Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity
https://doi.org/10.1007/s40519-020-00971-y

ORIGINAL ARTICLE

A comparison between body mass index and waist circumference for identifying continuous metabolic syndrome risk score components in Iranian school-aged children using a structural equation modeling approach: the CASPIAN-V study

Hanieh-Sadat Ejtahed[1,2] · Zohreh Mahmoodi[3] · Mostafa Qorbani[4,5] · Pooneh Angoorani[1] · Mohammad Esmaeil Motlagh[6] · Shirin Hasani-Ranjbar[1] · Hasan Ziaodini[7] · Majzoubeh Taheri[7] · Ramin Heshmat[5] · Roya Kelishadi[7]

Received: 13 June 2020 / Accepted: 25 July 2020

Abstract

Purpose The purpose of this study was to investigate the association of anthropometric indices with continuous metabolic syndrome (cMetS) risk score components in a large population-based sample of children and adolescents.

Methods This multi-centric study was performed on 3843 students aged 7–18 years who were selected by multistage, stratified cluster sampling method from 30 provinces of Iran. Demographic, anthropometric and biochemical factors were obtained and standardized residuals (*z*-scores) were calculated for MetS components. A structural equation modeling approach was applied to evaluate the relationships among the study variables and to implement the subsequent structural modeling.

Results The mean age of the participants (52.3% boys) was 12.4 ± 3.05 years. Standardized scores of body mass index (ZBMI) and waist circumference (ZWC) had a direct effect on standardized scores of mean arterial pressure (ZMAP) (0.23 and 0.24 in boys and 0.22 and 0.23 in girls, respectively) and triglyceride (ZTG) (0.07 and 0.04 in boys and 0.02 and 0.06 in girls, respectively), but the effect of ZWC was stronger than ZBMI on these variables. Age, socioeconomic status and sedentary behaviors showed a positive direct effect on ZWC (0.01, 0.05 and 0.07 in boys and 0.05, 0.08 and 0.002 in girls, respectively). These variables induced indirect effects on cMets risk score components through ZWC.

Conclusion The magnitude of association between WC and continuous metabolic syndrome risk score components was higher compared to BMI in school-aged children, emphasizing on paying more attention to central obesity in childhood.

Level of evidence Level V, cross-sectional descriptive study.

Keywords Continuous metabolic syndrome · Path analysis · Waist circumference

Abbreviations

BMI	Body mass index
cMetS	Continuous metabolic syndrome
DBP	Diastolic blood pressure
FBG	Fasting blood glucose
HDL-C	High-density lipoprotein-cholesterol

✉ Mostafa Qorbani
mqorbani1379@yahoo.com

✉ Ramin Heshmat

1 Obesity and Eating Habits Research Center, Endocrinology and Metabolism Clinical Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran

2 Endocrinology and Metabolism Research Center, Endocrinology and Metabolism Clinical Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran

3 Social Determinants of Health Research Center, Alborz University of Medical Sciences, Karaj, Iran

4 Department of Biostatistics and Epidemiology, School of Health, Non-communicable Diseases Research Center, Alborz University of Medical Sciences, Karaj, Iran

5 Chronic Diseases Research Center, Endocrinology and Metabolism Population Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran

6 Department of Pediatrics, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

7 Department of Pediatrics, Child Growth and Development Research Center, Research Institute for Primordial Prevention of Non-communicable Disease, Isfahan University of Medical Sciences, Isfahan, Iran

Published online: 09 August 2020

SBP	Systolic blood pressure
ST	Screen time
SES	Socioeconomic status
TG	Triglyceride
MAP	Mean arterial pressure
WC	Waist circumference

