FOLIA MEDICA CRACOVIENSIA
Vol. LXIII, 2, 2023: 149–163
PL ISSN 0015-5616
DOI: 10.24425/fmc.2023.145919

Prevalence of metabolic syndrome and improper nutritional status among adolescents

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Abstract: Prevalence of metabolic syndrome (MetS) and its components is a growing issue, including pediatric populations. However, because of many definitions used, it is difficult to assess the true frequency of these problems.
The aim of this study was to assess the prevalence of MetS and its components as well as the frequency of problems with inadequate nutritional status among adolescents.
One hundred ninety-six teenagers aged 15–18 years, living in Krakow and its vicinity were examined including measurement of blood pressure, anthropometric parameters and blood levels of cholesterol and glucose.
The prevalence of MetS was low and varied from 0.5% to 2.0% depending on the definition. Based on Cook's definition of MetS, the most common components were hypertension (12.8%) and hypertriglyceridemia (12.8%). Improper body weight (based on BMI) was found in 23.5% of adolescents, including 5.1% underweight, and 18.4% overweight or obese. According to the body fat percentage (BF%), 45.8% of the boys were underfat and 6.3% had too much body fat, while only 4% of the girls were below the BF% reference values and 15% above. All girls and 86.5% of boys had too low total body water.
In conclusion, the prevalence of metabolic syndrome in population of Krakow adolescents was relatively low, but more than 12% of the adolescents had a hypertension or hypertriglyceridemia. Based on BMI most of adolescents were found to have adequate body weight, but examination of fat content in the body high prevalence of underfat was observed, especially among boys.

Keywords: metabolic syndrome, adolescents, nutritional status, cholesterol, glucose, obesity.

Submitted: 20-Jun-2023; **Accepted in the final form:** 20-Jul-2023; **Published:** 30-Jul-2023.

Introduction

Many adult's diseases have their origin during the previous stages of life, including childhood and adolescence. During adolescence, young people establish behavior patterns as well as diet and physical activity that can protect their health or put their health at risk now and in the future. In the light of many studies, unhealthy lifestyle and diet are an important problem, which can be linked to development of metabolic diseases. These include arterial hypertension, diabetes, lipid disorders, obesity, which, in turn, constitute a cause-and-effect chain that increases the risk of cardiovascular disease [1, 2]. One of the most important health problems concerning the adolescents are increasing prevalence of excessive body weight and related to it rising frequency of metabolic syndrome [3, 4].

The improper body weight during the childhood and adolescence can be link with many health problems in adulthood, including obesity and other coexisting chronic non-communicable diseases such as diabetes or osteoporosis [2, 5]. Different measures are used to define inadequate body weight, including anthropometric indicators [6]. However, using only the anthropometric measures does not give a full idea of the nutritional status because they do not provide information about body composition [7]. There are several methods of body composition analysis, but electrical bioimpedance is one of the most commonly used in population studies. It allows to easily and non-invasively determine lean body mass, body fat, skeletal muscle mass, total water content and other parameters [8]. However, regardless of the method used, the problem is to adequately determine the cut-off points for determining the correct values of the tested parameters in populations of children and adolescents because they are sex, age, ethnicity, etc. dependent [9].

The metabolic syndrome (MetS), often associated with obesity, is a serious health condition that puts people at higher risk of heart disease, diabetes, stroke, and diseases related to fatty buildups in artery walls. In adult population, it is defined by presence of three out of five conditions: high blood glucose, low high-density lipoprotein cholesterol (HDL-C), elevated level of triglycerides in blood, abdominal adiposity, and high blood pressure. However, there is no universal definition of metabolic syndrome in the pediatric population. Several different definitions can be found in the literature and the prevalence of this health problem is then definition-dependent [10–12].

The aim of this study was to assess the prevalence of metabolic syndrome and its components as well as the frequency of improper nutritional status among adolescents.

