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Nutritional deficiencies and their changes in the diet of adolescents after 2000. The Warsaw Adolescents Study

Niedobory składników odżywczych po roku 2000 w dietach młodzieży w wieku pokwitania. Warszawskie Badanie Młodzieży

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Summary

Introduction. During adolescence eating habits are acquired which continue in the established form throughout adult life. To shift them into pro-health direction, recommendations should be formulated on the basis of understanding current nutritional mistakes.

Aim. The objective of this paper is to identify the prevalence of energy and selected nutrient deficiencies in adolescents' diet, and to analyse the directions of changes occurring between 1999/2000 and 2005/2006.

Material and methods. Cross-sectional studies of randomly selected samples of 11-15 year old adolescents from Warsaw area were carried out two times at an interval of 5 years. Nutrition of pupils was evaluated through interviews concerning food intake during the past 24 hours before the study. "Album of products and meals of diverse portion sizes" was used to evaluate the amount of food eaten. Contents of energy, minerals and vitamins were calculated using DIETA 4.0 Computer Software which takes into account nutrient losses resulting from the technology applied to prepare products and meals for eating. To assess the prevalence of deficient diets with reference to Polish Dietary Standards (Normy Żywienia) (2008), a probability evaluation method was applied in accordance with US IOM recommendations. To evaluate the prevalence of reduced body weight, the BMI index and international classification developed by Cole et al. (2007) were used.

Results. During the five-year period, the prevalence of reduced body weight increased slightly to 13.9% among girls and decreased to 6.4% among boys. A simultaneous increase in the prevalence of diets deficient in energy, protein and carbohydrates was found. The most common dietary deficiencies in adolescents, between 74% and 98% students, are calcium, vitamin D, potassium, magnesium and folates. The prevalence of deficiencies in such nutrients as vitamin E, C, A, B₁₂, PP, B₁, B₂, B₆, iron, iodine, zinc and phosphorus was also high. After five years, the percentage of deficient diets increased for nearly all nutrients analysed.

Conclusions. Frequent occurrence of multiple mineral and vitamin deficient diets and increase in their prevalence after the five-year period indicate the need for integrating health consideration and dietary goals by all professionals responsible for nutrition of adolescents.

Key words: adolescents, underweight, nutrients, intake, deficiencies

Streszczenie

Wstęp. W wieku młodzieńczym nabywane są nawyki żywieniowe, które w utrwalonej formie są kontynuowane w życiu dorosłym. Aby je skutecznie zmienić w prozdrowotnym kierunku, zalecenia powinny być formułowane na podstawie znajomości aktualnych wad żywienia.

Cel. Celem niniejszego opracowania jest zidentyfikowanie w diecie młodzieży częstości występowania niedoborów energii i wybranych składników odżywczych oraz analiza kierunków zachodzących zmian między latami 1999/2000 a 2005/2006.

Materiał i metody. Przekrojowe badania losowo wybranych prób młodzieży w wieku 11-15 lat z terenu Warszawy, przeprowadzono dwukrotnie w odstępie 5 lat. Żywność uczniów oceniono metodą wywiadu o spożyciu w ostatnich 24 godzinach poprzedzających badanie. W ocenie ilości spożytej żywności, wykorzystano „Album produktów i potraw o zróżnicowanych wielkościach porcji”. Zawartość energii, składników mineralnych i witamin wyliczono za pomocą programu komputerowego DIETA 4.0, który uwzględnia straty składników odżywczych wynikające z zastosowanych technologii przyrządzania do spożycia produktów i potraw. Do oceny częstości występowania diet niedoborowych w stosunku do Norm Żywienia Człowieka (2008), wykorzystano metodę oceny prawdopodobieństwa, przeprowadzoną zgodnie z rekomendacjami IOM USA. Do oceny występowania niedoborowej masy ciała zastosowano wskaźnik BMI i międzynarodową klasyfikację, opracowaną przez Cole i wsp. (2007).