Background

Metabolic syndrome (MetS) in adults is usually described as a constellation of abdominal adiposity, elevated levels of serum triglycerides (TG) and glucose, high blood pressure (BP), as well as low serum high-density lipoprotein-cholesterol (HDL-C) [1, 2]. Many studies in children and adolescents considering the same modified cutoff points, as used in adults, for each component which could be the reason of some controversies among epidemiologic studies as well as the low prevalence of MetS in some populations [3]. Accordingly, using a continuous score has been suggested in the former, instead of a dichotomous one [4]. Different methods have been used to calculate a continuous metabolic syndrome (cMetS) score from its components including principal component analysis, standardized residuals of Z-scores, and centile rankings [5]. Compared with binary definition of MetS, cMetS is more sensitive and less error-prone and might increase the statistical power particularly at early stages of metabolic abnormalities [6]. Although the association of obesity with higher risk of MetS is firmly established, it needs to be clarified at a population level, especially during periods of childhood, adolescence, and adulthood. The relationship between general and central obesity with MetS components can be better dissected using a multivariate multistage model like path analysis (structural equation modeling). Path analysis model is more complicated and realistic than multiple regression with its single dependent variable [7]. This approach has been previously used to examine the interrelationships among the components of MetS in selected groups of patients and adults [8]. Since there are limited evidences that determine the association between anthropometric measures and cMetS using path analysis method and also it is not obvious which of body mass index (BMI) or waist circumference (WC) can better identify cMetS risk score in children and adolescents, the current study aimed to assess association of anthropometric measures with cMetS risk score components and compare BMI and WC for identifying cMetS risk score components in children and adolescents using a path analysis.

Materials and methods

Study population

This study was performed on 3843 students aged 7–18 years who were selected by multistage, stratified cluster sampling method from 14,138 participant of fifth phase of a national school-based study entitled "Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease" (CASPIAN-V). The details of sampling and operation of the study has been described previously [9]. The study protocol was approved by the Research and Ethics Council of Isfahan University of Medical Sciences (code: 194049). Written informed consent and verbal assent were obtained from all the parents and students, respectively.

Procedures and measurements

The demographic questionnaire was completed for participants. The screen time (ST) was considered as the average number of hours per day spent watching television, leisure time use of computer using a validated questionnaire [10]. For calculating the family's socioeconomic status (SES), we included questions about the following socioeconomic indicators: (a) parental level of education (illiterate: score 1, less than high school: score 2, high school graduate: score 3, academic education: score 4); (b) parental occupational status (unemployed: score 1, worker/farmer: score 2, governmental employee: score 3, self-employed: score 4); (c) number of inhabitants in home, and (d) possessing a family private car (yes/no). Of note for questions (a) and (b) (i.e., parental occupational status and level of education) data from the parent with a higher occupational status/education was considered.

Trained healthcare providers measured the weight and height of students and parents. Height was measured in a standing position to the nearest 0.5 cm, without shoes. Weight was measured on a scale placed on a flat ground to the nearest 0.1 kg while the subjects were minimally clothed [11]. Body mass index (BMI) was calculated as weight (kg) divided by square of height (m^2). Waist circumference (WC) was measured at the point midway between the lower border of the rib cage and the iliac crest at the end of normal expiration to the nearest 0.1 cm by trained staff. It was measured two times and the average was registered [12]. Blood pressure (BP) was measured twice using a standardized mercury sphygmomanometer on the right arm after a 15-min rest in a sitting position; the first and fifth Korotkoff sounds were recorded as systolic blood pressure (SBP) and diastolic blood pressure (DBP), respectively. The mean of the two measurements was considered as the subject's blood pressure. Mean arterial pressure (MAP) was calculated using the following equation: $MAP = [SBP - DBP)/3] + DBP$ [13]. Fasting blood samples were obtained from students after 12–14 h of overnight fast. Fasting blood glucose (FBG), total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), and triglycerides (TG) were measured enzymatically by Hitachi auto-analyzer (Tokyo, Japan) [14]. The cMetS score was computed by standardizing the residuals (z-scores) of WC, MAP, HDL-C, TG, and FBG by regressing them according to age and sex to account for age and gender related differences. It should be noted that HDL-C was multiplied by—1, as it is inversely related to MetS risk. The methodology of the cMetS score calculation in details has been reported previously [15].

Statistical analysis

All variables were checked for normality. Continuous variables were expressed as means (standard deviation, SD), and categorical data as number (percentage). Student's two-tailed t test was applied to compare the mean differences of general characteristics and standardized components of cMetS between boys and girls. The Pearson correlation coefficient was calculated to evaluate the relationships among the variables. Afterwards, path analysis was applied to examine the relation of anthropometric measures with continuous metabolic syndrome. Path analysis was applied to evaluate the relationships among the study variables and to implement the subsequent structural modeling. Path analysis is an extension of the regression model that allows estimation of the strength and sign of directional relationships for complicated causal schemes with multiple dependent variables [7]. Figure 1 presents our conceptual model based on previous findings in the literature. Regarding the fitness indices of models in path analysis, the preferred value of normed fit index, comparative fit index, goodness of fit index, and adjusted goodness of fit index is above 0.9. About the root mean square error of approximation criteria, score ≤ 0.05 indicates a good fit, and score up to 0.08 is acceptable [16]. SPSS-16 and Lisrel-8.8 software were used for data analysis with the application of path analysis.

