CONTINUOUS METABOLIC SYNDROME SCORE IN CARDIOVASCULAR RISK ASSESSMENT IN ADOLESCENTS

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SUMMARY

Objectives: This study aimed to determine the metabolic syndrome (MS) prevalence in a sample of adolescents, to calculate their continuous metabolic syndrome scores, and to determine the associations of continuous metabolic syndrome score with overweight/obesity and selected cardiometabolic and lifestyle factors.

Methods: We enrolled a sample of 2,590 adolescents (1,180 males, mean age 17.1 ± 1.04 years) from 14 grammar schools and 48 secondary schools in the Bratislava Self-Governing Region, Slovakia. Data were collected from a standard anthropometric examination, biochemical analysis of fasting venous blood, blood pressure measurement, physical fitness assessment, and a comprehensive questionnaire focused on selected lifestyle characteristics. Continuous metabolic syndrome score and paediatric simple metabolic syndrome scores were calculated.

Results: The criteria for the MS diagnosis according to the International Diabetes Federation (IDF) guidelines for children and adolescents were fulfilled in the whole sample by 38 (1.4%) adolescents; all were classified as overweight/obese. In the obese subgroup (n = 270), the MS prevalence rose to 13.3%. The largest number of adolescents was in the group without any of the MS components (67.5%). In the groups with 1, 2 or 3 MS components, males predominated; 0.6% of males and no females had 4 components of MS. The increasing number of individual components of MS is accompanied by a continuous increase (in the case of HDL-cholesterol – a decrease) of mean values mostly of blood lipid levels. Mean values of blood pressure (BP) and anthropometric parameters were highest in the group with three MS components. Significant correlations with body fat content or with selected lifestyle factors were not found. Using the continuous MS score calculation we found 31 adolescents, of whom 14 (45.2%) had only 1 or at most 2 MS components, i.e., they did not meet the criteria for the MS diagnosis.

Conclusion: From the point of view of atherosclerosis prevention and early intervention, it is extremely important to monitor the MS prevalence in children and adolescents, especially in the current obesity pandemic. The paediatric MS score calculation is simple and accurate, allowing assessment of the severity of cardiometabolic risk in individuals even before the diagnosis of MS. The continuous MS score is useful in identifying individuals at increased risk and in the management of preventive health care for children and youth.

Key words: adolescent, metabolic syndrome, continuous metabolic syndrome score, cardiometabolic risk, lifestyle factors

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INTRODUCTION

Metabolic syndrome (MS) is an accumulation of selected cardiometabolic risk factors (abdominal obesity, increased glycaemia, blood pressure, and/or triglycerides (TG) level, and decreased HDL-cholesterol level). These disorders raise the risk of developing several chronic diseases (1). The Diabetes Working Group of the World Health Organization (WHO) proposed the first formalized definition of MS in 1998 (2, 3). In the following period, the WHO and other international professional and scientific organizations proposed different definitions of MS to eliminate ambiguities in the identification and diagnosis of MS patients.

Traditional MS definitions are based on cut-off values for each individual component (elevated blood pressure, elevated fasting glucose and TG level, reduced HDL-cholesterol level, and abdominal obesity), established by the International Diabetes Federation (IDF) for adults. Clinical diagnosis requires the presence of any three (or the presence of abdominal obesity and at least two other) components; the treatment of the mentioned disorders is also considered a positive criterion (4). There are several issues with these traditional definitions of MS. The use of cut-off values to identify abnormalities means that some people with values just below the cut-offs can be considered perfectly healthy, even if they have all the five basic components of MS just below the threshold levels. It is also necessary to pay increased attention to them as a part of chronic diseases prevention (5).

Another problem is the dichotomous definition of MS, especially in the case of obese children and adolescents (6), according to which there are only two possibilities: the studied person either has MS or not. This enables a simple and unambiguous

diagnosis of MS, but it is difficult to monitor the development of MS components over time and their ongoing evaluation in terms of worsening or improvement. MS likely exists as a spectrum of risks. Because of this, it is likely that an individual within the values of the MS components just below the threshold for all the five components may be at higher risk than someone who just exceeds the cut-offs in three components but has low or normal levels of the other two. In such a case, MS is not diagnosed and such a person does not receive the necessary attention. These problems can be eliminated by using the continuous MS score (cMSs) (5), which is accurate and provides the possibility of monitoring changes in the severity of cardiometabolic risk factors, especially in individuals who have not yet been diagnosed with MS (7). More and more evidence supports the use of cMSs for epidemiological analyses instead of a binary definition, which, however, remains useful for clinical practice (8). Cardiovascular risk increases with an increasing number of MS risk factors, whereas cMSs consider all MS components and not just any combinations of three risk components. This enables early risk identification, especially in children (9). The cMSs method is more sensitive and less prone to errors, which may increase the statistical significance compared to the binary definition of MS, especially in the early stages of metabolic abnormalities. Consequently, the use of cMSs is recommended as an alternative to categorical evaluations, which are often used in epidemiological studies (10, 11).

The originally proposed cMSs, calculated as the sum of z-scores for each individual component (12), often could not be easily calculated (it is necessary to know the mean values and standard deviations for each MS component in the studied population), it is related to a specific population, does not allow comparison between populations and is very impractical for clinical use. These difficulties have been overcome by a recently proposed simple method for to calculate continuous MS scores (siMSs) based on the IDF criteria for MS. In addition to its simple calculation, it is easily applicable in daily clinical practice; it enables the comparison of scores between different populations, as well as the comparison of the results of several studies. At the same time, it enables the calculation and monitoring of cMSs in an individual patient and shows a close correlation with the previous cMSs (2, 13).

