Diabetes & Metabolic Syndrome: Clinical Research & Reviews 13 (2019) 1779–1784

Contents lists available at ScienceDirect

Diabetes & Metabolic Syndrome: Clinical Research & Reviews

journal homepage: www.elsevier.com/locate/dsx

Original Article

New anthropometric indices in the definition of metabolic syndrome in pediatrics

Mostafa Fazeli [a, 1], Mohammad Mohammad-Zadeh [b, 1], Susan Darroudi [a], Zahra Meshkat [d], Alireza Moslem [c], Hamideh Ghazizadeh [g], Saeid Kargozar [h], Gordon Ferns [e], Hamidreza Bahrami-Taghanaki [f, **], Majid Ghayour-Mobarhan [g, *]

[a] Molecular Medicine Group, Department of Modern Sciences and Technologies, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
[b] Department of Physiology & Pharmacology, Cellular and Molecular Research Center, Sabzevar University of Medical Sciences, Sabzevar, Iran
[c] Department of Anesthesiology, Faculty of Medicine, Sabzevar University of Medical Sciences, Sabzevar, Iran
[d] Antimicrobial Resistance Research Center, Mashhad University of Medical Sciences, Mashhad, Iran
[e] Division of Medical Education, Brighton & Sussex Medical School, Falmer, Brighton, Sussex, BN1 9PH, UK
[f] Chinese and Complementary Medicine Research Center, Mashhad University of Medical Sciences, Mashhad, Iran
[g] Metabolic Syndrome Research Center, Mashhad University of Medical Sciences, Mashhad, Iran
[h] Tissue Engineering Research Group (TERG), Department of Anatomy and Cell Biology, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

ARTICLE INFO

Article history:
Received 15 February 2019
Accepted 14 March 2019

Keywords:
Metabolic syndrome
Adolescent
Anthropometric indices
Pediatrics

ABSTRACT

Pediatrics metabolic syndrome (MetS) may be associated with the risk of development of chronic diseases in adulthood; however, the definition of pediatric MetS is unclear, and may vary with ethnicity. The primary goal of this study was to determine the best anthropometric predictors for pediatric MetS. For this purpose, 988 high school girls were recruited. Anthropometric indices and biochemical parameters were measured using standard procedures. The adapted MetS for pediatrics, including the IDF, NCEP, and two modified-NCEPs (Cook's and DeFerranti's) were used to establish a diagnosis of MetS. Statistical analysis was performed using SPSS and MedCalc softwares. Except for body frame size (r), the values for anthropometric indices were significantly lower in an individual without MetS. Waist to height (WHtR), BMI and hip circumference (HiC) showed the strongest association with the different MetS definitions. For the IDF definition, the highest sensitivity and specificity were observed for HiC (100.0, 85.2) and WHtR (100.0, 84.7); while for the NCEP definition, the r index showed the highest sensitivity (85.0); but low specificity made it inapplicable. For the Cook's definition of MetS, wrist circumference (WrC), HiC, WHtR, BMI and SR had similar sensitivity values with WC (92.9%), and HiC (85.3%) have the highest specificity. WHtR (86.05, 80.5), SR (86.05, 82.7) and HiC (76.7, 87.0) sensitivity and specificity were the best indexes for DeFerranti's criteria. Based on this date, we concluded that HiC and WHtR might be helpful as auxiliary indexes for pediatric MetS definition; however, further studies are required in both genders.

1. Introduction

The metabolic syndrome (MetS) is a major risk factor for cardiovascular disease (CVD) and type 2 diabetes (T2D), and is defined by a clustering risk factors such as central obesity, impaired glucose metabolism, lipid profile disorders and hypertension [1]. There is a high prevalence of obesity as a common feature of MetS, among the pediatric population in some countries, and this issue has become a problem in public health as it has in adults; furthermore, obesity is an increasing challenge for pediatric care [2]. Obesity has been associated with the risk of some important pediatric diseases and as well with future risk of chronic diseases in adulthood [3]. Also, there is an association between obesity and MetS. However, the definition of MetS in pediatric individuals is controversial [4]. Many

* Corresponding author. Tel.: +985138002288.
** Corresponding author. Tel: +985138002288.
E-mail addresses: Bahramihr@mums.ac.ir (H. Bahrami-Taghanaki), ghayourm@mums.ac.ir (M. Ghayour-Mobarhan).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.dsx.2019.03.032
1871-4021/

studies have suggested criteria for MetS in pediatrics [5–8]. But these definitions are difficult to apply because all of them have problems in taking account of the physiological changes in life period such as growth and puberty. Furthermore, puberty has an influence on fat distribution, insulin sensitivity in the muscle and liver, and insulin secretion by pancreatic cells [4]. Some researchers have tried to introduce other indices for the definition of MetS in pediatrics to allow a more accurate assessment of central obesity and determining of body fat distribution.

