

## RELATIONSHIP BETWEEN THE INTAKE OF ENERGY AND BASIC NUTRIENTS AND THE BMI VALUES IN GROUP OF CHILDREN AGED 10-12

Mirosław Pysz<sup>1\*</sup>, Teresa Leszczyńska<sup>1</sup>, Ewa Cieślik<sup>2</sup>, Aneta Kopeć<sup>1</sup>,  
Barbara Wielgos<sup>1</sup>, Ewa Piątkowska<sup>1</sup>

<sup>1</sup>Department of Human Nutrition, Agricultural University of Krakow, Poland

<sup>2</sup>Department of Nutrition Technology and Consumption, Agricultural University of Krakow, Poland

### ABSTRACT

**Background.** According to the WHO data in January 2007, 14 million children were overweight in the countries of the European Union. The problem of childhood obesity should be considered as one of the biggest challenges facing twenty-first century nutrition and pediatrics.

**Objective.** The aim of this study was to show the correlation between energy, basic nutrients intake and BMI of school children aged 10-12 years, using *Pearson's* correlation coefficient.

**Material and Methods.** 169 pupils (69 from Krakow and 100 from Skawina), aged 10-12, participated in these studies. The studies were approved by the Board of Education, school principals and the parents. On the basis of measurements of weight and height, body mass index (BMI) was calculated. 24 h dietary recalls were collected in the spring and autumn of 2006, for 4 selected days per week.

**Results.** Intake of energy, total carbohydrate and fat did not meet requirements, but intake of protein was too high. Proper weight, based on BMI values in the population aged 10-12, were found in 74.9% of boys and 81.2% of girls. Deficiencies in body weight occurred in 4.2% and 3.4%, overweight in 15.6% and 10.0% while obesity in 5.3% and 5.4% of respondents.

**Conclusions.** Inverse correlation was found between the implementation of standards for energy and BMI values of children. It was observed positive correlation between the consumption of total and animal protein and BMI value.

**Keywords:** children, underweight, obesity, BMI, nutrients, nutrition, *Pearson's correlation coefficient*

### STRESZCZENIE

**Wprowadzenie.** Według danych WHO z 2007 roku, w krajach Unii Europejskiej 14 mln dzieci ma nadwagę. Problem otyłości u dzieci należy uznać za jedno z największych wyzwań stojących przed pediatrią XXI wieku.

**Cel.** Celem badań była próba wykazania korelacji pomiędzy pobraniem energii i podstawowych składników odżywczych a wartością BMI (Body Mass Index) dzieci szkolnych w wieku 10-12 lat, przy wykorzystaniu technik analizy statystycznej.

**Material i metody.** Badania sposobu żywienia i pomiary antropometryczne przeprowadzono wiosną i jesienią 2006 roku, w dwóch losowo wybranych Szkołach Podstawowych na terenie Krakowa i Skawiny. Grupę badawczą stanowiło 169 uczniów (69 z Krakowa i 100 ze Skawiny) w wieku 10–12 lat. Na przeprowadzenie badań uzyskano zgodę Kuratorium Oświaty, dyrekcji szkół oraz zgodę opiekunów każdego z uczniów.

**Wyniki.** Właściwą masę ciała stwierdzono u 74,9% chłopców i 81,2% dziewcząt. Niedobory masy ciała stwierdzono odpowiednio u 4,2% i 3,4%, nadwagę u 15,6 i 10,0%, a otyłość u 5,3% i 5,4% badanych.

**Wnioski.** Stwierdzono odwrotną korelację pomiędzy realizacją normy na energię a wartościami BMI badanych dzieci. Równocześnie zaobserwowano dodatnią korelację pomiędzy wielkością spożycia białka roślinnego i zwierzęcego oraz tłuszczów ogółem a wartościami wskaźnika BMI.