From the point of view of atherosclerosis prevention and early intervention, it is extremely important to monitor MS prevalence in children and adolescents, especially in the current pandemic of obesity, because it can predict the development of type 2 diabetes and cardiovascular diseases in adulthood. MS prevalence is rapidly increasing along with the prevalence of overweight and obesity (1, 5). From this point of view, the following two basic forces are spreading the health disorders above: the increase in consumption of high calorie-low fiber fast food and the decrease in physical activity due to mechanized transportations and sedentary form of leisure time activities (14). Problems in diagnosing MS in children and adolescents (criteria intended for adults were often used) were eliminated by the IDF in 2007 when it published the first international definition of MS in children and adolescents (15). This was an important step to overcome the use of multiple definitions of MS in childhood and adolescence with very different criteria (16, 17). Similar to the adult population, the simplified calculation of the so-called paediatric siMSs (PsiMSs) provides a combination of simplicity and high accuracy for the calculation of a continuous MS score in youth, it seems to be an accurate and efficient scoring system to assess and monitor the risk of adolescent MS in the research and clinical practice (13, 18).

This study aimed to determine MS prevalence in a sample of adolescents, calculate and compare cMSs and PsiMSs, and determine the associations of PsiMSs with overweight/obesity and selected cardiometabolic and lifestyle factors.

MATERIALS AND METHODS

The analysed sample of adolescents was selected as part of the project Support of Cardiometabolic Health in the Secondary Schools in the Bratislava Self-Governing Region, i.e., in 14 grammar schools and 48 secondary vocational schools (Respect for Health). The data were collected during the years 2013–2014. The project was conducted in cooperation with the Regional Public Health Authority of Bratislava. It was a cross-sectional study aimed at determining the prevalence of selected cardiometabolic, environmental, behavioural, and psychosocial risk factors for cardiovascular disease (CVD) in adolescents and their impact on health status. The project was approved by the Ethics Committee of the Bratislava Self-Governing Region, participation in the study was fully voluntary and anonymous, written informed consent was obtained from all legal representatives of children before being enrolled in the study.

From the entire sample of 4,382 adolescents who participated in this project, a group of 2,590 adolescents aged 14.00–18.99 years (mean age 17.1 ± 1.04 years) was selected; 1,180 males (45.6%) and 1,410 females (54.4%). Selection criteria were age (decimal age 14.00–18.99 years according to WHO criteria) and a complete anthropometric, venous blood sample biochemical examination and blood pressure (BP) examination. An exclusion criterion was the presence of any illness (acute and/or chronic).

The file and the methods used are described in detail in our previous work (19).

Basic standard anthropometric examination focused on overweight/obesity and abdominal obesity (weight, height, waist and hip circumference, body fat content using bioelectrical impedance method) was performed by the trained staff; body mass index (BMI) and waist/height ratio (WHtR) were calculated.

Blood pressure and resting heart rate (HR) were measured using an automated digital device OMRON M-6 COMFORT under standard conditions. Mean values of BP and HR from the 2nd and 3rd measurements (with a 5-minute break between measurements) were calculated.

A fasting venous blood sample was conducted by qualified nurses, and standard biochemical analyses were performed by a central certified laboratory. Biochemical CVD risk factors were evaluated (complete lipid profile, glycaemia, blood insulin level, high-sensitivity C-reactive protein – hsCRP). Atherogenic index of plasma AIP = log(TG/HDL-C) (20), non-HDL-cholesterol (21) and the homeostatic model assessment of insulin resistance (HOMA-IR) (22, 23) were calculated. A cut-off point ≥ 3.16 for HOMA-IR was considered to be risky for insulin resistance (22).

Overall physical fitness using the Ruffier test was assessed (24).

MS prevalence was evaluated according to the IDF consensus for the definition of MS in children and adolescents (15) as the presence of central obesity plus two or more other components.

The objective examination was complemented by a comprehensive questionnaire, where we focused mainly on selected lifestyle characteristics (leisure-time physical activity, smoking, sleeping duration, sedentary activities), psychosocial factors and nutrition, and nutritional habits (frequency of food group consumption and number and regularity of daily meals).

We calculated cMSs as the sum of the Z-score for waist circumference, mean arterial pressure MAP [MAP = (syst. BP – diast. BP)/3 + diast. BP], HDL-cholesterol, TG and glycaemia blood levels according to Eisenmann et al. (12). The following formula was used to calculate PsiMSs (13):

$$\text{PsiMSs} = \frac{2 \text{ x waist circumference}}{\text{height}} + \frac{\text{glycaemia}}{5.6} + \frac{\text{TG}}{1.7} + \frac{\text{systolic PB}}{130} - \frac{\text{HDL-cholesterol}}{1.02}$$

Legend: TG – triglyceride blood level; BP – blood pressure; HDL – high-density lipoprotein

Methods of descriptive statistics were used. For statistical data processing, the Shapiro-Wilk test was used to examine if the variables are normally distributed in the sample. The test rejects the hypothesis of normality when the p-value is less than or equal to 0.05. For normally distributed variables arithmetic means ± standard deviations were used, non-normal distribution data are presented as a median (lower quartile–upper quartile). The relationships between continuous variables were assessed using Mann-Whitney U test, Kruskal-Wallis test, Pearson and Spearman correlations. The categorical data were compared using contingency tables and the chi-square test. We evaluated differences for $p < 0.05$ as statistically significant. The statistical packages Epi InfoTM software, version 7.1.5.0, Atlanta, GA, USA, and SPSS, version 25 were applied.

