0.3
Sugar and sweets	9.1	11.0	8.5	4.5	6.9	11.7	6.9	10.8

Table 5. Dietary intakes of minerals in studied subjects as compared to EAR reference values

Mineral component (mg)	Girls (%)	Boys (%)
	< EAR	< EAR
Calcium	80.0	63.0
Magnesium	64.4	63.0
Phosphorus	28.9	18.5
Zinc	44.4	25.9
Copper	28.9	25.9

quality may be inferior. The province of Western Pomerania is just such an example especially for the smaller towns. This was the reason why the small town of Kamień Pomorski was selected; having around 9000 inhabitants.

The calorific content of diets forms one the more important indicators of nutritional value. The study however found this to be low. Such outcomes can disrupt growth and development in the young as well as retard both learning or in performing extracurricular activities, for instance sport. Other studies have likewise demonstrated insufficient calories in a daily adolescent diet. This calorific deficiency was observed in high school pupils from Szczecin, middle school pupils from Białystok and girls from boarding schools [8, 18, 20, 25]. Such a dietary deficiency of energy intake may be due to not eating enough meals or an inappropriate dietary content, for example in the amounts of fats and carbohydrates as shown by pupils from Zambrów [18] and both pupils [20] and students [25] from Szczecin. Low dietary fat intakes can decrease unsaturated fat consumption and water soluble vitamins present in fats, carbohydrates and especially fibre [20, 25]. Dietary protein was however found to be higher than normal, particularly in the boy subjects. This finding is widespread for male adolescents as confirmed by the following studies: *Falkowska et al.* [8], *Mierzwa et al.* [20] and *Markiewicz-Żukowska* [18].

The presented study showed that median intakes of sodium were high. This element is vital in regulating water/electrolyte balance, blood pressure, acid/base equilibrium and in nerve transmission. Excess intakes of sodium are however frequently recorded, as is typical of western diets, which can thus adversely affects many different population groups, including adolescents [2, 18, 20, 24, 25, 34]. Extensive studies from the medical literature demonstrate that an excess of sodium leads to hypertension, circulatory disorders, increased risk of cardiac stroke and premature death [15, 22, 28]. Many countries have therefore launched educational programmes targeted at a wide audience which depend on teaching the health risks caused by excess dietary salt and the content of salt in marketed or favourite foodstuffs, particularly in various ethnic groups [15, 22, 28].

A rather high intake of dietary copper was also observed. This element plays a significant role in the action of various metallo-enzymes such as oxidases, (e.g. Cytochrome C oxidase). It is involved in collagen synthesis, secretion of noradrenalin, protection against free radicals and helps prevent cardiovascular disease through regulating cholesterol metabolism. An excess of dietary copper may however be toxic by generating reactive oxygen species which include hydroxyl radicals. These may attack DNA, leading to mutation and thereby affecting cancerogenesis; cancer patients having higher serum copper concentrations than normal, healthy individuals [6]. Adolescent consumption data on copper are rather variable; some show an excess [18, 20, 34], whilst others a deficiency [7, 25]. The current study found that above all else, dietary copper came from bread in contrast to vegetables (31%) seen from another study on adolescents living in Warsaw aged 16-18 years [7]; here bread was the secondary copper source at 29%.

Dietary iron is a very important nutrient for adolescents especially so for girls. However, iron intake deficiencies have in fact been noted in many countries, including Poland [6, 7, 18, 25, 34], where children and adolescent females are the most susceptible [6, 16]. Iron is indispensable for transporting oxygen throughout the body, it is involved in the synthesis of carnithine, collagen, various neurotransmitters and in the development of immunological immunity. Iron deficiencies may give rise to anaemia (this is widespread in developing countries), lowers physical fitness/capacity, weakens muscles and leads to fatigue and apathy.

The presented study in fact demonstrates that iron intakes are raised compared to those recommended. It is also often seen that an excess intake of iron can be due to adopting a diet enriched with this element. A dietary excess of iron can lead to disorders of the circulation and cancer where in the latter case this may arise from the generation of reactive oxygen species as similar to copper. In addition, damage to various tissue is also observed [16, 35]. The studied subject's diet revealed that bread was the main dietary source of iron followed by meat and poultry. As a result, the question now arises of whether the usually hitherto observed meat sources of dietary iron excess has now been replaced by bread in the diet of adolescents in Poland. A dietary excess of phosphorus and zinc was also observed in the male subjects of the study. The former is vital for maintaining the proper structure of bone and teeth, together with regulating acid/base balance, cardiac and renal function, cellular development and renewal, as well as ATP synthesis and in protein activation. In Poland, a dietary excess of phosphorus in adolescents has been previously noted [18, 20, 25], and which may give rise to bone maturation/development disorders (especially when combined with calcium or Vitamin D deficiencies), in cardiac and parathyroid function. As is also illustrated in the previous case, an excess of phosphorus in the diet can arise from processed foodstuffs enriched with supplements.