Anthropometric indices have been applied for monitoring of health status including determining diseases, nutritional status, growth, and development. These measures can provide the identification of differences in body proportion between populations and can also be optimized for the diagnosis and treatment [9–11]. Waist circumference is the most frequently used anthropometric parameter which that used to measure central obesity and to screen for the presence of MetS [12–14]. For determining the presence of obesity, two commonly used anthropometric parameters include body mass index (BMI), and the waist-hip ratio (WHR) [15]; but BMI cannot adequately distinguish fat from muscle mass, and some studies have showed that WHR is not suitable for assessing central obesity in Caucasian population [10,15–17]. Another anthropometric index that has been proposed to assess central obesity is the waist-to-height ratio (WHtR). Imaging techniques have been shown that this has a strong correlation with abdominal fat. The correction of WC for height appears to be applicable in different ethnic, age and sex groups, while WC requires a population-specific cut off values [18,19]. Some researchers have proposed wrist (WrC) and as measures for cardio-metabolic disorders [20]; but data used for predicting MetS, especially in pediatrics is limited. Alternate anthropometric indexes may offer a simple, cost-effective, reproducible and easily applied measure for screening and monitoring of MetS in pediatrics. Therefore, this study investigated the association of some other anthropometric indices with the presence of MetS in girls, and aimed to identify the best anthropometric predictor for pediatric MetS in this population.

2. Materials and methods

2.1. Subjects

The studied population was composed of nine hundred eighty-eight schoolgirls aged between 12 and 18 years (14.56 ± 1.53), who were resident in the cities of Mashhad and Sabzevar in Khorasan Razavi province of Iran. The girls were recruited using a random cluster sampling approach. Written consent has been given from the subject or her parents if needed. This study was approved by Mashhad University of medical sciences Ethics Committee.

2.2. Anthropometric measurements

We were used standard methods to take anthropometric measures of weight (to the nearest 0.1 kg) and height (to the nearest 0.1 cm), and waist and hip circumferences at the sites defined by WHO. Data calculated from these measurements included BMI and waist-to-hip ratio (WHR). Due to differences in the obesity cut off in Iranian children with standard cut off, BMI percentiles were calculated based on Persian population data obtained from the CASPIAN study [21]. The wrist circumference was measured using a procedure previously used by Capizzi et al. [20]. Body frame size (r) was calculated using WrC/Height.

2.3. MetS definition

We used four common criteria for MetS: IDF [6], NCEP-ATPIII [8], Cook et al. [5], and De Ferranti et al. [7] definition for classification of subjects in groups with or without MetS. The latter two are modified versions of the NCEP criteria. These definitions are the most widely used, criteria for MetS for pediatrics, so were used for this study.

2.4. Statistical analyses

The Kolmogorov-Smirnov test examined normality of data. Data are presented as the mean ± standard deviation (SD) for normal variables. Independent *t*-test was used to compare measures between the subjects with and without risk factors. Point-biserial correlation tests were used for the estimation of the relation of quantitative and dichotomous variables [22]. These results were confirmed by using multi-variant regression tests.

All statistical analyses were performed using programs available in the SPSS version 15.0 statistical package for Windows (SPSS Inc., Chicago, IL, USA). P-value <0.05 was considered as significant. The area under curve (AUC) was computed using receiver operating characteristic curve (ROC). ROC analysis was performed using MedCalc software version 15.8 (MedCalc Software, Ostend, Belgium) by DeLong (1988) function. Sensitivity and specificity of each index for different MetS definition computed by Yandex index in MedCalc.

3. Results

Comparisons of means of several anthropometric parameters used in several definitions of MetS are shown in Table 1. In this study, the younger children have a higher prevalence for MetS. In all the definitions, weight was significantly different between the subject with and without MetS. Age differences were significant only in subjects categorized by IDF definition ($P = 0.042$). As expected, waist circumference (WC) values were significantly higher in individuals with MetS using all the definitions ($P < 0.001$). In all currently used adopted definitions, wrist circumference (WrC) and hip circumference (HiC) were lower in healthy participants than subjects with MetS ($P < 0.001$).

Our findings showed that significantly higher values for anthropometric indices including WHR, WHtR, BMI, SR and WSR were found in subjects with MetS compared to non-MetS individuals ($P < 0.001$), while body frame size index (r) had significantly lower values in MetS group for all adopted definition which that used in this study ($P < 0.05$).