Results

Totally, 3844 students (52.3% boys; mean age 12.4 ± 3.05 years) were assessed in this study. As observed in Table 1, there were no significant differences in general characteristics and cMetS score components between boys and girls except for mean age and SES ($p = 0.02$, $p < 0.001$).

The correlation among demographic, clinical and biomedical variables according to sex is presented in Table 2. For boys, ZBMI was positively correlated with ZMAP and ZTG but negatively with age. For girls, ZBMI was positively correlated with ZMAP and ZHDL. In both genders, a moderate correlation was observed between ZBMI and ZMAP ($r = 0.228$ for boys and $r = 0.219$ for girls). The other correlation coefficients which were statistically significant had weak amounts. ZWC in both sexes was positively correlated with ZMAP, SES and ST. Moreover, there was a negative correlation between ZWC and age in girls. ZWC showed strong correlation with ZBMI in both genders ($r = 0.544$ for girls and $r = 0.571$ for boys).

Table 3 illustrates the direct effect of each variable on cMetS risk score components according to sex. ST and SES in both groups had a significant positive direct effect on ZWC. The direct effect of ST on ZWC was greater in boys than girls (0.068 vs 0.001), while the direct effect of SES on ZWC was lower in boys than girls (0.050 vs 0.084). The direct effect of ST and SES on other outcome variables was not significant. Age had a negative direct effect on ZBMI in both genders, but it was significant only in boys (−0.047). Age showed a positive direct effect on ZWC which was

Table 1 General characteristics and continuous metabolic syndrome score components according to sex

Variable	Total ($n = 3844$)	Male ($n = 2013$)	Female ($n = 1831$)	P value
Age (year)	12.45 ± 3.049	12.63 ± 3.026	12.27 ± 3.064	0.00
SES (score)	−0.0132 ± 0.988	0.0211 ± 0.99	−0.05098 ± 0.975	0.02
ST (hour)	1.24 ± 0.654	1.25 ± 0.67	1.237 ± 0.635	0.54
ZWC	−0.045 ± 1.02	−0.07534 ± 1.06	−0.0123 ± .9628	0.06
ZBMI	−0.03162 ± 1.0007	−0. 02094 ± 0.99	−0.04336 ± 1.006	0.48
ZMAP	−0.049 ± .966	−0.044 ± 0.99	−0.055 ± .935	0.715
ZTG	0.00 ± .999	0.000 ± 1.007	0.00 ± .991	1
ZHDL	0.00 ± .999	0.000 ± 1.01	0.00 ± .981	1
ZFBS	0.00 ± .999	0.00 ± 1.06	0.00 ± .920	1

Table 2 Matrix for Pearson correlation among studied variable according to sex

		ZTG	ZHDL	ZMAP	ZFBS	AGE	SES	ST	ZBMI	ZWC
ZTG	Boys (n: 2013)	1	0.236*	0.039	0.155*	−0.003	−0.01	0.007	0.069**	0.001
	Girls (n: 1831)	1	0.291*	0.006	0.186*	0.003	0.004	0.002	0.018	0.011
ZHDL	Boys (n: 2013)		1	0.024	−0.013	0.058*	−0.031	0.005	0.007	0.00
	Girls (n: 1831)		1	−0.012	−0.006	−0.066*	0.002	0.025	0.06*	0.056*
ZMAP	Boys (n: 2013)			1	0.018	0.018	0.050*	0.024	0.228*	0.239*
	Girls (n: 1831)			1	0.02	0.008	−0.029	−0.012	0.219*	0.226*
ZFBS	Boys (n: 2013)				1	−0.006	0.004	0.008	−0.006	0.001
	Girls (n: 1831)				1	0.008	0.06*	−0.013	−0.006	0.022
Age	Boys (n: 2013)					1	−0.09*	0.054*	−0.048*	0.006
	Girls (n: 1831)					1	−0.020	0.032	−0.008	−0.05*
SES	Boys (n: 2013)						1	0.049*	0.039	0.053*
	Girls (n: 1831)						1	0.32	0.039	0.08*
ST	Boys (n: 2013)							1	0.005	0.07*
	Girls (n: 1831)							1	0.006	0.001*
ZBMI	Boys (n: 2013)								1	0.571*
	Girls (n: 1831)								1	0.544*
ZWC	Boys (n: 2013)									1
	Girls (n: 1831)									1