Wyniki. W okresie pięciu lat częstość występowania niedoborowej masy ciała uległa niewielkiemu zwiększeniu do 13,9% u dziewcząt i zmniejszeniu do 6,4% u chłopców. Stwierdzono równoczesny wzrost występowania diet niedoborowych w energię, białko i węglowodany. Najczęściej występujące niedobory w dietach młodzieży: w wapń, witaminę D, potas, magnez i foliany dotyczyły od 74 do 98% młodzieży. Niedobory składników, takich jak wit. E, C, A, B₁₂, PP, B₁, B₂, B₆, żelazo, jod, cynk i fosfor również występowały z dużą częstością. Po upływie pięciu lat odsetek diet niedoborowych zwiększył się niemal we wszystkich analizowanych składnikach odżywczych.

Wnioski. Częste występowanie diet niedoborowych w wiele składników mineralnych i witamin oraz wzrost ich częstości po upływie pięciu lat, wskazuje na konieczność podejmowania zintegrowanych działań, uwzględniających prozdrowotne elementy zaleceń żywieniowych w działaniach edukacyjnych, skierowanych do wszystkich specjalistów zajmujących się żywieniem młodzieży.

Słowa kluczowe: młodzież, niedobory masy ciała, dieta

INTRODUCTION

Puberty is a transitional period between childhood and young adulthood. It is a time of big changes in young bodies, not only morphological and physiological, but also resulting from young people's lifestyle. Adolescents eat more products and meals away from home, including products of high energy and low nutrient content, such as sweetened soft drinks and sweets (1, 2). At the same time, adolescents' participation in physical activity decreases with increasing age. Boys' participation in physical activity away from school decreases by 20% between the 11th and 15th year of life (3). HBSC studies also showed that deficiency in physical activity increased by more than 10% in the same age range (4).

Although over the past thirty years nutrition of adolescents generally improved, since the level of energy from fat, in particular from animal fat, decreased and the intake of plant fat increased, and cholesterol intake decreased, at the same time after 2000 an increase in nutritional status disorders was observed. A threefold increase in overweight and obesity among boys and a tenfold increase among girls were found (5), particularly intense after 2000. The percentage of pupils with reduced body weight decreased minimally and oscillates between 6% to 9% of boys and 13% to 14% of girls (6).

The year 2000 is a turning point as regards the state of health of the Polish people, since after a gradual improvement following 1991 this tendency slowed down (7). Nutritional mistakes in adolescents revealed in 2000 may be important predictors of developing diet-related diseases in adult life. Therefore, a question arises as to in which direction the intensification of nutritional risk factors for developing diet-related diseases after 2000 changes in this demographic group.

AIM

The objective of this paper is to identify the prevalence of energy and selected nutrient deficiencies in adolescents' diet, and to analyse the directions of changes occurring between 1999/2000 and 2005/2006.

MATERIAL AND METHODS

Data analysed in this paper come from the cross-sectional study among adolescents during periadoles-

cence (11-15 year olds), carried out several times in randomly selected samples from the entire Warsaw area. Analyses in terms of the occurrence of nutritional deficiencies were carried out as a part of the last two studies conducted in 1999/2000 and 2005/2006 (tab. 1).

Table 1. Number of pupils examined in particular years. The Warsaw Adolescent Study.

Years of examinations	Randomly chosen	Examined	Response rate (%)
1999-2000	1526	1136	74.4
2005-2006	1884	1054	55.9
Total	3410	2190	65.5

Nutrition status of pupils was evaluated through interviews concerning food intake during the past 24 hours before the study in accordance with the recommended methodology (8, 9). This method enables to evaluate the intake of all products, including enriched food, meals, drinks and food supplements by pupils.

Interviews were conducted with each pupil individually by professional nutritionists. To evaluate the amount of food eaten, „Album of products and meals of diverse portion sizes” was used (10).

Contents of energy, minerals and vitamins were calculated using proprietary computer software which takes into account subsequent amendments to the food composition and nutritional tables, and nutritional standards. DIETA 4.0 Software 2009 (11) that has been developed recently includes new food composition and nutritional tables in its databases (12) and amended Polish Dietary Recommended Standards (13). Nutrient losses resulting from the technology of product and meal preparation for eating have been taken into account in DIETA 4.0 Software, which means that the values provided in tables relate to the amount of food actually consumed with losses deducted.