**Słowa kluczowe:** dzieci, nadwaga, otyłość, BMI, składniki odżywcze, żywienie dzieci

### INTRODUCTION

The prevalence of obesity is associated with serious consequences for health and is a major problem in the healthcare system. Overweight and obesity should be

prevented during the different stages of growth, because these problems in children and adolescents may cause serious health problems in the future. It has been proven that obese children aged 10-13 years in adulthood will have a higher risk of obesity than slim children [23].

\*Corresponding author: Mirosław Pysz, Department of Human Nutrition, Agricultural University of Krakow, 122 Balicka street, 30-149 Krakow, Poland; phone: +48 12 662 48 17; fax: +48 12 662 48 12; e-mail: mpysz@ar.krakow.pl

*Must et al.* [19] also found that the prevalence of obesity in children is associated with increased morbidity and mortality after 50 years of age, regardless of the weight of these individuals in adulthood. Serious health consequences of obesity, as well as the rapid increase in the frequency of its occurrence means that it is defined as an epidemic [10, 16]. In recent years the number of children and adolescents with overweight and obesity has increased, particularly in developing and developed countries [21, 25, 37].

According to the WHO data, in January 2007, 14 million children were overweight in the countries of the European Union. The problem of childhood obesity should be considered as one of the biggest challenges facing twenty-first century nutrition and pediatrics [15, 25, 36].

The aim of this study was to show the correlation between energy, basic nutrients intake and BMI of school children aged 10-12 years with the *Pearson's* correlation coefficient test.

## MATERIALS AND METHODS

The study were carried out among 169 pupils (89 girls and 80 boys) aged 10-12, from primary schools located in Krakow (population of city 750 000) and Skawina (population of town 24 000). Studies were approved by the Board of Education, school principals and the parents. Pupils, their parents and teachers were educated on the methods before the research commenced.

Assessment of energy and nutrients intake was performed by 24-h dietary recalls, which were collected in the spring and autumn for 4 selected days per week (including Friday and Sunday, due to different eating habits in Poland).

A face-to-face interview was conducted with each child involved in the study. The size of consumed meals was estimated using pictures from the book "Album of photographs of food products and dishes" [32]. Parents verified the 24-hour dietary recalls. Negative verification resulted in the exclusion from the study. Krakow and Skawina were selected to compare nutritional habits of students from the rural and city areas. Pupils from Skawina were mainly from villages and from Krakow were from this city. Different residence (urban, rural) may suggest different income levels, nutritional education, and various eating habits.

Average daily intake of nutrients and food products, according to gender and season, was calculated using Diet 2.0 software (made by National Food and Nutrition Institute of Warsaw, Poland). Weight was measured by a trained person using a Digital Scale (Radweg Radom, Poland). Weight was measured in kilograms with an accuracy of 100 g. Height was measured using a stadiome-

ter with a vertical backboard and moveable headboard. Height was measured with an accuracy of 1 mm. On the basis of measurements of weight and height, body mass index (BMI) was calculated. To identify trends in BMI according to age, Polish growth charts were used [5]. In Poland the value to 3 percentile is used for identifying underweight children, while the 97 percentile is the cut off for identifying overweight children.

### *Statistical analysis*

The *Pearson's* correlation coefficient was used to calculate the correlation coefficient between the percentage of coverage of energy and the selected nutrients recommended values and BMI values. It was calculated separately for data obtained from the autumn and spring season. Intake of nutrients for each child was individually calculated as the mean of the four days of the week. The critical value of the correlation coefficient was calculated (for a sample consisting of 169 observations, with significance level  $\alpha = 0.05$ ). The *Pearson's* correlation coefficient has shown a linear relationship between the studied variables. The correlation coefficient ( $r$ ) in the range from -0.15 to 0.15 was used. The points located above or below this range meant that nutrients significantly influenced the value of BMI. This model does not include the impact of other factors (e.g. place of residence, gender and age). In this study, each nutrient was analyzed separately, depending on the season.

## RESULTS

### *Energy and basic nutrients intake*

Intake of energy and basic nutrients with average daily diets, depending on gender and the season are presented in Table 1.