ST screen time, *SES* socioeconomic status, *ZWC* Z score of waist circumference, ZBMI: Z score of body mass index; ZFBS: Z score of fasting blood sugar; ZHDL: Z score of high – density lipoprotein; ZTG: Z score of triglyceride

*Statistically significant

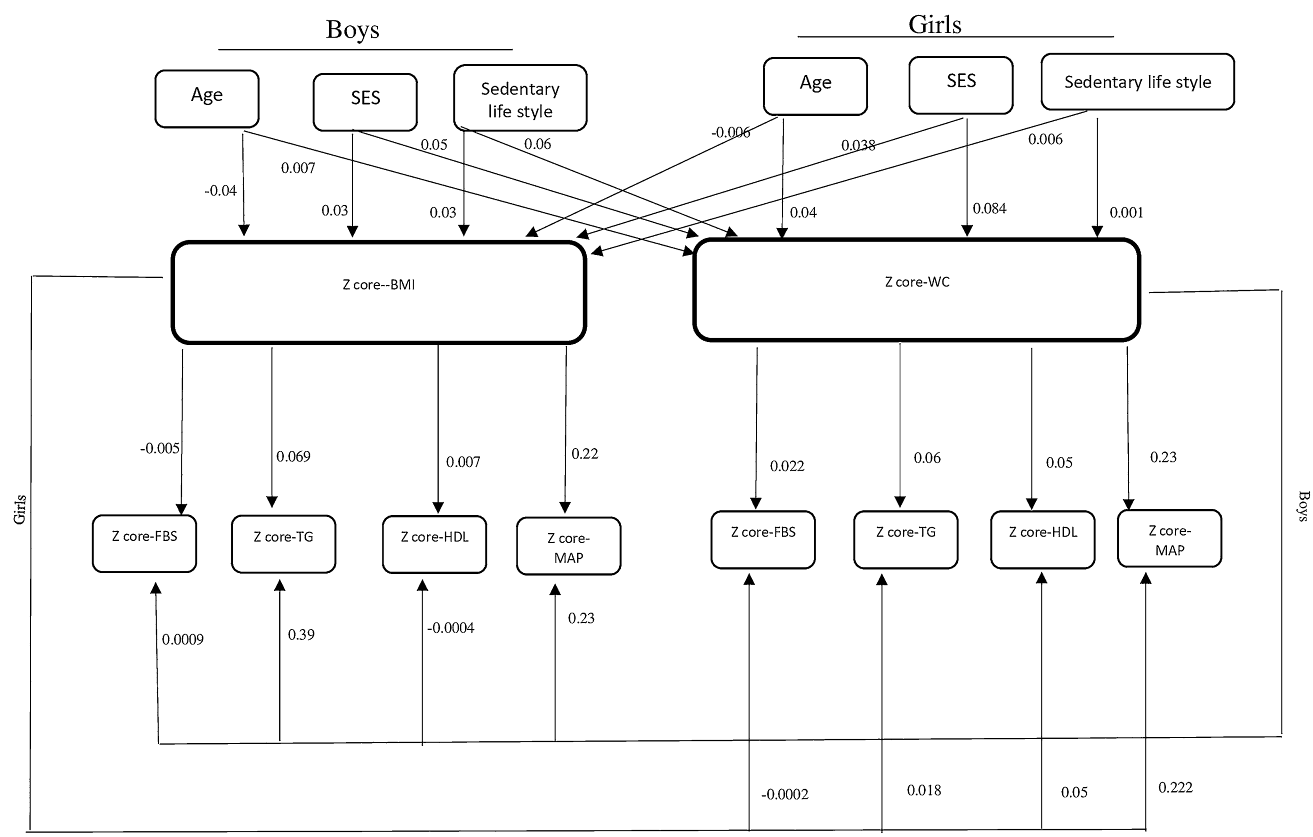

Fig. 1 Path analysis diagram of association of anthropometric measure and general characteristics with cMetS score components for boys and girls