To evaluate the prevalence of diets deficient in energy and selected nutrients, a probability method proposed by IOM – Institute of Medicine U.S.A. (14) was applied and adopted to Polish conditions.

Anthropometric measurements of height and body weight were performed in accordance with the requirements of the methodology (e.g. 15). Data concerning

the value of relative body weight index, Body Mass Index – BMI = body weight in kg: height in m², were used in this paper. To evaluate the prevalence of underweight, the BMI index and international classification developed by Cole et al. (16) were used.

RESULTS

The prevalence of reduced body weight

As results from data (fig. 1) presented after the five-year follow up in an adolescent population, a decrease in the percentage of reduced body weight was found – by 1.5% among boys, and increase by 0.3% among girls (p > 0.05). However, in both studies the percentages of girls with underweight reflecting the risk for protein-energy malnutrition were higher (13.6% and 13.9%) compared to boys (7.9% and 6.4%).

Nutritional standards (DRI) recommend relating reduced body weight to the evaluation of energy dietary intake (tab. 2). During both periods, the percentages of energy-deficient diets (< EER level – estimated requirement) were higher and increased more (to over 50% among boys and 60% among girls during the last year of the study) than the evaluation of relative body weight (BMI) indicated (fig. 1). It can be confirmed on this basis that energy-deficient diets certainly occur among adolescents, however, their prevalence is probably overstated due to underestimation of products rarely consumed or high-energy products, in particular by overweight or obese girls and boys, which is observed in the method applied to evaluate a one day food intake. High percentage of energy-deficient diets also may be related to weight loss diets periodically used by adolescents. HBSC 2002 study showed that nearly every fourth boy and every second girl wanted to lose weight or satisfied this need (17).

The prevalence of diets deficient in selected nutrients

As regards protein, and particularly carbohydrates, percentages of deficient diets (below the level of Estimated Average Requirement – EAR) increased after the five-year follow-up period in the adolescent population (tab. 2), however, their increase was considerably lower compared to the increase in energy-deficient diets.

Table 2. Percentage of diets with energy below the Estimated Energy Requirements (EER) or the Estimated Average Requirements (EAR) for protein and carbohydrates, in adolescents by year of study and gender.

	Boys (11-15 y) 1999/2000	Boys (11-15 y) 2005/2006
% below EER for energy	49.5	53.8
% below EAR for protein	5.4	8.4*
% below EAR for carbohydrates	0.2	1.1*
	Girls (11-15 y) 1999/2000	Girls (11-15 y) 2005/2006
% below EER for energy	50.9	61.8*
% below EAR for protein	16.5	17.7
% below EAR for carbohydrates	2.9	3.8

*significant differences between years of study, p < 0.05

After the five-year follow-up period, the average content of energy and selected nutrients decreased as well, in boys' diets considerably in the case of energy and carbohydrates, and among girls significantly (p < 0.05) in the case of nearly all nutrients except for cholesterol and fibre (tab. 3). Along with the lower content of basic nutrients, nearly all average intake levels for miner-

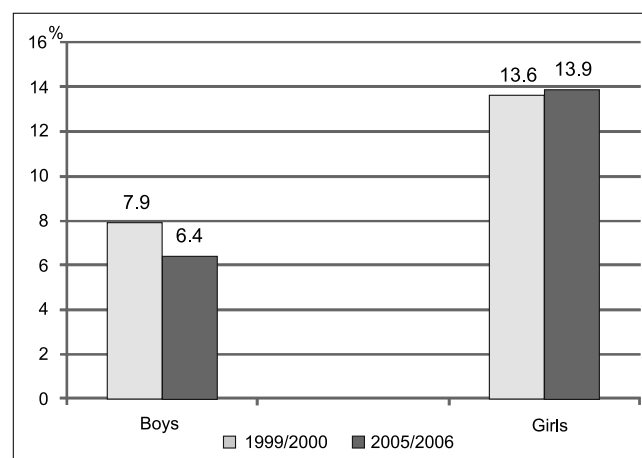


Fig. 1. Frequency of underweight in adolescents aged 11-15 years. The Warsaw Adolescents Study (Cole et al., classification of BMI, 2007).