Association of anthropometric indexes with four different MetS definitions is shown in Table 2. These correlation coefficients was computed by point-biserial correlation which that use to estimating of relationship between dichotomous and continuous variables. Age and body frame size were shown to have a negative association with all definitions, but the associations with age were not significant. To dispense with the weak correlations; height has a significant correlation with all definitions except De Ferranti's criteria ($r = 0.024$ ($P = 0.46$)). The r index that represent body frame size or WrC to height ratio showed the significant negative correlation with IDF ($r = -0.106$ ($P = 0.001$)), NCEP-ATP III ($r = -0.124$ ($P = 0.0001$)), Cook's ($r = -0.131$ ($P = 0.0001$)), and DeFerranti's ($r = -0.192$ ($P = 0.0001$)). Weight, WHtR, BMI, and HiC among studied anthropometrics had the strongest association with different MetS definition. According to these findings, SR showed one of the strongest associations with MetS based DeFerranti's criteria.

In all adopted definitions except DeFerranti's, WHtR and weight had a higher association in following WC which that used as an accepted criterion. In the DeFerranti's definition, BMI had a higher coefficient than WHtR and weight. WHR has been revealed that has

Table 1
Means of several anthropometric indexes in four different MetS definition.

Anthropometric indices	MetS definitions											
	IDF			NCEPT-ATP III			Cook et al.			De Ferranti et al.		
	Non-MetS	MetS	p	Non-MetS	MetS	p	Non-MetS	MetS	p	Non-MetS	MetS	p
Age (yrs.)	14.57 ± 0.49	13.75 ± 0.58	0.042	14.58 ± .049	14.12 ± .358	0.145	14.58 ± .049	13.79 ± .494	0.055	14.58 ± 0.05	14.16 ± .276	0.059
Height (cm)	157.59 ± 0.198	161.75 ± 1.64	0.019	157.56 ± .2	160.96 ± 1.04	0.005	157. 58 ± .199	162.00 ± 1.29	0.006	157.61 ± .201	158.33 ± .933	0.401
Weight (Kg)	52.58 ± 0.374	78.25 ± 4.33	0.0001	52.44 ± .368	70.46 ± 4.26	0.0001	52.52 ± .367	77.43 ± 6.07	0.0001	52.02 ± .358	71.53 ± 2.68	0.0001
WC (cm)	70.16 ± 8.8	90.75 ± 10.4	0.0001	70.04 ± 8.6	85.4 ± 13.95	0.0001	70.12 ± 8.7	90.9 ± 14.5	0.0001	69.7 ± 8.3	86.6 ± 10.9	0.0001
WrC (cm)	15.12 ± 0.036	16.75 ± 0.463	0.0001	15.1 ± .036	16.46 ± .366	0.0001	15.11 ± .036	17.00 ± .535	0.000	15.08 ± .035	16.4 ± .283	0.0001
HiC (cm)	91.57 ± 0.291	108.83 ± 2.87	0.0001	91.46 ± .248	104.67 ± 2.47	0.0001	91.54 ± .289	108.290 ± 3.42	0.0001	91.16 ± .284	105.21 ± 1.61	0.0001
WHtR	0.33 ± .07	0.48 ± .10	0.0001	0.33 ± .06	0.43 ± .12	0.0001	0.33 ± .06	0.47 ± .13	0.0001	0.33 ± .06	0.45 ± .10	0.0001
r	10.47 ± .77	9.73 ± .89	0.011	10.48 ± .76	9.86 ± .88	0.002	10.48 ± .76	9.62 ± .94	0.008	10.50 ± .73	9.77 ± 1.22	0.0001
WHR	0.76 ± .06	0.83 ± .04	0.0001	0.76 ± .06	0.81 ± .05	0.001	0.76 ± .06	0.84 ± .06	0.0001	0.76 ± .06	0.82 ± .04	0.0001
BMI	21.07 ± 4.16	30.1 ± 6.92	0.0001	21.03 ± 4.1	27.08 ± 7.47	0.0001	21.06 ± 4.12	29.41 ± 8.2	0.002	20.84 ± 3.87	28.47 ± 6.47	0.0001
SR	0.58 ± 0.05	0.67 ± 0.07	0.001	0.58 ± 0.05	0.65 ± 0.07	0.0001	0.58 ± 0.05	0.66 ± 0.07	0.001	0.58 ± 0.05	0.66 ± 0.06	0.0001
WSR	120.8 ± 10.1	134.74 ± 8.4	0.0001	120.7 ± 10.1	130. 85 ± 10.06	0.0001	120.75 ± 10.9	135.6 ± 10.0	0.0001	120.54 ± 10.1	130.15 ± 9.02	0.0001

WC: Waist circumference; WrC: Wrist circumference; HiC: Hip circumference; WHtR: waist circumference to height ratio; r: Body frame size or wrist to height ratio; WHR: Waist to hip ratio; BMI: body mass index; WSR: Waist circumference to stature ratio and, SR: stature ratio (Hip to height ratio). All data computed by mean ± SD and $p < 0.05$ have been considered as a significant level.

weakest association with MetS definitions except DeFerranti's, in later definition, WHR (r = 0.190 (P = 0.0001)) only stronger than WSR (r = 0.180 (P = 0.0001)).