significant only in girls. ZBMI and ZWC showed a significant direct effect on ZMAP in both sexes, which were greater in boys than girls (0.23 vs 0.22 and 0.24 vs 0.023, respectively). ZBMI and ZWC were directly associated with ZTG in both sexes. The direct effect of ZBMI on ZTG was greater in boys than girls (0.069 vs 0.018), while the direct effect of ZWC on ZTG was lower in boys than girls (0.039 vs 0.060). Totally in both genders, the direct effect of ZWC was stronger than ZBMI on ZMAP and ZTG. The direct effect of ZBMI on ZHDL was significant only in girls (0.059). In order to measure the indirect effects of age, SES and ST on our outcome variables, we analyzed their standardized β of indirect effects. All of these three variables showed significant slight indirect effects on ZMAP in both sexes. The results of statistical analysis evaluating the validity of our models are characterized in Table 4 which shows the overall fitness of four models was good. The path analysis diagrams of association of anthropometric measure and general characteristics with cMetS score components for boys and girls are shown in Fig. 1.

Discussion

Path analysis is a powerful statistical model in evaluating a complex cluster of dependent variables. This model is more complicated and realistic than multiple regression models with its single dependent variable [7]. The validity of anthropometric measures as easy, reputable and low-cost indicators for predicting MetS risk in Iranian children and adolescents was determined in previous CASPIAN studies [17, 18]. We previously in a liner regression model documented that higher anthropometric indices are associated with higher cMetS risk score in children and adolescents [19]. Here, we extend our previous work by evaluating the direct and indirect effect of ZBMI and ZWC, as pivotal indices, on cMets risk score components according to sex. Our study also provided new data regarding the effect of three predictive variables including age, sedentary behaviors and SES on ZBMI and ZWC. In this study, sedentary behaviors and SES in both groups were positively correlated with ZWC but not ZBMI. Age had significant effect on ZBMI and ZWC. The direct effect of age on ZBMI was negative, but on ZWC was positive in both genders. It means that in children and adolescents, by increasing age, increasing hours of sedentary behaviors and increasing level of SES, the tendency of accumulating fat centrally increases in spite of not changing or even decreased level of BMI. These results confirm the findings that WC can change independently of BMI [20]. Previous studies on children and adolescents revealed that WC is a better marker of metabolic risk factors than BMI and it was shown that children with a high BMI and high WC were twice as likely to have increased levels of TG and insulin and Mets, when compared to those who had a normal WC but high BMI [20–22]. Therefore, it seems that BMI by itself does not suffice for monitoring obesity and related metabolic complications in school-aged children, and it is suggested paying more attention to WC as predominant underlying risk factor for development of MetS in this age group. Comparison between BMI and other anthropometric indices such as tri-ponderal mass index (TMI) in Iranian children and adolescents demonstrated that TMI was a better predictor of MetS than BMI in both genders [23].

Another point in the current study is the relationship of higher SES with higher ZWC. We previously showed that higher SES was associated with unhealthy diet and inactive lifestyle in Iranian school children [24]. During the last decades, because of a rapid nutritional transition in Iran, the trend toward high-calorie diet and sedentary lifestyle has increased [25, 26]. It has been shown that in Iran similar to some other developing countries, the children in families with high SES have more preference to Western diets such as fast foods and they also spend a considerable part of their time with sedentary entertainments, such as watching television, playing computer games, and surfing the Internet which in turn lead to more fat accumulation and overweight in this group [27–29]. In PERSIAN cohort study, a negative association has been reported between SES and the level of physical activity, which in turn can lead to overweight and obesity among the high-SES population in Iran [30]. However, in contrast to our findings, some studies documented different results. In two recent papers on Mediterranean diet in school-aged children, the nutrition transition and the risk of obesity was more evident in children with low SES [31, 32]. This controversy may partly derive from the economical conditions in Iran as nutrition transition in a country as Iran could be more evident in high-SES families that in low-SES families, different from other countries. It seems that SES as a significant determinant of health [33] has intricate and multidimensional format, which needs to be standardized for each community.

In the present study, among different components of cMetS, ZBMI and ZWC showed a significant direct effect on ZMAP and ZTG in both sexes, but the effect of ZWC was stronger than ZBMI on these variables. It should be mentioned that in our models, age, sedentary behaviors and SES impressed indirect effects on cMets risk score components through ZWC.