RESULTS

Intersexual Differences of the Sample

The basic characteristics of the examined sample and intersexual differences are shown in Table 1 (mean age of boys and girls was the same, 17.1 years). Table 1 shows significant

Table 1. *Selected anthropometric, biochemical, and physiological characteristics in males and females, and prevalence of overweight, obesity and metabolic syndrome (N = 2,629)*

Variables		Total (N = 2,629)	Males (n = 1,205)	Females (n = 1,424)	p-value
Age (years)	mean ± SD	17.1 ± 1.0	17.1 ± 1.0	17.1 ± 1.0	0.289
Metabolic syndrome[1]	n (%)	38 (1.4)	32 (2.7)	6 (0.4)	< 0.001
Metabolic syndrome[2]	n (%)	42 (1.6)	36 (3.0)	6 (0.4)	< 0.001
BMI (kg.m^{-2})		21.7 (20.0, 24.1)	22.3 (20.5, 24,7)	21.3 (19.6, 23.7)	< 0.001
Overweight	n (%)	426 (16.2)	212 (17.6)	214 (15.0)	0.075
Obesity	n (%)	270 (10.3)	158 (13.1)	112 (7.9)	< 0.001
Z-score BMI		0.25 (−0.30, 1.05)	0.37 (−0.22, 1.16)	0.16 (−0.38, 0.91)	< 0.001
Body fat (%)	mean ± SD	24.5 ± 9.6	17.6 ± 7.4	30.4 ± 6.9	< 0.001
Waist circumference (cm)	mean ± SD	75.1 ± 9.3	79.3 ± 9.2	71.5 ± 7.8	< 0.001
WHtR	mean ± SD	0.44 ± 0.05	0.44 ± 0.05	0.43 ± 0.05	< 0.001
Cholesterol (mmol/L)	mean ± SD	4.03 ± 0.76	3.80 ± 0.69	4.24 ± 0.75	< 0.001
LDL-cholesterol (mmol/L)	mean ± SD	2.25 ± 0.60	2.16 ± 0.58	2.34 ± 0.60	< 0.001
HDL-cholesterol (mmol/L)	mean ± SD	1.38 ± 0.30	1.25 ± 0.23	1.50 ± 0.30	< 0.001
Non HDL-cholesterol (mmol/L)	mean ± SD	2.65 ± 0.68	2.22 ± 0.67	2.74 ± 0.68	< 0.001
Triglycerides (mmol/L)		0.77 (0.59, 1.03)	0.75 (0.58, 1.01)	0.79 (0.60, 1.04)	0.036
AIP	mean ± SD	−0.23 ± 0.22	−0.20 ± 0.23	−0.26 ± 0.20	< 0.001
Glycaemia (mmol/L)	mean ± SD	4.81 ± 0.64	4.93 ± 0.44	4.71 ± 0.75	< 0.001
hsCRP (mg/L)	mean ± SD	0.45 (0.19, 1.11)	0.43 (0.19, 10.46	0.46 (0.20, 1.19)	0.168
Insulin (mIU/L)		9.54 (7.20, 13.21)	9.28 (6.87, 12.65)	9.86 (7.41, 13,41)	0.002
HOMA-IR	mean ± SD	2.45 ± 1.91	2.53 ± 2.25	2.39 ± 1.58	0.077
Systolic BP(mmHg)	mean ± SD	114.3 ± 13.2	122.6 ± 12.1	107.3 ± 9.4	< 0.001
Diastolic BP (mmHg)	mean ± SD	71.5 ± 7.8	72.7 ± 7.9	70.4 ± 7.6	< 0.001
Mean arterial BP (mmHg)	mean ± SD	85.7 ± 8.6	89.4 ± 8.4	82.7 ± 7.6	< 0.001

Data are presented as a mean ± standard deviation for normal distribution, as a median (lower quartile–upper quartile) for non-normal distribution, or as a count (percentage) for categorical data.[1]Metabolic syndrome prevalence according to International Diabetes Federation guidelines, i.e., abdominal obesity presence + any 2 risk factors; [2]Metabolic syndrome prevalence in the presence of any 3 risk factors

BMI – body mass index; WHtR – waist to height ratio; LDL – low density lipoprotein; HDL – high density lipoprotein; AIP – atherogenic index of plasma; hsCRP – high-sensitivity C-reactive protein; HOMA – Homeostasis Model Assessment; IR – insulin resistance; BP – blood pressure

intersexual differences for almost all given parameters, with the exception of the overweight prevalence, blood hsCRP levels and the HOMA-IR index. Males had significantly higher values of anthropometric indicators, with the exception of the body fat content, higher values of the plasma atherogenic index, glycaemia, and blood pressure (systolic, diastolic, and mean arterial). Females had significantly higher body fat content and higher levels of total cholesterol, LDL-, HDL-cholesterol, non-HDL-cholesterol, and hsCRP. Males had a significantly higher obesity prevalence according to BMI.

Selected Lifestyle Characteristics of the Sample

Of the lifestyle factors (Table 2), males declared a significantly longer leisure-time physical activity duration per week (which was reflected in a higher physical fitness level), a longer sleep time on working days, a higher number of meals per day, and more frequent consumption of sugar-sweetened beverages. Females had a significantly longer sleep time on weekends and the total duration of sedentary activities. They skipped breakfast more often.