Material and Methods

The study population consisted of adolescents born in the years 2001–2004, participants in an ongoing prospective cohort study in Krakow, Poland. The study investigates the health impacts of prenatal exposure to air pollution on infants and children in Krakow. The study design and the detailed selection of the population have previously been described [13]. In year 2019 all participants in the cohort were invited to participate in the follow-up examination. During the follow-up visit blood pressure, anthropometric and body composition measurements were taken, and blood samples were collected.

The study was approved by the Bioethics Committee of Jagiellonian University and was conducted according to Helsinki declaration. Written informed consent was also obtained from all adolescents and parents of underage participants.

Measurements

Blood samples were taken early in the morning after a fast overnight. Blood samples were collected by venipuncture according to a standard protocol. Fasting plasma glucose, triglycerides and cholesterol concentrations were determined using the enzymatic colorimetric method. All measurements were made on a Cobas 8000 analyzer according to standard procedures. The trained personnel performed anthropometric and blood pressure measurements. Blood pressure was measured in the sitting position after 10 minutes of rest. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) was measured using a Omron blood pressure monitor (M2 Basic) in three repetitions. The final blood pressure values were calculated as an average of the second and third readings.

Anthropometric measurements were taken in while subjects wore light clothing and no shoes. All measurements were taken twice and the average was recorded. The height was estimated using a wall mounted stadiometer, with an accuracy of 0.1 cm. Measurements of body circumferences were made with an inextensible metric tape with an accuracy of 0.1 cm. Waist circumference was measured at the midpoint between the upper border of the iliac crest and the lower border of the costal arch. Hip circumference was measured at the widest part of the hips. Body weight with an accuracy of up to 0.1 kg, body fat mass and body fat percentage (BF%), muscle mass, and total body water were evaluated using the BIA method using an electronic analyzer Tanita BC-420. The prior-measured body height, age, and sex were manually entered into the analyzer. BF% was assessed and classified with the help of the built-in equations of the device.

Metabolic syndrome

The presence of metabolic syndrome was defined using two different classifications: definition of metabolic syndrome of the International Diabetes Federation [14] and definition of metabolic syndrome in adolescents developed by Cook *et al.* [15] — Table 1. In the second definition, modified criteria for adults were applied to the most representative values available from pediatric reference data. Instead of hard cut-offs for elevated systolic or diastolic blood pressure and elevated waist circumference, the 90th percentile value was used for the age and sex distribution.

Table 1. Definitions of metabolic syndrome.

		IDF definition for 15 years [14]	IDF definition for 16–18 years [14]	Cook *et al.* definition [15]
	Criteria	Central obesity and ≥2 components		≥3 components
Components of the metabolic syndrome	Central obesity	Boys: WC ≥94 cm Girls: WC ≥80 cm	Boys: WC ≥94 cm Girls: WC ≥80 cm	WC ≥90th percentile
	Hypertension	SBP ≥130 mmHg or DBP ≥85 mmHg	SBP ≥130 mmHg or DBP ≥85 mmHg	SBP ≥90th percentile or DBP ≥90th percentile
	Hypertriglyceridemia	TG ≥1.7 mmol/l	TG ≥1.7 mmol/l	TG ≥1.2 mmol/l
	Low HDL cholesterol	HDL <1.03 mmol/l	Boys: HDL <1.03 mmol/l Girls: HDL <1.29 mmol/l	HDL ≤1.03 mmol/l
	Impaired glucose	Glucose ≥5.6 mmol/l	Glucose ≥5.6 mmol/l	Glucose ≥6.1 mmol/l

WC — waist circumference, SBP — systolic blood pressure, DBP — diastolic blood pressure, TG — triglycerides, HDL — high-density lipoprotein

Nutritional status

The nutritional status of the participants was classified by age and sex, respectively, using three different criteria:

1. body mass index (BMI) calculated as weight [kg] divided by height [m] squared; categorized according to the latest Polish BMI growth charts [16], where: <5th

percentile — underweight, 5th–85th percentile — normal weight, >85th percentile — overweight, >95th percentile — obesity;

2. waist-height ratio (WHtR) — calculated as waist circumference [cm] divided by height [cm]; classified according to Polish charts [17], where: <5th percentile — underweight, 5th–95th percentile — normal weight, >95th percentile — obesity;
3. body fat percentage (BF%), using TANITA sex and age-specific cutoffs.