These results are consistent with several population studies which documented the close correlation between central obesity and MetS components [34–36]. The Bogalusa Heart Study showed that the distribution of central fat determined by WC was associated with abnormal concentrations of TG, LDL-C, HDL-C, and insulin in children and adolescents at the ages of 5-17 yeas [37]. It was shown that the association of BP with WC was stronger than those with BMI implicating that visceral fat is the primary etiological component of

Table 3 Direct effect of each variable on continuous metabolic risk score components according to sex

	Boys		Girls	
	Estimate	Standardized estimate	Estimate	Standardized estimate
ZWC → ZMAP	0.2222*	0.2390*	0.2245*	0.2310*
ZBMI → ZMAP	0.2272*	0.2277*	0.2048*	0.2202*
Age → ZBMI	− 0.015*	− 0.0470*	− 0.002	− 0.006
SES → ZBMI	0.0334	0.0335	0.039	0.038
ST → ZBMI	0.047	0.0320	0.0107	0.0067
Age → ZWC	0.0025	0.0071	0.015*	0.048*
SES → ZWC	0.0539*	0.0504*	0.0831*	0.0842*
ST → ZWC	0.0109*	0.0685*	0.0025*	0.0016*
ZBMI → ZFBS	− 0.0059	− 0.0055	− 0.0002	− 0.0002
ZWC → ZFBS	0.0009	0.0009	0.0214	0.0224
ZBMI → ZTG	0.0699*	0.0690*	0.0178*	0.0181*
ZWC → ZTG	0.0372*	0.0394*	0.0609*	0.0606*
ZBMI → ZHDL	0.0073	0.0071	0.0581*	0.0595*
ZWC → ZHDL	− 0.0004	− 0.0004	0.057	0.0561

ST screen time, *SES* socioeconomic status, *ZWC* Z score of waist circumference, *ZBMI* Z score of body mass index, *ZFBS* Z score of fasting blood sugar, *ZHDL* Z score of high-density lipoprotein, *ZTG* Z score of triglyceride

*Statistically significant

excess adiposity underlying the development of adiposity-related hypertension [38].

Since high fat mass during childhood and adolescence is associated with higher blood pressure and unfavorable metabolic profile, childhood nominates as an important period for interventions to manage obesity to minimize long-term metabolic abnormalities. This syndrome may have developed due to unhealthy diet, lack of exercise, overweight and central obesity [39, 40].

Compared to the previous studies regarding the parameters correlated with MetS in pediatrics, this study has the strength of using the path analysis in a large sample size. However, it had some limitations. First, the cross-sectional nature of study cannot demonstrate a causative relationship. Second, the information on SES and sedentary behaviors was obtained by self-report which may affect the estimates by under- or over-reporting. Third, some effective factors on MetS including dietary pattern, pubertal stage and smoking habits were not assessed in this study.

Conclusion

This is the first study using path analysis to ascertain the association of anthropometric measures with cMetS risk score components among a nationally representative sample of Iranian children and adolescents. We demonstrated that ZBMI and ZWC had a direct effect on ZMAP in both sexes, but the effect of ZWC was slightly stronger than ZBMI on this variable. In our models, age, sedentary behaviors and SES impressed indirect effects on cMets risk score components through ZWC. We suggest paying more attention to WC and other central obesity markers in childhood, as the substantial preventive strategy for MetS in this age group.

What is already known on this subject?

The interrelationships among the components of MetS in adults have been assessed. However, it is not obvious whether body mass index (BMI) or waist circumference (WC) can better identify cMetS risk score in children and adolescents.

What does this study add?

This is the first study using path analysis to ascertain the association of anthropometric measures with cMetS risk score components among a nationally representative sample of Iranian children and adolescents. We showed that the effect of ZWC was stronger than ZBMI on cMets risk score components.

Table 4 Characteristics of the goodness of fit of path analysis model

Model		X^2	Df	CFI	GFI	NFI	RMSEA	AGFI
ZBMI	Boys	173.29	26	0.95	0.97	0.97	0.076	0.95
	Girls	236.8	27	0.93	0.96	0.95	0.077	0.92
ZWC	Boys	177.02	28	0.96	0.97	0.97	0.066	0.95
	Girls	235.90	26	0.88	0.96	0.96	0.067	0.92

ZWC Z score of waist circumference, *ZBMI* Z score of body mass index, *df* degree of freedom, *CFI* comparative Fit Index, *GFI* goodness of fit index, *RMSEA* root mean square error of approximation, *AGFI* adjusted goodness of fit index

Acknowledgements The authors are thankful to all participants and large team working on this project in different provinces. We appreciate Isfahan University of Medical Sciences and other relevant national regulatory organizations (Project number: 194049) for supporting this project. The funder had only a supporting role in this project.