MS Prevalence in the Examined Sample

The criteria for the MS diagnosis according to the IDF for children and adolescents (14) were fulfilled in the whole sample by 38 (1.4%) adolescents; 32 boys (2.7%) and 6 girls (0.4%) ($p < 0.001$), all were classified as overweight/obese. In this subgroup (overweight + obesity, n = 696), MS prevalence was 5.5% (8.6% of males and 1.8% of females, $p < 0.001$). In the obese subgroup (n = 270), MS prevalence rose to 13.3% (19.0% of males and 5.4% of females). However, if we used the presence of any 3 of the five risk factors as a criterion for the MS diagnosis, MS prevalence increased to 42 (1.6%) adolescents, but only in males (n = 36, 3.0%) (Table 1).

Table 3 shows a high significant increase in both cMS Z-score and PSiMSs with weight increase, as well as an increase in all the MS components except HDL-cholesterol, where we observed an opposite trend.

The whole sample of adolescents was divided according to the number of MS components (Fig. 1). The largest number of adolescents was in the group without any MS components (67.5%; males 56.3%, females 77.1%). In the groups with 1, 2 or 3 MS

Table 2. *Selected lifestyle characteristics of males and females (N = 2,629)*

Variables	Total (N = 2,629)	Males (n = 1,205)	Females (n = 1,424)	p-value
Smokers (current/former)	1,062 (40.4)	469 (38.9)	593 (41.6)	0.167
Ruffier index	9.6 (7.1, 12.4)	8.8 (6.4, 11.6)	10.4 (8.0, 13.2)	< 0.001
Physical activity (mins./weekly)	126.0 (38.4, 337.5)	300.0 (90.0, 450.0)	78.0 (16.1, 208.0)	< 0.001
Sleeping duration – Mon-Fri (hours)	7.1 ± 1.1	7.2 ± 1.1	7.1 ± 1.1	0.001
Sleeping duration – weekends (hours)	9.2 ± 1.4	9.1 ± 1.4	9.3 ± 1.4	0.003
Sedentary activities – Mon-Fri (hours)	6.4 ± 2.9	6.2 ± 2.7	6.7 ± 3.0	< 0.001
Sedentary activities – weekends (hours)	8.4 ± 3.7	8.3 ± 3.7	8.5 ± 3.7	0.129
Average number of meals per day	4.0 ± 1.3	4.1 ± 1.4	4.0 ± 1.3	0.012
Breakfast skipping	466 (17.7)	180 (14.9)	286 (20.1)	< 0.001
Sweetened beverages consumption (3 to 7 times per week)	862 (32.8)	466 (38.7)	396 (27.8)	< 0.001

Data are presented as a mean ± standard deviation, as a median (lower quartile–upper quartile) for non-normal distribution, or as a count (percentage) for categorical data. Mon-Fri – working days; sedentary activities – watching TV, work/game at the computer, and/or learning; smokers – those who smoked or quit smoking in the last month

Table 3. *Mean levels of metabolic syndrome components, HOMA, PsiMSs and cMS Z-score in adolescents according to BMI categories (N = 2,629)*

Variables	Underweight + normal weight (n = 1,933)	Overweight (n = 426)	Obesity (n = 270)	p-value
WHtR	0.42 (0.40, 0.43)	0.46 (0.45, 0.48)	0.52 (0.49, 0.56)	< 0.001
Glycaemia (mmol/L)	4.76 (4.51, 5.02)	4.78 (4.54, 5.05)	4.88 (4.63, 5.18)	< 0.001
HOMA	1.37 (1.39, 2.51)	2.36 (1.71, 3.25)	3.43 (2.35, 5.01)	< 0.001
Triglycerides (mmol/L)	0.74 (0.58, 0,97)	0.81 (0.61, 1.12)	0.98 (0.74, 1,37)	< 0.001
Systolic BP (mmHg)	111.0 (103.5, 120,5)	117.0 (107.5, 126.6)	122.0 (113.5, 131.5)	< 0.001
Mean arterial BP (mmHg)	84.3 (78.8, 89.5)	87.7 ± 8.5	91.2 (85.2, 97.2)	< 0.001
HDL-cholesterol (mmol/L)	1.38 (1.21, 1.59)	1.30 (1.15, 1.49)	1.19 (1.05, 1.36)	< 0.001
PsiMSs	1.65 (1.37, 1.92)	1.92 (1.91, 2.18)	2.34 (1.94, 2.67)	< 0.001
cMS Z-score	−0.79 (−2.32, 0.67)	0.88 (−0.55, 2.46)	3.74 (1.37, 6.02)	< 0.001

Data are presented as a median (lower quartile–upper quartile) for non-normal distribution and as a mean ± standard deviation for normal distribution.
WHtR – waist to height ratio; HOMA – Homeostasis Model Assessment; BP – blood pressure; PsiMSs – paediatric simple metabolic syndrome score; cMS Z-score – continuous metabolic syndrome Z-score

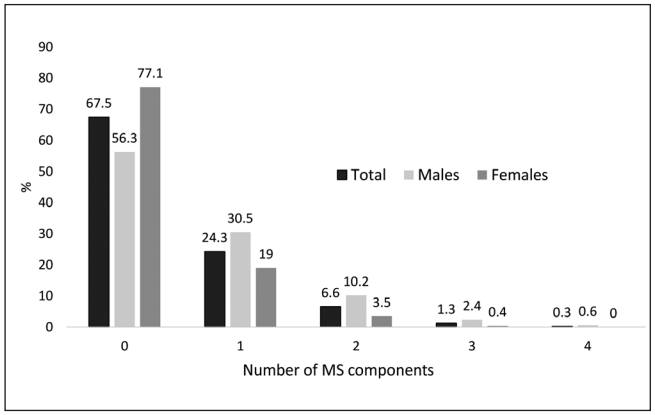

Fig. 1. *Distribution of adolescents according to the number of metabolic syndrome components (N = 2,629).*

components, males predominated; 0.6% of the males and no females had 4 components of MS.