Table 3. Mean intake (SD) of energy and chosen nutrients by year of study and gender.

Nutrient	Boys 1999/2000 N = 593	Boys 2005/2006 N = 500	Girls 1999/2000 N = 543	Girls 2005/2006 N = 554
	X (SD)	X (SD)	X (SD)	X (SD)
Energy (kcal)	2527 (954)	2405* (932)	1996 (761)	1832* (707)
Protein total (g)	80.9 (34)	77.8 (32)	63.3 (27)	59.1* (25)
Protein g/kg body mass	1.7	1.6	1.4	1.3
Fat total (g)	98.1 (48)	96.0 (47)	74.0 (36)	69.7* (33)
Cholesterol (mg)	261.9 (163)	264.2 (169)	207.1 (133)	198.2 (124)
Carbohydrates total (g)	348.0 (130)	323.5* (123)	283.8 (108)	255.4* (100)
Saccharose (g)	86.6 (49)	84.1 (51)	73.5 (42)	67.2* (39)
Fibre (g)	19.9 (9)	18.0* (8)	16.3 (8)	15.4 (7)

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Fibre (g)	19.9 (9)	18.0* (8)	16.3 (8)	15.4 (7)

*significant differences between years of study, $p < 0.05$

Table 4. Mean intake (SD) of minerals and vitamins by year of study in boys and girls (from foods without supplements).

Nutrient	Boys 1999/2000 N = 593	Boys 2005/2006 N = 500	Girls 1999/2000 N = 543	Girls 2005/2006 N = 554
	X (SD)	X (SD)	X (SD)	X (SD)
Sodium (mg)	4129.7 (1699)	3981.0 (1591)	3189.3 (1402)	3014.8* (1284)
Potassium (mg)	3308.4 (1428)	3117.2* (1395)	2844.5 (1272)	2597.8* (1195)
Calcium (mg)	823.5 (571)	854.5 (550)	676.2 (407)	686.9 (448)
Phosphorus (mg)	1310.2 (572)	1292.9 (552)	1046.2 (444)	1002.0 (428)
Magnesium (mg)	311.1 (128)	285.5* (118)	259.3 (112)	232.8* (100)
Zinc (mg)	11.4 (6)	9.8* (4)	9.4 (6)	7.6* (3)
Iron (mg)	12.6 (7)	11.4* (5)	10.7 (7)	9.1* (4)
Iodine (μg)	148.1 (86)	132.9* (72)	126.4 (78)	107.8* (60)
Vitamin A (μg)	1505 (2091)	1014* (900)	1329 (1802)	916* (961)
Vitamin E (mg)	15.2 (16)	11.57* (7.6)	13.43 (19.9)	9.21* (5.9)
Vitamin B ₁ (mg)	1.687 (1.15)	1.473* (0.75)	1.501 (1.3)	1.109* (0.54)
Vitamin B ₂ (mg)	1.991 (1.17)	1.816* (0.94)	1.802 (1.3)	1.410* (0.69)
Vitamin PP (mg)	18.44 (10.7)	17.61 (9.7)	16.19 (14.2)	12.92* (7.1)
Vitamin B ₆ (mg)	2.26 (1.2)	2.03* (1.1)	2.05 (1.4)	1.56* (0.8)
Vitamin C (mg)	140.8 (141)	104.7* (114)	152.4 (158)	118.2* (127)
Folate (μg)	273.5 (146)	241.2* (108)	243.17 (137.3)	206.9* (99)
Vitamin B ₁₂ (μg)	3.74 (3.3)	3.40 (2.8)	3.29 (3.6)	2.45* (1.9)
Vitamin D (μg)	4.40 (4.9)	3.09* (3.8)	3.84 (4.6)	2.08* (1.7)

*significant differences between years of study (in each gender), $p < 0.05$

als and vitamins decreased during the five-year period both among boys and girls (tab. 4).