The daily intake of zinc has been shown to greatly vary in Poland, where recommended levels are often exceeded in both directions. Such has been observed in the male study subjects, consistent with other studies like Mierzwa et al. [20], Wolnicka and Taraszewska [34] and in females by Markiewicz-Żukowska et al. [18]. Other similar studies have demonstrated a dietary insufficiency of zinc [7, 19, 20, 24, 25]. Zinc actually constitutes a vital dietary element. It is necessary for the function of various enzymes, including those in DNA and RNA synthesis, plays a vital role in cell division, foetal development and in attaining adequate growth. Zinc is also necessary for immunological immunity and insulin metabolism together with its affects on gene expression. Due to its antioxidant properties and in stabilising cellular membranes, zinc affords protection against oxidised polyunsaturated fat compounds and

from inflammatory cytokines as well being a dietary atherosclerosis factor [11]. Excess intakes of dietary zinc are not usually toxic, however raised levels can result in copper deficiency and gastro-intestinal problems.

The greatest deficiency in mineral elements was seen with potassium, as has been consistently recognised in the literature, coupled to a frequently observed excess intake of sodium. Sources of potassium are usually vegetables and fruit whose consumption amongst most of the population is insufficient [28]. Such lacks in potassium intake as demonstrated in the current study are consistent with the following studies: Schenkel et al. [24], Seidler and Szczuko [25], Mierzwa et al. [20], Markiewicz-Żukowska [18] and Wolnicka and Taraszewska [34]. Potassium together with sodium takes part in muscle contraction, maintaining cellular water integrity, regulating blood pressure and furthermore it is necessary for the proper functioning of the nervous system and also of gastric secretion.

Potassium deficiency may lead to low blood pressure that may cause fatigue, insomnia and irregular heart rhythm. When coupled with raised levels of dietary sodium, there is an additional decrease in the body's potassium levels. In keeping somewhat with traditional diets in Poland, potatoes were the main dietary source of potassium reflecting an insufficient consumption of fruit and other vegetables.

Magnesium and calcium deficiencies were also found in some study subjects, being especially pronounced in females. During the time of the body's intensive growth, such lowered levels are particularly detrimental. Calcium is the essential building block of bones as well as being vital in enzyme activity, nervous transmission, muscle contraction, hormone secretion, blood coagulation and in regulating cardiac function. Deficits in dietary calcium result in its being mobilised from bones, thus leading to osteoporosis (of which women are especially prone to), whereby the risk of bone fracture are increased together with decreased growth rates in children [9, 21]. In addition, excessive intakes of sodium and protein can arise through calcium intake deficiencies [21, 31]. Such calcium deficiencies are widespread in the diets of Polish adolescents [18, 20, 25, 34] which is likewise seen in other countries [9, 23, 24]. The presented study in fact shows that the observed calcium deficiencies fall within those of other population groups. It has been found that decreased consumption of milk and dairy products are the main cause of these calcium deficits. Indeed USA studies have demonstrated that it is practically impossible to fulfil the daily dietary requirement of calcium by omitting milk and dairy products. Furthermore, diets that are poor in these foodstuffs also show deficiencies in other nutritional components such as Vitamin D, riboflavin, Vitamin B12 and magnesium [9, 23, 25].

Magnesium is present mainly in bones and the intracellular fluid. It is a vital part of many enzyme complexes, is indispensable for maintaining cellular membrane function, plays a key role in metabolism and endothelial function in blood vessels, and stabilises both protein and nucleic acid structure [33]. Magnesium deficiency leads to neuro-muscular hypersensitivity, increased risk of atherosclerosis, cardiac arrhythmia, hypertension, type II diabetes, decreased immune response and increased oxidative damage in the heart, erythrocytes, endothelia and in neurons [1, 4, 5, 10, 14, 17, 32, 33]. This deficiency arises from relying on eating food that has been highly processed, drinking water with a low magnesium content and when overall food intake is low [5]. Population studies have demonstrated that significant numbers of children in Central Europe suffer from low magnesium levels [30]. The current study has shown that magnesium intakes in its pupil subjects are similar to those of adolescents in other regions of Poland [18, 20 25, 34].

In summary, the presented study has found that the mineral content of pupil's diets from Kamień Pomorski were not properly balanced. Both excesses and deficiencies were observed. Such findings can negatively affect growth and development. Greater care in ensuring more effective education about nutrition is thus indicated and for motivating adolescents to take responsibility for their own health.

CONCLUSIONS

1. The dietary content of most mineral elements was found to be unbalanced.
2. Potassium intakes were deficient and calcium and magnesium intakes were partly so. Sodium intakes were excessive and in many cases were also phosphorus, iron, copper and zinc.
3. Females consumed significantly less phosphorus, sodium, iron and zinc than boys
4. Changes were seen in the dietary sources of some elements compared to those previously used as reference.
5. More effective education on healthy nutrition, targeted at adolescents, is required.

Conflict of interest

The authors declare no conflict of interest.

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