WC showed the greatest AUC for all studied definition, WC followed by WHtR (0.941 (0.925-0.955)) and HiC (0.933 (0.915-0.948)) in IDF definition, in NCEPT-ATPIII definition HiC (0.832 (0.738-0.926)) and SR (0.815 (0.726- 0.905)) have largest AUC after WC, as well in MetS based on Cook et al. criteria, HiC (0.894 (0.802- 0.986)) and WHtR (0.891 (0.785- 0.996)) have largest AUC, in addition in DeFerranti's definition BMI (0.889 (0.843- 0.935)) and SR (0.886 (0.843- 0.929)) following WC (Table 3, Fig. 1).

As showed in Table 4, in subjects which that categorized by IDF definition, HiC, WHtR, BMI, and SR showed sensitivity as much as WC (100.00%). HiC (85.20%) and WHtR (84.66%) showed the highest specificity for IDF after WC as adopted criterion. In an interesting manner in NCEP-ATP III, WC showed lower sensitivity contributed to r (87.50%), and WSR (83.33%), while the specificity of WC (87.58%), HiC (85.76%) and WHtR (84.99%) have been highest percentages.

Our findings showed that HiC, WHtR, WrC, BMI, and SR have equal sensitivity with WC (92.86%) in Cook's definition; but regarding specificity, HiC has highest value (85.28%) after WC (87.18%). Considering the DeFerranti's definition, WHtR and SR showed the highest sensitivity equally (86.05%) and HiC revealed the highest specificity (86.98%) even more than WC (85.05%) (Table 4).

4. Discussion

We intended to study the association between several anthropometric indices with four definitions of MetS in a pediatric population. Our findings showed that frequently used anthropometric parameters have significantly higher values in MetS than in non-MetS. Only body frame size that determined with r index was higher in non-MetS individuals. We found that often indexes used in this study showed a positive correlation with four different definitions which that adopted for children and adolescents except for r index. In general, hip circumference (HiC) and WHtR showed the largest AUC among the other indices in three definitions, only in DeFerranti et al. definition BMI and SR have larger AUC than HiC and WHtR.

To date, it is known that abdominal obesity plays a significant role in metabolic diseases including metabolic syndrome, diabetes, and dyslipidemia. In recent MetS introduced as one of the major problems for health care especially in pediatrics, this problem has been interested in developing countries such as Iran which that have a lower prevalence of obesity among children [10]. In spite of the importance of pediatric MetS, there is no overall consensus and comprehensive definition. Often existed definitions adopted from adult definitions which that no considered physiological changes during growth and puberty in children and adolescent [4]. With increasing of the prevalence of obesity in pediatric age groups and relation of obesity with many metabolic and cardiovascular diseases, many investigators searching the new ways to identify who at risk of obesity-related disorder such as MetS. Some biochemical marker and anthropometric indexes maybe good indicator for MetS in pediatrics; but anthropometrics are cost-effective measures especially in population-based studies.

Previous research has shown that there is relationship between some anthropometric indexes and CVD risk factor among adults [11,18], therefore due to limited studies and different age groups in investigations in children and adolescents, the correlation of anthropometric indices and risk factors of the MetS have been confusing. Variation in growth rate and fat distribution pattern among different population [23] resulted to development of some

Table 2
The association of anthropometric data with the presence of MetS based on four common definitions used in children.