Body fat distribution was evaluated by waist-to-hip ratio (WHR), calculated by dividing waist circumference by hip circumference. Abdominal obesity was defined according to WHO criteria as WHR ≥0.85 for girls and ≥0.90 for boys [18]. Additionally, the total body water content was analyzed assuming the correct range of 50–65% for boys and 45–60% for girls in accordance with Tanita's guidelines.

Concentration of biochemical parameters such as glucose, HDL-C and triglycerides was classified according to both definitions of MetS, and the results of total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C) were classified using the following criteria: TC ≥5.2 mmol/l — high, LDL-C ≥2.6 mmol/l — high [19].

Statistical analysis

All parameters are presented separately for boys and girls. All continuous variables were presented as median with interquartile range (first quartile, third quartile) because most of the variables in the analysis did not follow a normal distribution. Differences between sex groups were tested using the Mann–Whitney test for continuous variables or the Chi^2 test for categorical variables or the Fisher exact test when necessary. All tests were two-sided and the level of significance was set at a = 0.05. All analysis were done using SPSS 28 (PS ImagoPro, ver 8.0).

Results

The study included 196 adolescents (15–18 years old), including 100 girls and 96 boys. 78.9% of them lived in Krakow and the rest in surrounding area.

In the first step of analysis, the boys and girls have been compared based on the anthropometry, body composition, and biochemical indicators. As expected, we have found higher height, weight, as well as waist circumference, and WHR in boys than in girls. But there were no differences between group in BMI and WHtR observed. Skeletal muscle mass was higher in boys, while the girls were characterized by higher fat mass as well as percentage of body fat. Additionally, in boys higher percentage of body water was observed.

The data showed that the median systolic blood pressure was significantly higher in the group of boys (p <0.001), but diastolic blood pressure was slightly higher for girls (p = 0.051). As for the results of biochemical tests, boys were characterized by a lower level of total cholesterol in the blood, but a higher level of glucose compared to girls. Detailed characteristics are listed in Table 2.

Table 2. Characteristics of the population of adolescents using selected anthropometric, body composition and biochemical indicators by sex (n = 196).

	Boys n = 96	**Girls n = 100**	**p**
	Median (Q1–Q3)	**Median (Q1–Q3)**	
Age (years)	16.0 (16.0–17.0)	16.0 (16.0–17.0)	0.397
Weight (kg)	65.4 (60.7–74.8)	58.7 (53.3–63.7)	<0.001
Height (cm)	178.5 (175.5–183.3)	165.5 (162.0–169.7)	<0.001
BMI (kg/m^2)	20.9 (19.2–22.7)	21.2 (19.9–23.1)	0.217
Waist circumference (cm)	72.0 (69.0–74.5)	66.0 (62.0–69.0)	<0.001
Hip circumference (cm)	91.0 (89.0–95.0)	92.0 (87.0–95.0)	0.716
WHR	0.8 (0.8–0.8)	0.7 (0.7–0.7)	<0.001
WHtR	0.4 (0.4–0.4)	0.4 (0.4–0.4)	0.072
Body fat percentage (%)	10.7 (8.3–15.0)	23.7 (19.2–27.2)	<0.001
Body fat mass (kg)	7.3 (4.8–11.0)	14.0 (10.3–17.2)	<0.001
Fat free mass (kg)	58.5 (54.8–63.3)	44.6 (42.8–46.7)	<0.001
Total body water (%)	42.8 (40.1–46.3)	32.6 (31.1–34.1)	<0.001
Muscle mass (kg)	55.6 (52.0–60.1)	42.3 (40.6–44.3)	<0.001
Systolic blood pressure (mmHg)	117.5 (109.5–124.0)	105.0 (100.5–110.5)	<0.001
Diastolic blood pressure (mmHg)	62.0 (56.5–68.0)	64.0 (59.0–70.0)	0.051
Heart rate (bpm)	72.5 (64.5–82.0)	75.0 (68.0–82.0)	0.242
Glucose (mmol/dl)	5.2 (5.0–5.5)	5.1 (4.8–5.3)	<0.001
Triglycerides (mmol/dl)	0.8 (0.6–1.05)	0.8 (0.6–1.0)	0.845
Total cholesterol (mmol/dl)	3.7 (3.3–4.1)	4.0 (3.6–4.4)	<0.001
HDL cholesterol (mmol/dl)	1.3 (1.1–1.5)	1.6 (1.4–1.8)	<0.001
LDL cholesterol (mmol/dl)	1.9 (1.6–2.3)	2.0 (1.6–2.4)	0.329