The prevalence of mineral and vitamin deficiencies

The average intake values give only the general view on the intake of a particular nutrient since they do not provide any information about the prevalence of extreme values: deficient diets or diets excessive in a nutrient. For evaluation of the nutrient intakes state across the group, it is important to determine the prevalence of deficient diets, which was done in this study using deficiency occurrence probability method (fig. 2, 3). This method (recommended by the US Institute of Medicine (14) reveals the scope of threats to the study group resulting from estimation of dietary deficiency risk.

Figures 2 and 3 show that percentages of deficient diets for nearly all nutrients increased in the last year of study 2005/2006 compared to the period five years before. Order of deficiency levels in particular nutrients also changed. Negative changes included an increase in the percentage of diets deficient in vitamin D, potassium, folates, magnesium and calcium. Admittedly, in the case of calcium deficiency a minimum decrease in the percentage of deficient diets was observed during the last period of the study, but it doesn't change the fact that calcium deficiencies are invariably one of the most common deficiencies among Polish adolescents. Deficiencies in nutrients mentioned above were the most common during both years of the study, and their prevalence was higher than 74%. In the case of diets

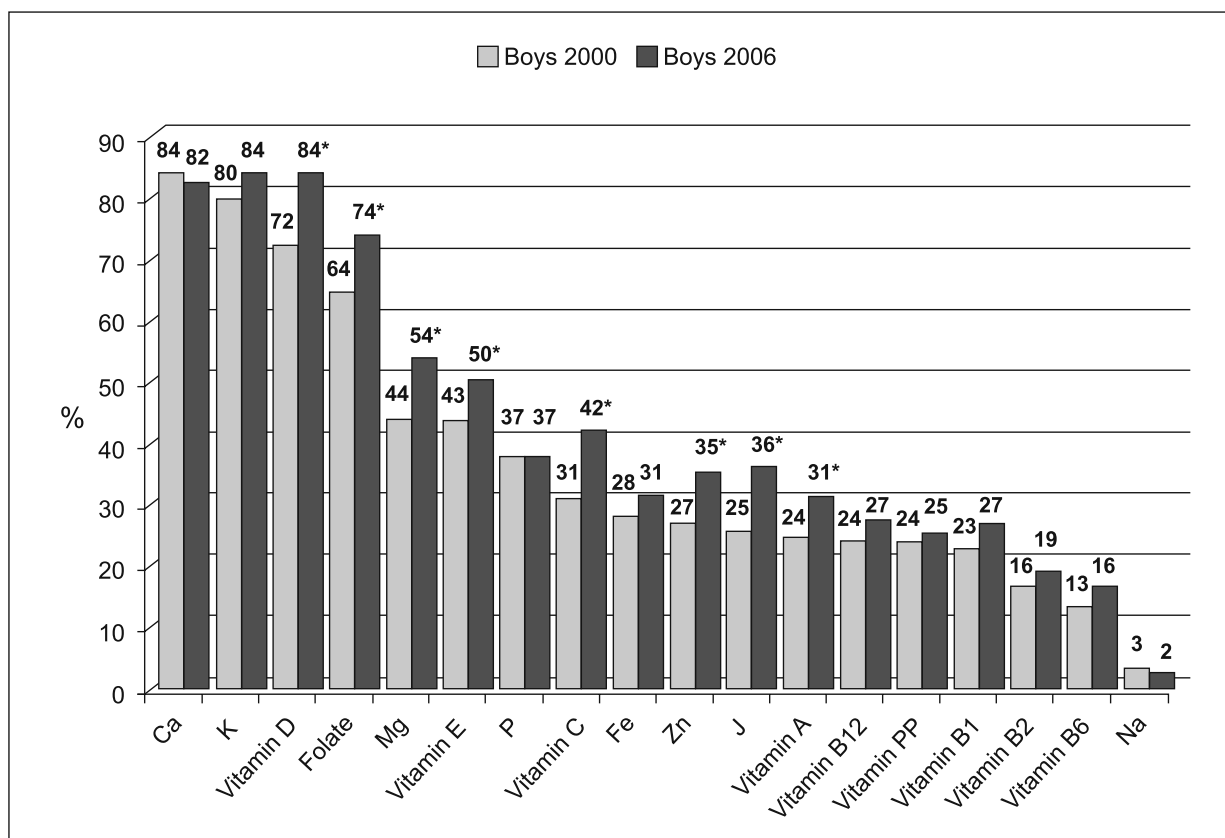


Fig. 2. The percentage of boys with inadequate intake of some vitamins and minerals below EAR (Estimated Average Requirements) calculated using the probability method of the transformed data, from food only without supplements). *significant differences between years of study, $p < 0.05$

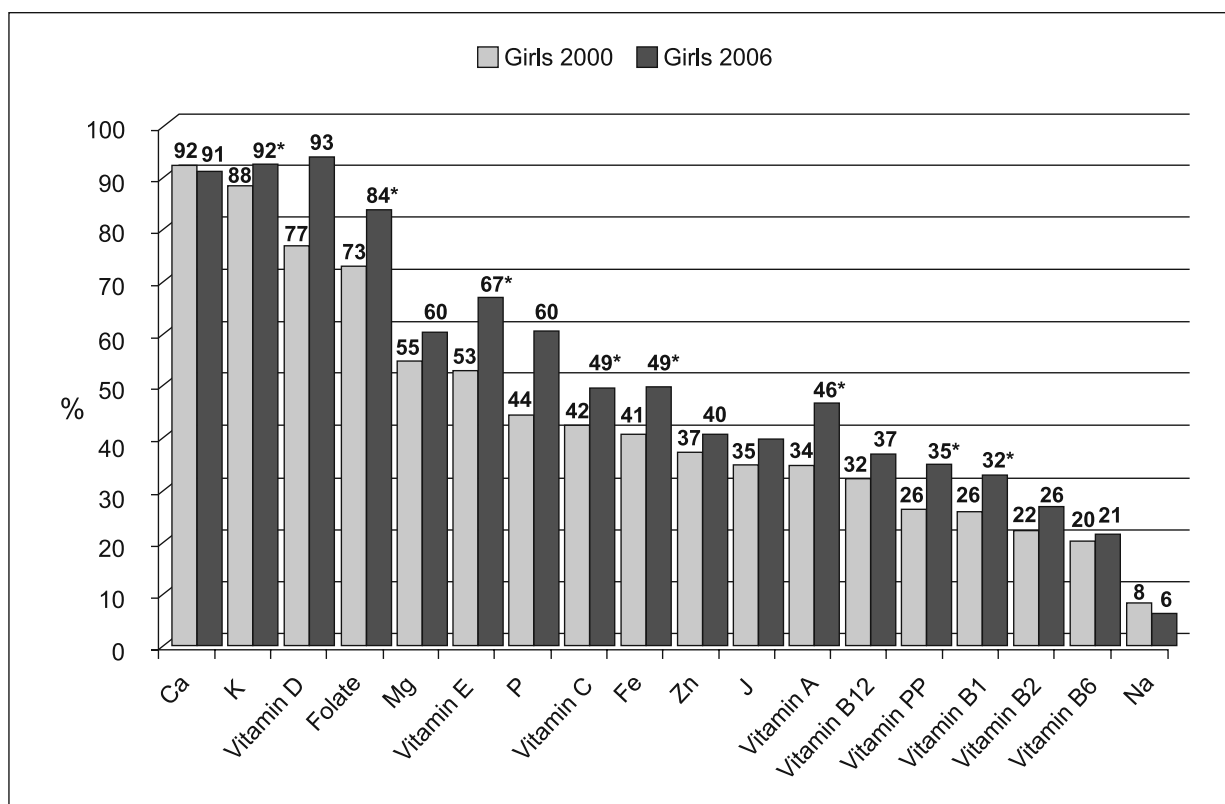


Fig. 3. The percentage of girls with inadequate intake of some vitamins and minerals below EAR (Estimated Average Requirements) calculated using the probability method of the transformed data, from food only without supplements). *significant differences between years of study, $p < 0.05$