Author contributions The concept of this study was proposed by H-SE, MQ. This study was designed by RH, MQ, RK. Data collection or processing was done by RH, MEM, ZM, PA, H-SE, SH, HZ, MT. Analysis or interpretation was performed by H-SE, MQ, PA, ZM. Literature search was done by H-SE, MQ, PA. This study was written by H-SE., PA. All authors have read and approved the manuscript.

Funding This study was funded by Isfahan University of Medical Sciences.

Availability of data and materials The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethics approval The study protocol was approved by the Research and Ethics Council of Isfahan University of Medical Sciences (code: 194049).

Consent to participate Written informed consent and verbal assent were obtained from all the parents and students, respectively.

Consent for publication Not applicable.

References

1. Ahrens W, Moreno L, Mårild S, Molnár D, Siani A, De Henauw S et al (2014) Metabolic syndrome in young children: definitions and results of the IDEFICS study. Int J Obes 38(S2):S4. https://doi.org/10.1038/ijo.2014.130
2. Hwang I-C, Kim K-K, Jee S-H, Kang H-C (2011) Comparison of predictability of cardiovascular events between each metabolic component in patients with metabolic syndrome based on the revised national cholesterol education program criteria. Yonsei Med J 52(2):220–226. https://doi.org/10.3349/ymj.2011.52.2.220
3. Heshmat R, Heidari M, Ejtahed H-S, Motlagh ME, Mahdavi-Gorab A, Ziaodini H et al (2017) Validity of a continuous metabolic syndrome score as an index for modeling metabolic syndrome in children and adolescents: the CASPIAN-V study. Diabetol Metab Syndr 9(1):89. https://doi.org/10.1186/s13098-017-0291-4
4. Kahn R, Buse J, Ferrannini E, Stern M (2005) The metabolic syndrome: time for a critical appraisal. Diabetologia 48(9):1684–1699. https://doi.org/10.1007/s00125-005-1876-2
5. Pandit D, Chiplonkar S, Khadilkar A, Kinare A, Khadilkar V (2011) Efficacy of a continuous metabolic syndrome score in Indian children for detecting subclinical atherosclerotic risk. Int J Obes 35(10):1318. https://doi.org/10.1038/ijo.2011.138
6. Viitasalo A, Lakka TA, Laaksonen DE, Savonen K, Lakka H-M, Hassinen M et al (2014) Validation of metabolic syndrome score by confirmatory factor analysis in children and adults and prediction of cardiometabolic outcomes in adults. Diabetologia 57(5):940–949. https://doi.org/10.1007/s00125-014-3172-5
7. Streiner DL (2005) Finding our way: an introduction to path analysis. Can J Psychiatry 50(2):115–122. https://doi.org/10.1177/070674370505000207
8. Chen W, Srinivasan SR, Berenson GS (2008) Path analysis of metabolic syndrome components in black versus white children, adolescents, and adults: the Bogalusa Heart Study. Ann Epidemiol 18(2):85–91. https://doi.org/10.1016/j.annepidem.2007.07.090
9. Motlagh ME, Ziaodini H, Qorbani M, Taheri M, Aminaei T, Goodarzi A et al (2017) Methodology and early findings of the fifth survey of childhood and adolescence surveillance and prevention of adult noncommunicable disease: the CASPIAN-V study. Int J Prev Med. https://doi.org/10.4103/2008-7802.198915
10. Kelishadi R, Majdzadeh R, Motlagh M-E, Heshmat R, Aminaee T, Ardalan G et al (2012) Development and evaluation of a questionnaire for assessment of determinants of weight disorders among children and adolescents: the Caspian-IV study. Int J Prev Med 3(10):699
11. Expert W (1995) Committee on physical status. Physical status: the use and interpretation of anthropometry. WHO Tech Rep Ser. https://doi.org/10.1093/ajcn/64.4.650
12. Organization WH (1995) The use and interpretation of anthropometry: report of a WHO expert committee. WHO Tech Rep Ser 854:312–409
13. Meaney E, Alva F, Moguel R, Meaney A, Alva J, Webel R (2000) Formula and nomogram for the sphygmomanometric calculation of the mean arterial pressure. Heart 84(1):64. https://doi.org/10.1136/heart.84.1.64
14. McNamara JR, Schaefer EJ (1987) Automated enzymatic standardized lipid analyses for plasma and lipoprotein fractions. Clin Chim Acta 166(1):1–8. https://doi.org/10.1016/0009-8981(87)90188-4
15. Shafiee G, Kelishadi R, Heshmat R, Qorbani M, Motlagh ME, Aminaee T et al (2013) First report on the validity of a continuous metabolic syndrome score as an indicator for Metabolic Syndrome in a national sample of paediatric population—the CASPIAN-III study. Endokrynol Pol 64(4):278–284. https://doi.org/10.5603/ep.2013.0006
16. Vieira AL (2011) Interactive LISREL in practice: Springer link. https://doi.org/10.1007/978-3-642-18044-6
17. Yazdi M, Assadi F, Qorbani M, Danieli SS, Heshmat R, Motlagh ME et al (2020) Validity of anthropometric indices in predicting high blood pressure risk factors in Iranian children and adolescents: CASPIAN-V study. J Clin Hypertens 22(6):1009–1017. https://doi.org/10.1111/jch.13895
18. Angoorani P, Heshmat R, Ejtahed HS, Motlagh MS, Ziaodini H, Taheri M et al (2018) Validity of triglyceride–glucose index as an indicator for metabolic syndrome in children and adolescents: the CASPIAN-V study. Eat Weight Disord 23(6):877–883. https://doi.org/10.1007/s40519-018-0488-z
19. Ejtahed HS, Qorbani M, Motlagh ME, Angoorani P, Hasani-Ranjbar S, Ziaodini H et al (2018) Association of anthropometric indices with continuous metabolic syndrome in children and adolescents: the CASPIAN-V study. Eat Weight Disord 23(5):597–604. https://doi.org/10.15171/jcvtr.2019.xx
20. Janssen I, Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C et al (2005) Combined influence of body mass index and waist circumference on coronary artery disease risk factors among children and adolescents. J Pediatr 115(6):1623–1630. https://doi.org/10.1542/peds.2004-2588
21. Ejtahed HS, Kelishadi R, Qorbani M, Motlagh ME, Hasani-Ranjbar S, Angorani P et al (2019) Utility of waist circumference-to-height ratio as a screening tool for generalized and central obesity among iranian children and adolescents: the CASPIAN-V study. Pediatr diabetes. https://doi.org/10.1111/pedi.12855