The energy value of daily diets of girls, in the spring and autumn season did not meet requirements. Average implementation of requirements was 69.7% in spring and 67.8% in autumn season. The energy value of daily diets of boys also was too low; it met requirements only in 75.7% in spring and 71.3% in autumn. The percentage of coverage of recommended energy intake by boys was significantly higher ( $p < 0.05$ ) than by girls. Our results showed that only 10% of girls and 25% boys in both seasons met requirements for energy. About  $\frac{1}{3}$  of the assessed group did not meet requirements for energy even at 66.7%, in both seasons. In accordance with the recommendations for the energy share from carbohydrates should be in the range of 55-65%, from the fat in the range 25-30%, while the protein should be in range 12-14% [38]. The percentage of energy from fat and carbohydrates in the total energy value of daily diets, both boys and girls, was consistent the recommendations, while the share of energy from protein was higher.

Table 1. The intake of energy, proteins, fat, and carbohydrates from daily diets, and the average implementation of the recommendations

Components	SPRING			AUTUMN			YEAR			
	Intake	Implementation of standards [%]		Intake	Implementation of standards [%]		Intake	Implementation of standards [%]		
<b>GIRLS</b>										
Components	$\bar{x} \pm SD$	CV	Range	$\bar{x}$	$\bar{x} \pm SD$	CV	Range	$\bar{x}$	$\bar{x} \pm SD$	$\bar{x}$
Energy [kcal]	1439±447,6	31,0	35,5-131,6	69,7	1435,0±487,2	33,7	27,8-127,9	67,8	1436,9±467	68,7
Total protein [g]	52,3±17,5	33,4	52,4-228,5	123,8	51,1±18,6	36,3	38,4-240,7	115,0	51,7±18,1	119,4
Animal protein [g]	34,7±14,5	41,9	25,6-281,7	119,7	33,7±15,1	44,9	18,4-289,5	116,2	34,2±14,8	117,9
Vegetable protein [g]	17,7±6,00	33,9	34,9-341,3	118,0	17,4±6,30	36,0	29,1-297,2	116,0	17,5±6,2	116,7
Total fat [g]	45,3±21,7	47,2	19,7-160,3	62,1	46,1±25,2	53,7	15,2-166,3	61,9	45,7±23,5	62,0
Carbohydrates [g]	217,1±67,0	30,9	22,2-163,6	62,0	215,2±69,7	32,3	14,3-111,6	61,5	216,1±68,4	61,8
<b>BOYS</b>										
Components	$\bar{x} \pm SD$	CV	Range	$\bar{x}$	$\bar{x} \pm SD$	CV	Range	$\bar{x}$	$\bar{x} \pm SD$	$\bar{x}$
Energy [kcal]	1698,5±670	39,7	30,7-163,7	75,7	1689,6±622,6	36,4	26,8-144,2	71,3	1694±646,3	73,5
Total protein [g]	60,6±25,2	41,7	46,4-304,3	140,9	61,5±21,9	35,1	53,9-271,9	128,9	61,1±23,6	134,9
Animal protein [g]	39,7±19,5	49,2	14,6-508,1	136,9	40,9±17,8	43,4	21,9-509,2	141,0	40,3±18,7	138,9
Vegetable protein [g]	20,9±9,30	44,9	31,3-460,5	139,3	20,7±7,80	38,3	31,3-378,7	138,0	20,8±8,60	138,7
Total fat [g]	56,5±30,2	53,7	22,0-195,2	72,7	58,0±33,9	57,9	17,3-187,9	70,3	57,3±32,1	71,5
Carbohydrates [g]	250,7±102,5	41,3	11,2-187,2	71,6	243,4±85,6	34,8	20,4-172,8	69,5	246,8±94,0	67,1

SD – standard deviation; CV – coefficient of variation [%]

Table 2. Underweight, normal weight, overweight and obesity prevalence (%) among girls and boys