Anthropometric indices	MetS definitions[b]			
	IDF	NCEPT-ATP III	Cook's	De Ferranti's
Age (yrs.)	-.061 (.064)	−0.045 (.155)	−0.061 (.055)	−0.056 (.079)
Height (cm)	0.074 (.021)	0.085 (.008)	0.085 (.008)	0.024 (.46)
Weight (Kg)	0.238 (.0001)	0.234 (.000)	0.249 (.0001)	0.336 (.0001)
[a]WC (cm)	0.250 (.0001)	0.262 (.0001)	0.272 (.0001)	0.382 (.0001)
WrC (cm)	0.158 (.0001)	0.184 (.0001)	0.197 (.0001)	0.237 (.0001)
HiC (cm)	0.208 (.0001)	0.224 (.0001)	0.218 (.0001)	0.316 (.0001)
WHtR	0.239 (.0001)	0.231 (.0001)	0.245 (.0001)	0.356 (.0001)
r	−0.106 (.001)	−0.124 (.0001)	−0.131 (.0001)	−0.192 (.0001)
WHR	0.119 (.0001)	0.117 (.0001)	0.136 (.0001)	0.190 (.0001)
BMI	0.231 (.0001)	0.218 (.0001)	0.231 (.0001)	0.364 (.0001)
SR	0.191 (.0001)	0.201 (.0001)	0.193 (.0001)	0.330 (.0001)
WSR	0.140 (.0001)	0.143 (.0001)	0.161 (.0001)	0.180 (.0001)

WC: Waist circumference; WrC: Wrist circumference; HiC: Hip circumference; WHtR: waist circumference to height ratio; r: Body frame size or wrist to height ratio; WHR: Waist to hip ratio; BMI: body mass index; WSR: Waist circumference to stature ratio and, SR: stature ratio (Hip to height ratio). $P < 0.05$ have been considered a significant level and showed in parenthesis.
[a] WC identified and accepted as central obesity in many MetS criteria, and illustrated in this table for comparison of other indexes for standard ones.
[b] Point-biserial correlation has been used for estimation of correlation coefficients between dichotomous and quantitative variables.

Table 3
The AUC of anthropometrics with MetS based four common definitions.

Anthropometric indices	MetS definitions			
	IDF	NCEPT-ATP III	Cook et al.	De Ferranti et al.
*WC (cm)	.952 (.937−.965)	.848 (.765−.931)	.924 (.856−.992)	.922 (.891−.953)
WrC (cm)	.823 (.797−.846)	.763 (.667−.860)	.891 (.785−.996)	.783 (.713−.853)
HiC (cm)	.933 (.915−.948)	.832 (.738−.926)	.894 (.802−.986)	.874 (.825−.922)
WHtR	.941 (.925−.955)	.808 (.702−.914)	.891 (.785−.996)	.883 (.833−.932)
r	.737 (.632−841)	.707 (.606−.808)	.764 (.662−.866)	.782 (.708−.856)
WHR	.861 (.798−.924)	.740 (.648−.831)	.833 (.742−.924)	.817 (.766−.869)
BMI	.927 (.893−.961)	.800 (.696−.903)	.880 (.781−.980)	.889 (.843−.935)
SR	.899 (.858−941)	.815 (.726−.905)	.869 (.789−.949)	.886 (.843−.929)
WSR	.884 (.821−.947)	.783 (.702−863)	.871 (.791−.951)	.787 (.724−.849)

AUC (CI 95%); WC: Waist circumference; WrC: Wrist circumference; HiC: Hip circumference; WHtR: waist circumference to height ratio; r: Body frame size or wrist to height ratio; WHR: Waist to hip ratio; BMI: body mass index; WSR: Waist circumference to stature ratio and, SR: stature ratio (Hip to height ratio). WC identified and accepted as central obesity in many MetS criteria, and illustrated in this table for comparison of other indexes for standard ones.

applicable and straightforward anthropometrics for the screening of at-risk individuals; instant BMI and WC have been shown that accurate measures for prediction of MetS in girls [9].

Wang et al. found that WC showed high AUC for predicting of MetS, and do not have a significant difference with both genders. Therefore in baseline all indexes play a substantial role in MetS diagnosis [11], in this case, WC also showed the highest AUC among studied indexes, but this study enrolled girls and further validation in boys is needed.

Some research introduced WC as the best predictor of CVD risk factors such as MetS components [14], but in other studies, WC and waist circumference to stature ratio (WSR) were best indexes for CVD [24]. Among Iranian girls based on age groups, best predictors have been different. BMI and WSR; WC and WSR; and WC have been found as the best predictor in 6–9.9, 10–13.9 and 14–18-year-age groups respectively [10]. In the present study that covers almost nearby age group, WC and WHtR showed the best prediction for MetS; but there was no strong association between WSR and pediatric MetS in our population. These different results may arise from ethical and geographical differences between WC, HiC and height which that used to determine of WSR, or different in definitions have been used in two studies.

Kelishadi et al. [10] have reported that WC and WHR showed the strongest and weakest association with the used definition of MetS. As well, among Sweden determined similar results [25]. Our findings showed that WC and WHtR are good predictors but WHR was one of the weakest indexes, so these findings could be confirmed two research that mentioned above.