BMI — body mass index, WHR — waist-to-hip ratio, WHtR — waist-to-height ratio, HDL — high-density lipoprotein, LDL — low-density lipoprotein

To assess the prevalence of metabolic syndrome in our population, two different definitions have been used. Based on IDF, the prevalence of MetS was 0.5%, and this was only one boy. However, when the Cook *et al.* definition was applied to this population, the prevalence of MetS was found to be 2.0% (3.1% in boys and 1.0% in girls). The analysis of the specific components of MetS show that in case of both definitions a sizable percentage of adolescents qualified to the group with hypertension, but higher in Cook *et al.* definition. The use of this last definition also highlighted the problem with hypertriglyceridemia (12.8%). However, the use of the IDF definition drew attention to too high glucose levels in 16.8% of participants (much higher percentage in boys than girls) and too low HDL levels in 10.2% of adolescents. The detailed data are presented in Table 3.

Table 3. Prevalence of the metabolic syndrome and its individual components in the youth population according to the IDF definition and Cook et al. definition (n = 196).

Variable	IDF definition				Cook *et al.* definition			
	Boys n (%)	Girls n (%)	Total n (%)	P	Boys n (%)	Girls n (%)	Total n (%)	P
Metabolic syndrome	**1 (1.0)**	**0 (0.0)**	**1 (0.5)**	**0.490**	**3 (3.1)**	**1 (1.0)**	**4 (2.0)**	**0.361**
Central obesity	1 (1.0)	0 (0.0)	1 (0.5)	0.490	8 (8.3)	2 (2.0)	10 (5.1)	0.064
Hypertension	9 (9.4)	1 (1.0)	10 (5.1)	0.009	11 (11.5)	14 (14.0)	25 (12.8)	0.594
Hypertriglyceridemia	2 (2.1)	2 (2.0)	4 (2.0)	1.000	13 (13.5)	12 (12.0)	25 (12.8)	0.746
Low HDL cholesterol	12 (12.5)	8 (8.0)	20 (10.2)	0.298	13 (13.5)	3 (3.0)	16 (8.2)	0.007
Impaired glucose	24 (25.0)	9 (9.0)	33 (16.8)	<0.001	3 (3.1)	4 (4.0)	7 (3.6)	1.000

HDL — high-density lipoprotein cholesterol

In the study we used several indicators to estimate nutritional status. According to all anthropometric indicators, the nutritional status of the majority of participants was adequate. But based on the data presented in Table 4, it can be observed that, depending on the definition, the percentage of adolescents in particular categories of nutritional status was different. For example — obesity was found for 0.5%–3.1% of respondents of this cohort, depending on the indicator used. Interestingly, based on anthropometric indicators, we did not observe differences in the distribution of different categories of nutritional status between boys and girls, but while taking into

Table 4. Nutritional status and other health indicators of adolescents from Krakow and surrounding area by gender (n = 196).