The mean levels of cardiovascular risk factors according to the number of MS components are shown in Table 4. A continuous increase (in the case of HDL-cholesterol, a decrease) in the mean value is observed with an increasing number of MS components, most pronounced in biochemical parameters. The mean levels of BP, hsCRP and anthropometric parameters were highest in the group with three MS components.

The selected lifestyle characteristics (Table 5) no longer showed an unequivocal linear association with the number of MS components. The most risk factors were recorded in the group with three and/or four MS components. Adolescents in the group with four MS components had the highest prevalence of smokers, the worst physical fitness, and the shortest duration of leisure-time physical activity. The longest duration of sedentary activities during both the working days and the weekends, and the most frequently sugar-sweetened beverages consumption were found in the group with three MS components.

Continuous MS Score, Comparison with Number of MS Components

The continuous MS score was calculated in both ways and compared to each other (Fig. 2). Both values show a linear dependence and a strong correlation (reliability equation $R^2 = 0.8668$, correlation coefficient $r = 0.9305$).

The continuous and linear increase of cMSs calculated in two ways according to the number of MS components are presented in Figures 3 and 4.

Both values (cMSs and PsiMSs) demonstrate highly significant correlations ($p < 0.001$) with subsequent biochemical parameters (the first value indicates r_1 for PsiMSs; the second r_2 for cMSs): hsCRP ($r_1 = 0.152$, $r_2 = 0.141$), insulin blood level ($r_1 = 0.359$, $r_2 = 0.397$), HOMA-IR ($r_1 = 0.374$, $r_2 = 0.442$), and AIP ($r_1 = 0.826$, $r_2 = 0.658$). Significant correlations with body fat content or with selected lifestyle factors were not found.

From the whole sample, we collected individuals with a high level of cMSs calculated according to both methods. In the case

Table 4. *Selected variables in adolescents according to the number of metabolic syndrome components (N = 2,629)*

Variables	Number of metabolic syndrome components				
	0 (n = 1,776)	1 (n = 638)	2 (n = 173)	3 (n = 35)	4 (n = 7)
Age (years)	17.0 (16.0, 17.0)	17.0 (16.0, 18.0)	17.0 (16.0, 18.0)	17.0 (15.0, 18.0)	17.2 ± 1.3
BMI (kg.m^{-2})	21.1 (19.6, 22.9)	23.4 (20.9, 26.1)	27.0 ± 4.9	31.3 ± 4.1	29.6 ± 4.9
Body fat (%)	24.8 (16.7, 30.7)	23.7 (16.4, 33.8)	28.2 ± 10.3	33.4 ± 7.5	28.9 ± 9.2
Waist circumference (cm)	72.0 67.0, 76.0)	79.0 (73.1, 84.9)	87.0 ± 11.1	100.8 ± 10.8	95.0 (94.0, 99.0)
WHtR	0.42 (0.40, 0.44)	0.45 (0.42, 0.49)	0.50 ± 0.06	0.56 ± 0.06	0.52 ± 0.05
Cholesterol (mmol/L)	3.95 (3.54, 4.46)	3.93 (3.41, 4.48)	4.15 (3.53, 4.68)	4.16 ± 1.01	4.58 ± 1.08
LDL-cholesterol (mmol/L)	2.17 (1.83, 2.57)	2.22 (1.83, 2.64)	2.42 (1.99, 2.86)	2.44 ± 0.86	2.46 (2.07, 2.63)
HDL-cholesterol (mmol/L)	1.41 (1.24, 1.61)	1.27 (1.09, 1.47)	1.10 (0.98, 1.31)	0.97 (0.84, 1.07)	0.91 ± 0.11
Non-HDL-cholesterol (mmol/L)	2.51 (2.14, 2.95)	2.59 (2.18, 3.15)	3.03 (2.48, 3.49)	3.22 ± 0.92	3.68 ± 1.11
Triglycerides (mmol/L)	0.73 (0.58, 0.96)	0.81 (0.61, 1.08)	1.12 (0.81, 1.71)	1.56 (0.93, 1.94)	2.37 ± 0.97
AIP	−0.28 (−0.40, −0.16)	−0.18 ± 0.22	−0.00 ± 0.22	0.20 (−0.04, 0.31)	0.38 ± 0.21
Glycaemia (mmol/L)	4.73 (4.49, 4.97)	4.84 (4.59, 5.15)	4.92 (4.67, 5.30)	5.06 ± 0.53	5.47 ± 0.24
hsCRP (mg/L)	0.38 (0.18, 0.87)	0,58 (0.23, 1.60)	0.84 (0.31, 2.39)	1.9 (0.69, 3.92)	1.2 (0.52, 9.55)
Insulin (mIU/L)	8.96 (6.78, 11.76)	10.61 (7.78, 14.16)	14.33 (9.84, 20.13)	20.50 (16.05, 30.3)	33.06 ± 15.47
HOMA-IR	1.88 (1.40, 2.51)	2.31 (1.65, 3.14)	3.21 (2.26, 4.64)	4.39 (3.31, 6.65)	7.95 ± 3.59
Systolic BP (mmHg)	109.5 (103.0, 117.5)	120.5 (110.0, 131.5)	130.5 (117.0, 136.5)	132.9 ± 14.0	130.5 ± 8.6
Diastolic BP (mmHg)	69.5 (65.0, 74.0)	74.0 (68.5, 79.5)	78.4 ± 9.0	82.4 ± 11.3	76.9 ± 9.4
Mean arterial BP (mmHg)	83.2 (78.3, 88.0)	90.0 ± 9.1	94.8 (88.4, 101.0)	99.2 ± 11.0	94.8 ± 6.8