Age	Underweight		Normal weight		Overweight		Obesity	
	girls	boys	girls	boys	girls	boys	girls	boys
10	0.0	0.0	82.4	56.3	5.8	31.2	11.8	12.5
11	6.8	5.7	75	85.7	13.7	8.6	4.5	0.0
12	3.4	6.9	86.2	82.8 75.0	10.4	6.9	0.0	3.4
Total	3.4	4.2	81.2	74.9	10.0	15.6	5.4	5.3

The major source of energy in the daily diets should be carbohydrate. The average intake of these nutrients with diets of children was too low. Diets of boys realized the standard for carbohydrates in 71.6% in the spring and in 69.5% in the autumn season. Intake of carbohydrates by girls was lower and amounted in 62.0 and 61.5% of requirements. Percentage of girls who did not cover the demand for carbohydrates was very high i.e. 80% in the spring and more than 59% in the autumn season. At the same time consumption of these nutrients in amounts of less than  $\frac{2}{3}$  of the requirements was declared by 44% boys and 80% girls. It was also found that boys met the requirement for carbohydrates significantly higher ( $p < 0.05$ ) than girls.

The amount of energy provided by sucrose, in daily diets of girls, in spring and autumn season amounted ~14.0% of the total energy value. Sucrose contained in diets of boys has delivered 16.0% of the energy in both seasons. Results obtained in this study indicate that boys and girls did not meet recommended value of intake of

dietary fiber (52.7 and 51.0%). In none of the daily diets in both seasons dietary fiber intake did not exceed the recommended amount.

The daily diets of students in both seasons were deficient in fat. Average intake of fat with daily diets by girls in the spring and autumn met requirements in 62.1 and 61.9%. Intake of fat from the diets by boys met requirements in 70.3 and 72.7% respectively; in addition, it was significantly higher compared to girls. About 28% of boys and 46% girls consumed fat in amount which not allowed covering  $\frac{2}{3}$  of the recommended value. About a  $\frac{1}{3}$  of boys and  $\frac{1}{5}$  of girls met requirements for these nutrients in range 90-110%.

Intake of protein by girls met requirements in 123.8% in spring and 115.% in autumn. Intake of protein by boys met requirements in 140.9% and 128.9% respectively. Percentage of coverage of recommendation for this macronutrient by the boys was significantly higher ( $p < 0.05$ ) in comparison to the percentage of coverage by girls (Table 1). The demand for animal

origin protein in the spring season and autumn were covered by girls in 119.7 and 116.2%, respectively and for boys 136.9 and 141% respectively.

In total amount of protein consumed by both girls and boys, more than half of them were animal origin protein. The daily diets in which  $\frac{2}{3}$  of the total amount of protein is animal origin, there is generally a good composition and ratio of essential amino acids. It has been shown that the  $\frac{1}{3}$  girls and  $\frac{1}{5}$  boys met requirements for this component, while more than half of the girls (56%) and boys (about 78%) consumed total protein in excess of 110% of the recommended value in both seasons.

### BMI value

Table 2 shows the percentage of population of boys and girls in the age of the 10, 11 and 12 years with normal weight, determined on the basis of BMI.

The risk of energy-protein malnutrition, determined on the basis of body mass index (BMI), was on average 3.8% of children aged 10-12 years. Average 4.2% of boys and 3.4% of girls had a risk of malnutrition, taking into account the percentage of children with deficiency in body weight. The highest percentage of children with malnutrition was found in children aged 11 years of both genders and in boys aged 12 years. Among children aged 10 years, there was no risk of malnutrition.

The correct proportions of weight in relation to height (BMI) were measured in 74.9% of boys and 81.2% of girls. It was also found that the smallest percentage of 10 year old boys and 11 year old girls had correct BMI. On the other hand, the highest percentage of children with normal BMI was found in the group of boys at the age of 11 years old and girls at the age of 12 years old.