Variable		Boys n (%)	Girls n (%)	Total n (%)	P
BMI	Underweight	7 (7.3)	3 (3.0)	10 (5.1)	0.454
	Normal	74 (77.1)	76 (76.0)	150 (76.5)	
	Overweight	12 (12.5)	18 (18.0)	30 (15.3)	
	Obese	3 (3.1)	3 (3.0)	6 (3.1)	
WHR	Normal	93 (96.9)	97 (97.0)	190 (96.9)	1.000
	Abdominal obesity	3 (3.1)	3 (3.0)	6 (3.1)	
WHtR	Underweight	8 (8.3)	14 (14.0)	22 (11.2)	0.260
	Normal	87 (90.6)	86 (86.0)	173 (88.3)	
	Obese	1 (1.0)	0 (0.0)	1 (0.5)	
Body fat percentage	Underfat	44 (45.8)	4 (4.0)	48 (24.5)	< 0.001
	Normal	46 (47.9)	81 (81.0)	127 (64.8)	
	Overfat	4 (4.2)	13 (13.0)	17 (8.7)	
	Obese	2 (2.1)	2 (2.0)	4 (2.0)	
Total body water	Low	83 (86.5)	100 (100.0)	183 (93.4)	< 0.001
	Normal	13 (13.5)	0 (0.0)	13 (6.6)	
Total cholesterol	Normal	94 (97.9)	91 (91.0)	185 (94.4)	0.035
	High	2 (2.1)	9 (9.0)	11 (5.6)	
LDL cholesterol	Normal	85 (88.5)	81 (81.0)	166 (84.7)	0.143
	High	11 (11.5)	19 (19.0)	30 (15.3)	

BMI — body mass index, WHR — waist-to-hip ratio, WHtR — waist-to-height ratio, LDL — low density lipoprotein

account the percentage of body fat, we observed a significantly higher percentage of boys with too little body fat (45.8%) compared to girls (4.0%) and opposite, more frequent overfat status among girls — 13.0% vs 4.2% among boys.

The total water content in the body turned out to be a big problem for the population, because all girls and up to 86.5% of boys had too low a water content.

Most of the adolescents in both groups were within the reference ranges for total blood cholesterol and LDL-C concentration. However, more girls (9.0%) than boys (2.1%) were found to have an elevated level of total cholesterol (P = 0.035) as well as high LDL cholesterol (19.0% vs 11.5%, respectively), but the difference in the prevalence of high LDL-C was not significant.

Discussion

In the studied population of adolescents aged 15–18 years, a low incidence of metabolic syndrome was found according to the IDF definition (0.5%) and slightly higher (2.0%) using the Cook *et al.* definition. Regardless of the criteria used to determine the presence of the metabolic syndrome, our study had a lower percentage of adolescents with MetS than in other Polish [20] and European studies [21–24] in which the prevalence of MetS was found in the range of 1.3%–3.8% for IDF and 3.5%–3.8% for Cook *et al.* definitions.

The IDF definition includes central obesity as a necessary factor to recognize the MetS, in addition, the cut-off points are relatively high and similar to those used for adults. This criterion was fulfilled by only one respondent (15 years old boy), and this determined an exceptionally low prevalence of metabolic syndrome in this population despite the presence of other components of MetS. On the other hand, in the definition of Cook *et al.* the central obesity is defined based on sex and age specific centiles established for the specific population, so based on this criterion, more adolescents were found to have this factor present. Furthermore, this definition does not require central obesity to be a necessary factor. The second particularly crucial difference between the MetS definitions used in this study is the cut-off applied for the HDL-C level. Cholesterol levels, particularly HDL levels in males, are affected by puberty [25] and this fact was considered in part in the definition of IDF, but the only criterion was age, not the tanner stage. In the Cook *et al.* definition is only one cut-off for both girls and boys, in contrast to the IDF definition for adolescents over sixteen, where a higher cut-off is used for girls. This resulted in a higher prevalence of low HDL cholesterol among girls as defined by the IDF.