Data are presented as a median (lower quartile–upper quartile) for non-normal distribution and as a mean ± standard deviation for normal distribution.
BMI – body mass index; WHtR – waist to height ratio; AIP – atherogenic index of plasma; hsCRP – high-sensitivity C-reactive protein; HOMA – Homeostasis Model Assessment; IR – insulin resistance; BP – blood pressure; metabolic syndrome components – abdominal obesity, elevated blood pressure, elevated fasting glucose and triglycerides level, reduced HDL-cholesterol level

Table 5. *Selected lifestyle factors of adolescents according to the number of metabolic syndrome components (N = 2,629)*

Lifestyle factors	Number of metabolic syndrome components				
	0 (n = 1,776)	1 (n = 638)	2 (n = 173)	3 (n = 35)	4 (n = 7)
Smokers (current/former)	671 (37.8)	247 (38.7)	70 (40.5)	9 (25.7)	3 (42.9)
Ruffier index	9.6 (7.0, 12.4)	10.4 (7.2, 12.8)	10.4 (7.6, 13.2)	10.4 (7.9, 14.0)	6.4 (3.3, 8.6)
Physical activity (mins./weekly)	112.5 (38.4, 312.0)	128.0 (38.4, 420.0)	157.5 (55.0, 418.1)	112.5 (14.0, 128.1)	90.0 (60.0, 420.0)
Sleeping duration – Mon-Fri (hours)	7.0 (6.0, 8.0)	7.0 (7.0, 8.0)	7.0 (7.0, 8.0)	7.0 (7.0, 8.0)	8.0 (7.0, 8.0)
Sleeping duration – weekends (hours)	7.0 (6.0, 8.0)	9.0 (8.0, 10.0)	9.0 (8.0, 10.0)	9.0 (8.0, 10,0)	8.0 (7.0, 9.0)
Sedentary activities – Mon-Fri (hours)	6.0 (4.0, 8.0)	6.0 (5.0, 8.0)	6.0 (4.0, 8.0)	7.0 (5.0, 9.0)	6.0 (7.0, 8.0)
Sedentary activities – weekends (hours)	8.0 (6.0, 11.0)	8.0 (6.0, 12.2)	8.0 (6.0, 11.0)	10.0 (6.0, 13.0)	7.0 (6.0, 10.0)
Average number of meals per day	3.5 (3.5, 5.5)	3.5 (3.5, 5.5)	3.5 (3.5, 5.5)	3.5 (3.5, 3.5)	3.5 (3.5, 3.5)
Breakfast skipping	317 (17.8)	104 (16.3)	38 (22.0)	6 (17.1)	1 (14.3)
Sweetened beverages consumption (3 to 7 times per week)	579 (32.6)	223 (35.0)	45 (26.0)	13 (37.1)	2 (28.6)

Data are presented as a median (lower quartile–upper quartile) for non-normal distribution, or as a count (percentage) for categorical data.
Mon-Fri – working days; sedentary activities – watching TV, work/game at the computer, and/or learning; metabolic syndrome components – abdominal obesity, elevated blood pressure, elevated fasting glucose and triglycerides level, reduced HDL-cholesterol level; smokers – those who smoked or quit smoking in the last month

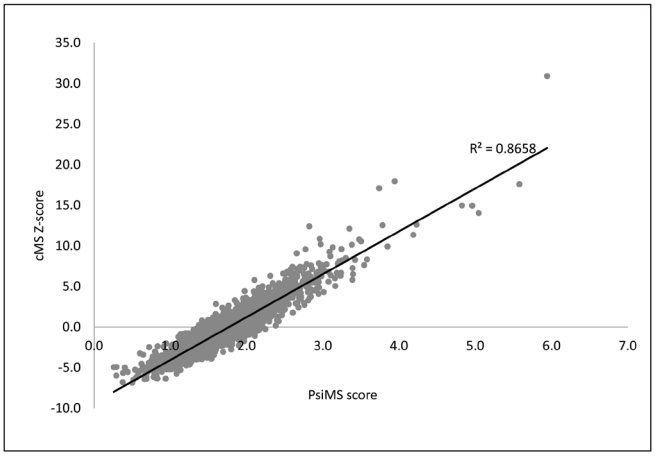

Fig. 2. *Correlation between the continuous metabolic syndrome score (cMSs) calculated from the Z-score of individual MS components and the simple paediatric metabolic syndrome score (PsiMSs) (N = 2,629).*