The presence of excessive body weight was observed in 18.1% of the total population, including 15.6% of overweight boys and 10.0% girls, and obesity in 5.3% of boys and 5.4% girls. Exceeded body weight was characterized by 20.9% of the total population of boys. The proportion of girls having exceeded body weight was 15.4%.

### Correlations

In this study are only presented the results concerning to correlation between the consumption of energy, basic nutrients and the values of BMI.

A negative relationship ( $r=-0.16$ ,  $p=0.0442$ ) was found between the implementation of recommendations for energy and the BMI of the pupils. Children, who in the spring season delivered more energy with average daily diets, had a lower BMI compared to pupils who had the lower level implemented recommendations and a higher body mass index (Figure 1).

A positive correlation ( $r=0.17$ ,  $p=0.0247$ ) between the meeting of requirements for animal origin protein in the autumn season and the BMI in pupils were found

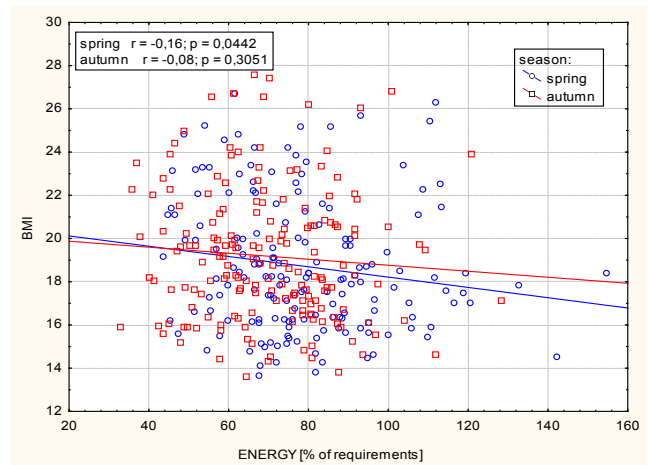


Figure 1. The correlation between the implementation of standards for energy and BMI values

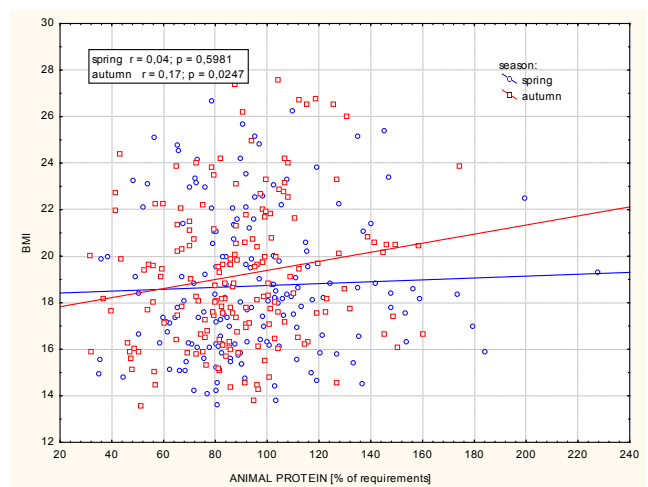


Figure 2. The correlation between the implementation of standards for animal protein and BMI values

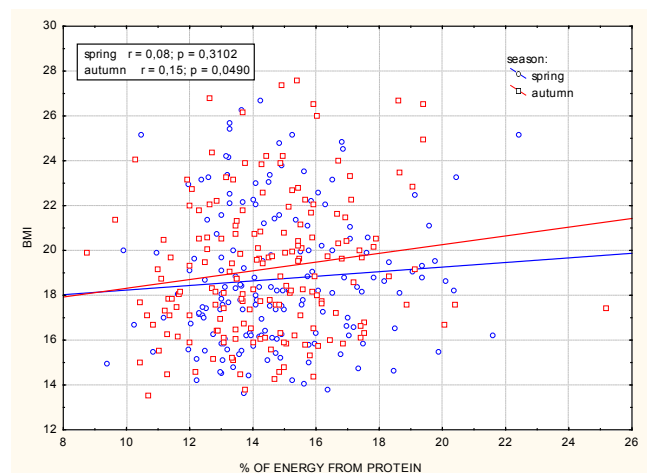


Figure 3. The correlation between the share of energy from total protein and BMI value

(Figure 2). Additionally a positive correlation ( $r=0.15$ ,  $p=0.0490$ ) between the share of energy from total protein in the autumn season and the values of BMI was also found (Figure 3). There was no correlation between another basic macronutrient intake and BMI.