The odds of MetS increased with increasing BMI and WC among normal weight adolescents [1]. In adolescents, regardless of BMI, WC was also a strong predictor of insulin resistance [12,13]. Studies among children of European, Turkish and Arab race determined that BMI was better predictor from WHR [15–17]. In present research also BMI was better WHR than in all different definitions have been used.

In the opinion of some researchers, WHtR may be a useful as sex and age-specific BMI percentiles to identify children with CVD risk factors [26]. In this study, BMI showed a better association with MetS than some anthropometrics such as WHR, WSR and stature ratio (SR) in all studied definition and WHtR observed more than better BMI. Freedman et al. concluded that there is no different between BMI and WHtR for recognizing of adolescents at risk of CVD [27], while in another study WHtR showed strong association with CVD risk factor more than BMI [24,26]. ROC analysis indicated that WHtR and BMI mean values had the largest area under the curve for some CVD risk factors [28]. As well, WHtR was found as best predictor of metabolic risk in both genders [29], in another research, WHtR, WC and BMI were significant predictors for cardiometabolic disorders such as diabetes and CVD [30], almost the same results observed in the present study and WC, WHtR, BMI and HiC showed the strongest association with MetS in pediatrics. However, BMI could not show fat distribution pattern and not capable for distinguished fat from muscle mass, while WHtR correlation with abdominal fat proved by imaging methods, so WHtR determined as