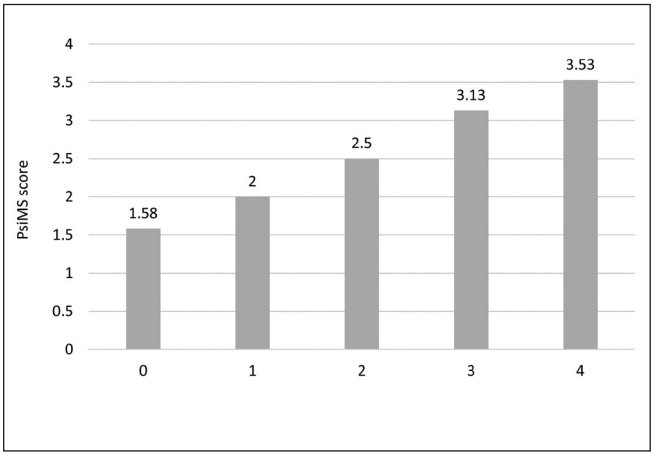

Fig. 4. *Mean values of the paediatric simple continuous metabolic syndrome scores (PsiMSs) according to the number of MS components (N = 2,629).*

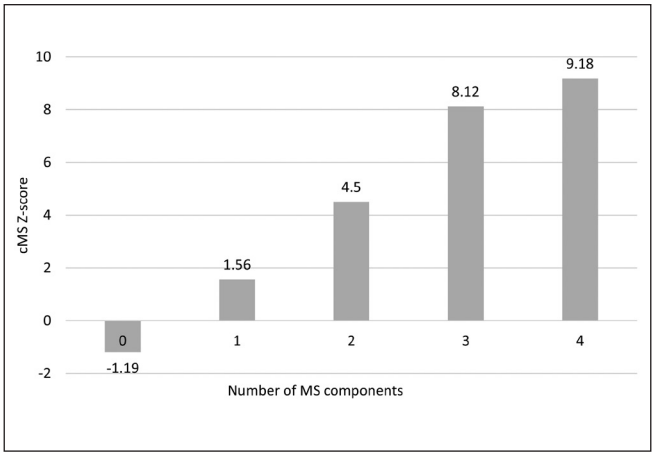

Fig. 3. *Mean values of the continuous metabolic syndrome scores calculated from the Z-score of individual MS components (cMSs Z-score) according to the number of MS components (N = 2,629).*

of cMSs Z-scores, these were values ≥ 8.12 (i.e., the mean value of the respondents with three MS components present, Fig. 3). We found 28 adolescents, of whom 9 (32.1%) had only 1 or 2 MS components. Similarly, in the case of PsiMSs, we selected respondents with values ≥ 3.13 (according to the same criteria as for cMSs; Fig. 4). We found 31 adolescents, of whom 14 (45.2%) had only 1 or at most 2 MS components, i.e., they did not meet the criteria for the MS diagnosis.

DISCUSSION

In the large sample of 2,329 adolescents from secondary schools in the Bratislava Self-Governing Region, MS prevalence according to the IDF criteria was detected. Intersexual differences of the sample were in line with expectations; worse results were achieved by males in terms of anthropometric values (except of

body fat content) and BP levels together with the significantly higher prevalence of MS; females had significantly worse blood lipid values. Selected lifestyle characteristics showed worse habits among females (more frequent smoking, sedentary activities, breakfast skipping, and lower level of physical activity and physical fitness). Simultaneously, cMSs was calculated using two different methods. A dichotomous classification of MS (i.e., the presence of at least three components with values higher than given limits) allows a simple MS diagnosis, but does not allow continuous assessment of the gradually increasing values of single MS components and thus simultaneously increasing cardiovascular risk. Modelling of the association between risk factors and categorical MS variables revealed controversial findings (10). For these reasons, several procedures have been suggested for the calculation of cMSs that is accurate and allows to monitor changes in the severity of cardiovascular risk in an individual who has not yet been diagnosed with MS (7). In addition, risk is a progressive function and cannot simply be considered present or absent depending on whether or not thresholds for each component are exceeded. The fact that cardiovascular risk is a progressive function of several MS risk factors and that risk increases with a growing number of MS risk factors has implications for continuous risk assessment. The continuous MS score considers all components of MS regardless of combinations of any two or three risk factors, allowing for early risk identification, especially in children (9). Therefore, it is appropriate to ask how many individuals have a high cardiovascular risk, but have not yet been diagnosed with MS, because they have risk values of only one or two MS components and thus do not meet the criteria for the dichotomous MS classification.

According to this dichotomous classification, in the sample of adolescents with a mean age of 17.1 years, we found relatively low MS prevalence – 1.4% or 1.6% (according to the evaluation criteria used). It is not high prevalence in relation to other countries. Data from the US National Health and Nutrition Examination Survey (NHANES) III from 1988–1994 showed that the MS prevalence rate was 4% among 12- to 19-year-old adolescents (25), which in subsequent years (1999–2000) increased to 6% (26) and in the years 1999–2012 it further increased to 9.8% (27). Representative data from other countries are relatively limited, e.g., MS prevalence in children and adolescents in northern Mexico was 6.5% (28), in Korea 9% (29), in Turkey 2% (30), and in Quebec, Canada, 10% (31).

In obese children and adolescents, MS prevalence is much higher, estimated at approximately 30–50% (25, 32, 33). MS prevalence in obese adolescents in our sample reached 13.3%, which is significantly lower than in other countries (34).

Continuous scores (cMSs) take into account all MS risk components and not just selected ones. Its calculation is based on the assumption that all MS components are equally important and serious in determining cardiovascular risk. The strength of each variable is considered equal in the final score (9).