deficient in magnesium, iron and iodine, an increase in their prevalence (between 50% and 73%) during the last year of the study is worth noting. The prevalence of deficiencies in the remaining nutrients was lower, below 50% to 16%. Virtually no sodium deficient diets can be observed since the prevalence of such diets was between 2% and 6%, depending on gender.

DISCUSSION OF THE RESULTS

To achieve optimal physical and mental development and to reduce the intensity of risk factors for the development of chronic diseases, adolescents should eat in accordance with modern nutritional standards (Polish DRI 2008) and regularly participate in physical activity to maintain energy balance. However, a decrease in the average energy content throughout the five-year period by 122 kcal among boys and by 164 kcal among girls from Warsaw area did not result in an increase in the percentage of reduced body weight in adolescents which reflects protein-energy deficiency. On the contrary, despite the decrease in the energy value of diets, the percentage of adolescents who were overweight or obese increased in the same period (5). This tendency suggests that a change in lifestyle, including lack of physical activity, rather than excess in energy consumed is the main risk factor for increased obesity among Polish adolescents. A different direction of changes as regards the energy consumed occurred among 11-19 year old girls in the United States, where an increase in energy consumed by 225 kcal was observed between subsequent NHANES I and NHANES III studies (18). Despite such high increase in the average energy value of diets in USA, up to the level of 1989 kcal, this average is lower than as much as 2405 kcal/daily among girls from Warsaw in 2005/2006.

Irrespective of the influence of energy value of diets on body weight, the structure of diet consumed is important as it influences the health status and intensity of the risk of developing diet-related diseases. In other words, a content of minerals and vitamins consumed as a part of the diet is important, which has a specific energy value called nutrient density of a diet. The average nutrient content in diets of adolescents from Warsaw turned out to be lower than in American adolescents of similar age (11-19 year olds) in the case of such nutrients as: calcium, iron, vitamin D, B₂, and folates, whereas the contents of potassium, magnesium, and vitamin A, E, B₆, and C in diets of adolescents from Warsaw were higher (19-21).

Minerals and vitamins are involved in multiple metabolic processes that may inhibit or contribute to the development of chronic diseases. Therefore, the assessment of nutritional risk for the development of diseases is not limited to analyses of the average nutrient content in diets, but the probability of nutritional deficiencies development is evaluated. The results of nutrition analyses among adolescents from Warsaw area raise large reservations due to the high prevalence of deficient diets. The most common deficiencies (54% to

93% of diets) occur in the case of five important nutrients, which are calcium, potassium, magnesium, vitamin D and folates. These deficiencies occurred during both study periods 1999/2000 and 2005/2006, and did not improve after five years. It indicates that durable and adverse eating habits are present in adolescent.

Chronic calcium, magnesium and vitamin D deficiencies during adolescence may result in reduced peak bone mass, which constitute a basic risk factor for the development of osteoporosis in adult life (22). Calcium balance in the body is regulated hormonally by parathormon hormone (PTH), active metabolite of vitamin D – 1.25-dihydroxycholecalciferol and calcitonin. PTH and vitamin D₃ increase gastrointestinal calcium absorption, inhibit its elimination in the urine and release calcium from bones.

Except for essential role in bone tissue, calcium plays considerably bigger role since it is involved in many metabolic processes such as neural conduction, muscle contractility, blood clotting, constitutes an element of hormones and some enzymes, and is important for arterial blood pressure regulation. Calcium deficiencies accompanied by magnesium deficiencies (55% among girls and 67% among girls during 2005/2006) may additionally increase the risk of the development of osteoporosis manifesting through hypocalcaemia and hypokalaemia. High magnesium deficiencies may also result in disorders of neuroskeletal and cardiovascular systems, insulin resistance and insulin secretion impairment.