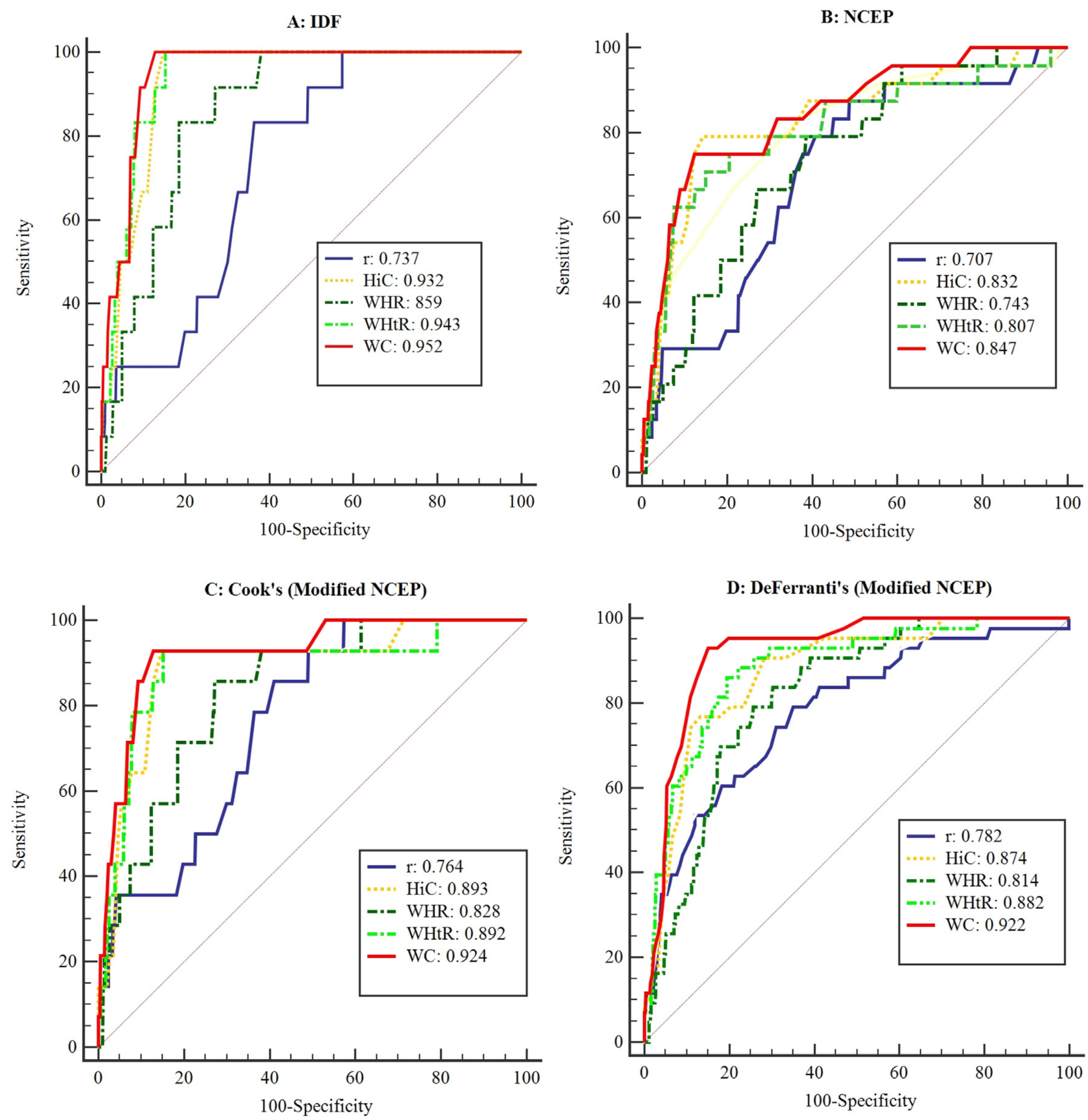

Fig. 1. ROC for some anthropometric indices for the four different definitions of MetS. AUC of anthropometrics illustrated for A: IDF, B: NCEP, C: Cook's and D: DeFerranti's definitions. WC used as an accepted measure in applied criteria, WHR as a marker for central obesity, WHtR, and HiC with high sensitivity and specificity in often used criteria in this study and r (body frame size) as a measure with negative correlation with criteria. r or body frame size: dark blue; HiC: yellow dash; WHR: dark green dash; WHtR: pale green dash and WC: red.

Table 4
ROC analysis for anthropometrics for different definitions of MetS.

Anthropometric indices	MetS definitions							
	IDF		NCEPT-ATP III		Cook's		De Ferranti's	
	Sens.	Spec.	Sens.	Spec.	Sens.	Spec.	Sens.	Spec.
*WC (cm)	100.00	87.11	75.00	87.58	92.86	87.18	93.02	85.05
WrC (cm)	91.7	65.30	79.17	65.75	92.86	84.73	79.09	66.67
HiC (cm)	100.00	85.20	79.17	85.76	92.86	85.28	76.74	86.98
WHtR	100.00	84.66	70.83	84.99	92.86	84.73	86.05	80.47
r	83.33	63.56	87.50	51.22	85.71	58.97	79.07	64.94
WHR	83.33	81.28	79.17	61.34	85.71	72.71	79.07	74.24
BMI	100.00	83.30	70.83	83.62	92.86	83.37	83.72	84.90
SR	100.00	81.43	75.00	81.83	92.86	81.49	86.05	82.72
WSR	91.67	82.65	83.33	60.06	85.71	82.72	67.44	79.57

WC identified and accepted as central obesity in many MetS criteria, and illustrated in this table for comparison of other indexes for standard ones. WC: Waist circumference; WrC: Wrist circumference; HiC: Hip circumference; WHtR: waist circumference to height ratio; r: Body frame size or wrist to height ratio; WHR: Waist to hip ratio; BMI: body mass index; WSR: Waist circumference to stature ratio and, SR: stature ratio (Hip to height ratio).

fat distribution index and may be preferred to BMI.

WrC has been showed association with cardio-metabolic risk factors but has significantly inverse with HDL-C, also among obese Italian children have been observed significant association between WrC and insulin levels or homeostasis model assessment of insulin resistance (HOMA-IR) [20]. We also found the associations of WrC with MetS in all four different criteria had been used; even in Cook et al. definition, WrC showed one of the largest AUC and highest sensitivity and specificity with MetS.

It should be noted that the study population is only composed of schoolgirl children who cannot represent of the general population and functionality of studied indexes for diagnosis of pediatric MetS in boys is not clear with these data. In final, further study for determining of applicability of these indices is needed.

5. Conclusion

MetS in children and adolescents is related to future risk of chronic diseases in adulthood. One the major risk factor for MetS is central obesity, which also is a major feature in T2D and CVD. In spite of important of pediatric MetS for health care and increasing prevalence of it among children and adolescent, there is no clear definition for it in pediatrics. One reason for this problem in pediatric MetS definition is the lack of standard measurement for growth and puberty. As well, neither of applied measures capable of determining fat distribution pattern as enough as suitable. Accordingly, some studies suggest a simple, low cost, reproducible and easily applied measure to the prediction of pediatric MetS including anthropometric indices.

According to our findings, we concluded that WHtR and HiC might be useful for the diagnosis of MetS in this population as excessive indexes in addition to the standard criterion for central obesity such as WC or BMI; but further research needs to confirm these suggestions and prove the way of applying these indices in pediatric MetS definitions.

Acknowledgments

This study was granted by Mashhad University of Medical Sciences and Sabzevar University of Medical Sciences (No: 95091).