It is worth emphasizing that the percentage of metabolic syndrome among adolescents is low, but if we look at its individual components, it turns out that many more people have abnormal values of these parameters. For example, according to the IDF definition, 0.5% of our study population suffers from MetS while 5.1% suffers from hypertension, and a similar trend has been noted by Agirbasil *et al.* [22] — only 1.6% of adolescents had MetS based on IDF definition and as much as 12.4% suffered from hypertension. Quite a high percentage is disturbing, especially since hypertension is major cardiovascular disease risk factor. In adolescents, it can contribute to the development of atherosclerosis and premature cardiovascular disease in adulthood [26].

According to the BMI index, 18.4% of the population examined in Krakow's youth had excessive body weight, including 3.1% obese, and this is a slightly higher prevalence than reported in other studies conducted in other regions of Poland (14.4%–16.2%) [17, 27, 28], as well as in nationwide studies (16.3%) [29]. However, higher prevalence was observed in Wroclaw (25.3%, including 10.4% obese) [30] or central Poland (23.6%, including 11.3% obese) [31]. Contrary to what was expected from the literature [32, 33], in this study, a higher prevalence of adolescent with too high body weight based on BMI assessment was reported than based on the BF% (10.7%, including 2% obese). Similarly to our results, Więch *et al.* observed a higher percentage of people classified as obese (19.4%) and overweight (66.9%) using BMI than BF% (3.6% obese, 15.1% overweight) [7]. This suggests that BMI, even while using percentile charts, has relatively low accuracy in identifying overweight in the underage population, especially boys. Apart of calculating the BMI, the muscle mass of the examined teenagers should be additionally checked, as a greater amount of muscle tissue could explain the higher BMI values of some youth classified as overweight.

It is also very important to assess the distribution of the excess fat, because particularly the accumulation of visceral fat poses a great risk for cardiometabolic risk [34]. One of the most often studied indicators is a waist circumference, but one have to have in mind that the waist circumference is insufficient as an independent indicator of nutritional status — it should be used to determine the type of obesity, not just obesity [35]. In our study, based on waist circumference WHtR has been calculated, which indicated 0.5% of abdominal obesity among the youth population from Krakow and its vicinity. This is an exceptionally low percentage as compared to study in the Lesser Poland conducted in 2017, where as many as 9.7% of boys and 5.2% of girls with abdominal obesity were observed [28]. In addition, we have used also WHR to assess the type of obesity — only 3.1% of participants had this parameter above normal range, which is tantamount to a higher risk of metabolic diseases [36]. A higher WHR was observed in boys than in girls, which is consistent with the results of other researchers [27].

Most studies on the nutritional status of adolescents focus on excessive body weight and the problem of underweight seems to be overlooked. Our research shows that 5.1% of adolescents in the study population were underweight according to BMI and this percentage was lower than observed in other studies, both in Lesser Poland (6.1%) [28], in central Poland (6.9%) [31] and nationwide (10.9%) [29]. However, while comparing with the results of BF% analysis, the assessment of BMI in this study did not detect a significant proportion of adolescent with underfat. This is especially evident in the case of boys, in whom 7.3% were underweight according to BMI and as much as 45.8% had too low BF%. A similar trend was noticed by Błaszczyk-Bębenek *et al.* for both genders [28]. Interestingly, in our study a much lower percentage of girls were characterized by low body fat percentage (4%) than in already cited study (38.3%) [28], but this difference can be partly explained by different age group examined in this study (7–16 years old) that can be linked with the changes in the body related to maturation. A comparative analysis of BMI and BF%, carried out in our population, showed that only in relation to 50% of boys and 85% of girls, both indicators qualified respondents to the same category. In particular, as many as

84.1% of the examined boys with too low adipose tissue content indicated by BF% according to BMI were classified as normal body weight, which may be due to increased muscle mass.