The cMSs calculation is based on the sum of the Z-scores of all MS parameters, which are usually specific to a certain population, and thus they may not coincide with a sample of other populations. Thus, one limitation of this score is that it cannot be compared with scores calculated in other studies unless demographic characteristics, data distribution, means, and variabilities are similar in the populations being compared. It is true that the lower the cMSs, the lower the cardiometabolic risk (9), and that there is a graded relationship between cMSs and the number of MS risk components, which has been confirmed in our study as well. Eisenmann et al. (12) found in a cohort of 378 children aged 7–9 years that only about half of the subjects had no risk factors, while about 5% had MS. Consistent with our results, cMSs was the lowest in the group without any risk factor (-1.59 ± 1.76) and highest in patients with diagnosed MS (≥ 3 risk factors) (7.05 ± 2.73). They proposed an optimal cut-off value of cMSs for predicting MS presence of 3.72, given that none of the children with diagnosed MS had cMSs lower than 3.72. In our sample, even though they were older adolescents, we achieved better results: 67.5% of the subjects were without any risk factor, their mean cMSs was -1.19 ± 1.96 and only 1.6% had MS (≥ 3 risk factors). However, their mean cMSs was higher (8.3 ± 3.2), indicating a less favourable metabolic profile. Other authors (10) in a large cohort of 3,843 Iranian children aged 7–18 years suggested a cut-off value for cMSs of 1.76 (1.79 for boys and 2.72 for girls). Based on a study of 348 children aged 8 and 9 years (MS prevalence 8.9%), Brazilian authors (35) proposed a cut-off value of 1.86. The determination of the cut-off value for cMSs thus encounters many barriers, it is specific for a particular population, and therefore it is advisable to use cMSs rather for the application of preventive and intervention measures in a specific population.

The calculation of cMSs suffers from several limitations, as follows from the above. It is specific to individual population groups and the individual score of one person is not the same in two different studies, even considering that different authors use different variables and statistics, scoring procedures, main components of MS, etc. (2). Therefore, the need to develop universal scoring criteria that could be used and compared in clinical and research practice became evident. Soldatovic et al. (2) developed a simple calculation of siMSs that is highly correlated with other cMSs, but is much easier to calculate, apply to individual patients (compared to other cMSs that require groups of patients), and can be used for individual patient follow-up. Due to significant differences in the MS definition in children compared to adults, there is a need to modify and validate siMSs for use in the assessment of children and youth. From several formulas for calculating paediatric siMSs (PsiMSs), Vukovic et al. (13) proposed the one also used in our study because it showed the highest correlation with the most complex continuous scores. This variant has the simplest calculation, making it the most suitable for daily clinical practice and providing an excellent combination of simplicity and high accuracy for the calculation of cMSs, especially in obese youth (36). Some authors recommend including the HOMA value (or insulin blood level) instead of the glucose level in the calculation of cMSs because most children have a normal fasting glucose level and HOMA is more related to the degree of insulin resistance. Similarly, mean arterial pressure is sometimes included in the calculation instead of systolic blood pressure because it represents the value of both systolic and diastolic pressure at the same time (2, 12).

The use of cMSs makes it possible to estimate the severity of the cardiometabolic risk in the so-called low-risk persons, i.e. individuals who do not yet meet the criteria for the MS diagnosis. It is confirmed in our sample, too, where a relatively high representation of individuals with high-risk values of one or two

MS components was detected, but in whom MS would not have yet been diagnosed. Similarly, after preventive or therapeutic interventions in a patient with MS, cMSs can be used to monitor the improvement of cardiometabolic risk parameters, which is not detectable using the dichotomous MS definition (13).

Considering the importance of lifestyle modification for reducing the risk of MS-related diseases, the decrease in cMSs value can also be used to motivate patients to physical activity or dietary changes (37). From lifestyle factors, the association of MS to physical activity and some eating habits was detected, based on PsiMSs as continuous but not categorical data. This procedure is recommended as more statistically sensitive and less prone to error than dichotomous approaches (38). The results of the study by Stabelini et al. (39) confirmed that physical activity, especially moderate to high intensity, is inversely related to the MS risk score in adolescents. In our sample, an association of a decrease in the weekly physical activity duration, as well as a decrease in physical fitness with a higher number of MS components was confirmed. A study by Sun et al. (40) investigated associations between dietary habits and cMSs in young adults. They found out that adherence to nutritional recommendations (especially regarding reducing fat and fatty foods) did not affect metabolic risk in 2,410 participants aged 26–36. In our sample, we evaluated only the total number of meals per day, skipping breakfast, and the consumption of sweetened beverages frequency. The worst data were obtained from the groups with 3 and 2 MS components (the most frequent sweetened beverages consumption and the most frequent breakfast skipping, respectively). However, the results in the group with 4 MS components may be affected by the low number of members in this group (n=7). When evaluating eating habits in a group of at-risk (obese) adolescents, we often encounter the problem of presumed underestimation of risky foods consumption, especially those that are generally known to contribute to weight gain (sweets, sweet and salty snacks, fried and fast foods). Similar results were reached by Štefániková et al. as well (41) in a sample of overweight/obese university students who had a more favourable energy balance than normal-weight students. It is typical for individuals with a higher body weight to underestimate the amount of food consumed. We assume that a similar phenomenon occurred in our sample of adolescents, and therefore the associations of cMSs with eating habits did not yield consistent and unambiguous results.

CONCLUSION

The PSiMSs calculation is simple and accurate, allowing assessment of the severity of cardiometabolic risk in individuals even before they are diagnosed withMS. The continuous MS score is useful in identifying individuals at increased risk and in managing preventive health care for children and youth.

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Conflicts of Interest

None declared

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