References

[1] Qorbani M, et al. Association of anthropometric measures with cardiovascular risk factors and metabolic syndrome in normal-weight children and adolescents: the CASPIAN III study. Obes Facts 2013;6(5):483–92.
[2] Batsis JA, Nieto-Martinez RE, Lopez-Jimenez F. Metabolic syndrome: from global epidemiology to individualized medicine. Clin Pharmacol Ther 2007;82(5):509–24.
[3] Williams CL, Strobino BA. Childhood diet, overweight, and CVD risk factors: the Healthy Start project. Prev Cardiol 2008;11(1):11–20.
[4] Zimmet P, et al. The metabolic syndrome in children and adolescents. Lancet 2007;369(9579):2059–61.
[5] Cook S, et al. Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988-1994. Arch Pediatr Adolesc Med 2003;157(8):821–7.
[6] Zimmet P, et al. The metabolic syndrome in children and adolescents - an IDF consensus report. Pediatr Diabetes 2007;8(5):299–306.
[7] de Ferranti SD, et al. Prevalence of the metabolic syndrome in American adolescents: findings from the third national health and nutrition examination survey. Circulation 2004;110(16):2494–7.
[8] Expert Panel on Detection, E. and A. Treatment of High Blood Cholesterol in. Executive summary of the third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III). J Am Med Assoc 2001;285(19):2486–97.
[9] Andaki AC, et al. Anthropometry and physical activity level in the prediction of metabolic syndrome in children. Publ Health Nutr 2014;17(10):2287–94.
[10] Kelishadi R, et al. Paediatric metabolic syndrome and associated anthropometric indices: the CASPIAN Study. Acta Paediatr 2006;95(12):1625–34.
[11] Wang H, et al. Comparison of anthropometric indices for predicting the risk of metabolic syndrome and its components in Chinese adults: a prospective, longitudinal study. BMJ Open 2017;7(9):e016062.
[12] Lee S, et al. Waist circumference is an independent predictor of insulin resistance in black and white youths. J Pediatr 2006;148(2):188–94.
[13] Camhi SM, Kuo J, Young DR. Identifying adolescent metabolic syndrome using body mass index and waist circumference. Prev Chronic Dis 2008;5(4):A115.
[14] Hirschler V, et al. Can waist circumference identify children with the metabolic syndrome? Arch Pediatr Adolesc Med 2005;159(8):740–4.
[15] Al-Attas OS, et al. Association of body mass index, sagittal abdominal diameter and waist-hip ratio with cardiometabolic risk factors and adipocytokines in Arab children and adolescents. BMC Pediatr 2012;12:119.
[16] Agirbasli M, et al. Comparison of anthropometric indices in predicting metabolic syndrome components in children. Metab Syndrome Relat Disord 2011;9(6):453–9.
[17] Larsson C, Hernell O, Lind T. Moderately elevated body mass index is associated with metabolic variables and cardiovascular risk factors in Swedish children. Acta Paediatr 2011;100(1):102–8.
[18] Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. Obes Rev 2012;13(3):275–86.
[19] Yoo EG. Waist-to-height ratio as a screening tool for obesity and cardiometabolic risk. Korean J Pediatr 2016;59(11):425–31.
[20] Capizzi M, et al. Wrist circumference is a clinical marker of insulin resistance in overweight and obese children and adolescents. Circulation 2011;123(16):1757–62.
[21] Kelishadi R, et al. Percentiles for anthropometric measures in Iranian children and adolescents: the CASPIAN-IV study. J Pediatr Endocrinol Metab 2016;29(9):1069–76.
[22] Demirtas H, Hedeker D. Computing the point-biserial correlation under any underlying continuous distribution. Commun Stat Simulat Comput 2016;45(8):2744–51.
[23] Goran MI, et al. Visceral fat in white and African American prepubertal children. Am J Clin Nutr 1997;65(6):1703–8.
[24] Savva SC, et al. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000;24(11):1453–8.
[25] Neovius M, Linne Y, Rossner S. BMI, waist-circumference and waist-hip-ratio as diagnostic tests for fatness in adolescents. Int J Obes (Lond) 2005;29(2):163–9.
[26] Kahn HS, Imperatore G, Cheng YJ. A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. J Pediatr 2005;146(4):482–8.
[27] Freedman DS, et al. Relation of body mass index and waist-to-height ratio to cardiovascular disease risk factors in children and adolescents: the Bogalusa Heart Study. Am J Clin Nutr 2007;86(1):33–40.
[28] Ribeiro RC, et al. Association of the waist-to-height ratio with cardiovascular risk factors in children and adolescents: the three cities heart study. Int J Prev Med 2010;1(1):39–49.
[29] Bosy-Westphal A, et al. Value of body fat mass vs anthropometric obesity indices in the assessment of metabolic risk factors. Int J Obes (Lond) 2006;30(3):475–83.
[30] Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev 2010;23(2):247–69.