## DISCUSSION

Reported in this study dietary mistakes of children, concerning to low intake of energy, total carbohydrates (including excessive consumption of sucrose and too low fiber), fat and at the same time to high intake of protein, are very often described by other authors. It has been also reported that boys, in general, realised, the requirements in higher amount than girls [7, 26, 31, 39].

Daily diets of children aged 10-12 years exceeded the requirements for protein and share for energy intake from these nutrients in total energy intake. A high protein intake with the inadequate consumption of other nutrients such as vitamins, minerals and fiber, increases the risk of some chronic non-communicable diseases. A high intake of protein increases the demand for other nutrients involved in the metabolism of amino acids, mainly B vitamins. This may also damage the kidneys and the liver. A diet high in protein promotes calcium excretion, depleting the bones of their major mineral. In addition, other minerals like magnesium, iron and zinc are also reabsorbed from bones which also cause a weakening of bone structure. The consequence of this process may be the occurrence of osteoporosis in old age [13].

Too low intake of carbohydrates and fat which has been demonstrated in this study, causes their oxidation as the essential way of their metabolism. During oxidation process obtained energy is used for thermogenesis and basic anabolism. In addition, the proper ratio of carbohydrates to fat (it was reported in this study) causes complete oxidation of fatty acids. The amino acids, derived from the degradation of protein, are used for the synthesis of body protein (structural and functional). They can also be used as a supplementary source of energy, or some of them are used for the synthesis of glucose and fatty acids. Such processes occur after to high intake of protein (it was found in this study), because the body is not able to utilize them for the purposes of building processes.

In this study, the percentage of boys and girls, aged 10-12 years, with low body mass was lower compared to data reported by *Czeczlewski* and *Raczynski* [7], *Szponar* et al. [31] and *Cisek* et al. [6] or higher, compared to the results of similar studies carried out in a group of school children from the region of Podlasie [3].

The comparison of results of this study with published by other authors shows a similar prevalence of body weight among the children aged 10-12 years [3, 6, 8, 31]. *Czeczlewski* and *Raczynski* [7] as well as *Szponar* et al. [31] stated that the proportion of the population of children aged 10-12 years showing excess body weight (overweight and obesity) was 6.7% higher. In both of the cited studies, it was observed that overweight

appeared frequently than obesity. In terms of age it was found that the most vulnerable were obese 10 year olds, which was also confirmed by *Obuchowicz* et al. [24]. In our study, underweight occurred less frequently in relation to exceeded weight gain in children aged 10-12 years old. It should be noted that obesity was reported in a group of 10 year old; in addition, in this group the underweight was not observed. Obesity and overweight, occurring in the population of children aged 10-12 years, especially among the youngest group may be, among others factors, a consequence of the ongoing economic development of our country. It consequently, increases of consumption highly processed food and changes in social behavior. Other important factor is too low physical activity. The results presented above confirm the global statistical data on the growing number of obese children, especially in developed countries, including Poland [4, 11, 33].

Assessment of intake of nutrients by overweight and obese children aged 7-12 years has shown that the average energy value of daily diets was varied. The lowest concentration of energy was found in diets children aged 7-9 years, while the highest content in diets of children aged 10-12 years. Despite the prevalence of overweight and obesity, intake of energy was too low [2]. Similar results to the obtained in this study, were published by *Veugelers* et al [34], dealing with the problems of feeding different population groups. Some published data are not confirmed by results obtained in this study [29]. It has been suggested that the main cause of obesity in children and adolescents is too high intake of fat, irrespective of the energy value and the total content of carbohydrates in the diet [2, 9, 18].