The atherosclerotic process begins in childhood and can lead to cardiovascular disease in adulthood. Therefore, in addition to the percentage of fat in the body, it is also important to evaluate the lipid profile. The most atherogenic is LDL cholesterol [37]. In our study more girls (9.0%) than boys (2.1%) were found to have an elevated level of total cholesterol, as well as high LDL cholesterol (19.0% vs 10.5%, respectively). A previous study by Wyka [30] showed a lower percentage of adolescents with abnormal LDL cholesterol level than in the present study. However, in general the difference between girls and boys in body fat is primarily due to the fact that it changes with puberty and the average age at which girls reach specific markers of puberty is lower than for boys.

A big problem among the examined youth turned out to be low water content in the body, which concerns all girls and 86.5% of boys. Also, studies conducted by other researchers on a similar group of young people from the Malopolska Province showed a sizable percentage of people inadequately hydrated (49,2% of girls, 55,9% of boys) [38], but our results were much higher. Dehydration is a severe problem because it causes disturbances in blood pressure regulation, and also manifests itself in deterioration of concentration and some cognitive functions [39].

In summary, depending on the definition of improper body weight used, 5.1%–24.5% of underweight, 8.7%–15.3% of overweight and 0.5%–3.1% of obese were observed. The discrepancies are due to the fact that different indicators contain different information about the tested organism. Moreover, BMI in children and adolescents depends on many factors, including age and sex, as well as the reference population from which the cutoff points for the reference values were created [9]. In addition, BMI does not contain any information on body composition, including the content and distribution of adipose tissue, which makes it difficult to determine nutritional status, and in particular obesity [40]. The distribution of body fat can be analyzed using WHR or WHtR indices, which, although they are strongly correlated with BMI values [41, 42], still require more precise determination of borderline values in the pediatric population [43]. This does not change the fact that all the above indicators of nutritional status are positively correlated with risk factors for the development of cardiovascular diseases, and this relationship is particularly visible at their higher values [44, 45]. In addition, it is also difficult to compare the results from different studies because even if the same reference population is used, different cut-off values may be applied. For example, most researchers define obesity in the same way as in this study, that is, above the 95th percentile of sex and age specific values [27–29, 31], but another uses a cutoff point above the 97th percentile [17] or above the 98th percentile [7].

Our study included a small number of adolescents, with relatively good socio-economic status, so the results of this examination probably are not fully representative for the entire population. The main limitation is that estimated prevalence of study outcomes depends on definitions of MetS and the tools used to assess the proper weight and that is why the comparison with other studies and populations should be careful — different definitions can lead to different estimations of the prevalence of a given health problem. We tried to control for this using waist circumference percentiles based on age and gender for the Polish pediatric population.

Conclusions

The prevalence of metabolic syndrome in population of Krakow adolescents was relatively low. Most of adolescents were found to have a proper body weight according to the BMI, but especially among boys remarkably high prevalence of underfat was observed. Additionally, we have found that more than 90% of adolescents experienced low water content in their bodies.

Acknowledgment

Data were collected in the research "A join project studying the long-term impacts of coal-related air pollutants on children's health in Krakow" conducted in cooperation between Columbia University, New York (principal investigator: prof. F.P. Perera) and Jagiellonian University Medical College, Krakow (principal investigator: dr hab. A. Pac).

Blood samples collection and analysis was performed by the team of Diagnostics Department of The University Hospital in Krakow (chair: dr B. Maziarz).

Author contribution statement

The authors confirm the contribution to the article as follows: study conception and design: A.P.; analysis and interpretation of results: A.O., A.P., E.S.T.; draft manuscript preparation: A.O., A.P., E.S.T. All authors reviewed the results and approved the final version of the manuscript.

Funding

This work was supported by Jagiellonian University Medical College, Krakow, Poland (N41/DBS/000725).

Conflict of interest

None declared.

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