High prevalence of vitamin D deficient diets is particularly alarming, not only because of its role in the development of healthy bone tissue, but also due to the possibility of pleiotropic actions of vitamin D in many other tissues and organs. After five years, the prevalence of deficient diets increased by 16% among girls, and by 12% among boys from Warsaw area. The percentage of such diets reached respectively 93% and 84%, whereas the number of such diets in American adolescents was lower by a half, in 53% of girls and in 47% of boys in NHANES 2005-2006 (21).

Vitamin D deficiencies in the diets of girls from Warsaw area were confirmed through determinations of serum vitamin D concentrations. The prevalence of insufficient levels (< 50 nmol/l S-25OHD) during the winter season was 87% (23). Insufficient vitamin D nutritional status in Warsaw girls resulted from low vitamin D content in everyday diets, since during years 2005-06 the average dietary intake of vitamin D was 3.1 µg/daily among boys and 2.1 µg among girls, and in the American population it was 5.5 µg and 5.2 µg respectively in NHANES 2005/2006 (21).

Folates were the next nutrient in the case of which the prevalence of deficiencies in the diets of adolescents from Warsaw was high and increased after five years (74% among boys and 84% among girls during 2005/2006). In similar age groups in USA, the prevalence of diets deficient in folates was considerably lower, from 3% to 4% among boys depending on age, and

3% to 19% among girls (19). Common folate deficiencies in diets, and especially the increase in their intensity after the five-year period, raise justified concerns over the health status of adolescents in the future. Health effects that at first manifest through subclinical decrease in the plasma and red cell concentration caused by accompanying increase in homocysteine level, promote the development of cardiovascular diseases, increase cell susceptibility to malignant transformations as a result of RNA and DNA synthesis impairment, can lead to megaloblastic anaemia. During the reproductive period, they may cause congenital neural tube defects.

The last of five nutrients with the highest prevalence of deficiencies was potassium (84% among boys and 92% among girls from Warsaw). Diets deficient in this element were equally common among American adolescents (up to 93%). It is thought that even moderate potassium deficiencies may lead to increased arterial pressure and, as a consequence, to circulatory diseases, brain stroke and bone loss. If potassium deficiency is accompanied by magnesium deficiency, more severe symptoms appear: from hypokalaemia leading to cardiac arrhythmias, decreased muscle strength, central nervous system disorders, to acid-base balance disorders.

Out of other deficient nutrients for which the prevalence is lower, it is worth noting that the prevalence of iodine deficiencies in the diets of adolescents from Warsaw area increased significantly during 2005/2006 up to 36% among boys and 46% among girls. The reasons for it are low consumption of saltwater fish, and probably the effective campaign to reduce the consumption of iodized salt available on the market.

Due to the increased iodine requirement in 13-18 year olds (up to the level of 150 μg according to RDA standard) and the fact that long-term insufficient iodine intake may lead to many disorders called iodine deficiency disorders (IDD), changes in the intensity of dietary iodine deficiencies should be monitored.

CONCLUSIONS

In the case of more than half of adolescent population, probability of insufficient intake of nutrients essential for health was found. The most common deficiencies (50-93% of adolescents) relate to five nutrients: vitamin D, calcium, potassium, magnesium and folates. Deficiencies in the remaining minerals and vitamins that occur in < 50% of adolescents' diets also pose a risk of the negative influence on health of adolescents.

During the analysed period of five years, the increase in the prevalence of diets deficient in nearly all nutrients was noted. It reflects the increase in the consumption of products of low nutritional value by adolescents during the last years. This phenomenon indicates the need for integrating health consideration and dietary goals by all professionals responsible for nutrition of adolescents.

Insufficient contents of minerals and vitamins apply not only to energy-deficient diets, but also to the diets of all adolescents. Since the risk factors for the development of many chronic diseases start to appear in adolescence from even small, subclinical nutrient deficiencies, remedial actions by developing effective partnership are necessary to increase nutrition density of adolescents' diets and to replace food high in empty calories with healthy products.

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