It has been reported that one of the major factors in the prevalence of overweight and obesity is excessive energy intake by different groups of populations. However, the coexistence of many other factors (i.g. age, level of physical activity, gender) affecting results makes the relationship between energy intake and BMI value extremely difficult to prove [14, 20]. Results obtained in our study confirmed data given by *Rocandio* et al. [27] who reported that the intake of energy and nutrients by children with proper body weight were higher than by overweight and obese children. It can be suggested that the intake of energy by obese children was higher in relation to their daily energy expenditure connected with low physical activity level, compared to children with normal body mass. The level of physical activity is the most important factor, but children very often replace physical activity with inactive ways of spending free time and thus spend too little energy [1, 30, 35].

It has been well reported that intake of protein by children especially in infancy and early childhood was correlated with body height and weight. However, in some studies the correlation between the intake of

protein and overweight and obesity was not calculated [13]. In many studies, the effects of protein on BMI, was used as a measure for the tendency of children to become overweight and obese [28]. BMI is not a proper indicator of measurement of fat content in the body, particularly among boys which have lower fat content in comparison to girls [22]. What is more, BMI is often higher during adolescence [1].

Summarizing the above considerations in relation to the results obtained in our study, it should be noted that the increase of protein intake by the children aged 10-12 years, which was probably used to gain muscle mass, as well as increased BMI, indicated their rapid development. It did not reveal the occurrence of overweight or obesity, because the exceeded intake of protein probably was used for energy production which intake was too low.

In this study the positive correlation between intake of fat, carbohydrates and BMI was not found. Probably it was connected with low intake of these nutrients. *Czeczeliwski* and *Raczyński* [7] showed that daily diets of the overweight and obese children exceeded recommendations for intake of fat and carbohydrates. Diets of children with overweight and obesity (BMI above 90 percentile) were characterized by a higher share of fat and carbohydrates in the diet compared to lean children (with a BMI below 10 percentile). *McGloin* et al. [17], assessing the daily diets of adolescents showed that fat was the only macronutrient, whose content in diets significantly affected the occurrence of overweight and obesity in this population. The opposite effect was obtained in studies *Aeberli* et al. [1] who analysed the effect of diet on the nutritional status of Swedish children aged 6-14 years. These authors reported that intake of fat and carbohydrates did not correlate with overweight and obesity.

*Gazzaniga* and *Burns* [12], analysing the daily diets of 48 children aged 9-11 years showed that the composition of diets had an impact on the prevalence of obesity in the children, regardless of energy, as well as the physical activity of respondents.

The studied pupils aged 10-12 is a group which is in a period of intense growth and development. In this age changes in body composition are not usually dependent on the diet. This may explain the effect of the reverse correlation between the energy intake with diets and BMI. Moreover, the assessment of nutritional status showed that overweight and obesity is most common in the youngest group of children, i.e., at the age of 10 years. The dietary mistakes found in this study may not only increase risk of overweight and obesity but also other non-communicable diseases. It is known that improper nutrition in childhood results in the development of diet-related diseases in adulthood. To ensure the maintenance of normal body weight and

the adequate intake of nutrients, nutritional education of parents, children, and teachers should be planned as a part of basic education.

## CONCLUSION

1. Children participating in the study, showed incomplete coverage of demand for energy, fat and carbohydrates in general, significantly lower for girls in relation to boys. At the same time students exceeded the demand for total protein.
2. Proper weight, based on BMI values in the pupils aged 10-12, were found in 74.9% of boys and 81.2% of girls. Deficiencies in body weight occurred in 4.2% and 3.4%, overweight in 15.6 and 10.0%, while obesity in 5.3 and 5.4% of respondents.
3. Inverse correlation was found between the implementation of standards for energy and BMI values of children and a positive correlation between the volume of consumption of plant and animal protein, total fat and BMI value.

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## Conflict of interests

*The authors declare no conflict of interests.*

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