22. Downs SM, Marshall D, Ng C, Willows ND (2008) Central adiposity and associated lifestyle factors in Cree children. Appl Physiol Nutr Metab 33(3):476–482. https://doi.org/10.1139/H08-027
23. Khoshhali M, Heidari-Beni M, Qorbani M, Motlagh MS, Ziaodini H, Heshmat R et al (2020) Tri-ponderal mass index and body mass index in prediction of pediatric metabolic syndrome: the CASPIAN-V study. Arch Endocrinol Metab 64(2):171–178. https://doi.org/10.20945/2359-3997000000206
24. Kelishadi R, Motlagh ME, Roomizadeh P, Abtahi SH, Qorbani M, Taslimi M et al (2013) First report on path analysis for cardiometabolic components in a nationally representative sample of pediatric population in the Middle East and North Africa (MENA): the CASPIAN-III Study. Ann Nutr Metab 62(3):257–265. https://doi.org/10.1159/000346489
25. Golzarand M, Mirmiran P, Jessri M, Toolabi K, Mojarrad M, Azizi F (2012) Dietary trends in the Middle East and North Africa: an ecological study (1961 to 2007). Public Health Nutr 15(10):1835–1844. https://doi.org/10.1017/S1368980011003673
26. Ejtahed HS, Bahadoran Z, Mirmiran P, Azizi F (2015) Sugar-sweetened beverage consumption is associated with metabolic syndrome in iranian adults: tehran lipid and glucose study. Endocrinol Metab (Seoul) 30(3):334–342. https://doi.org/10.3803/EnM.2015.30.3.334
27. Angoorani P, Heshmat R, Ejtahed HS, Qorbani M, Motlagh ME, Ziaodini H et al (2017) Body weight misperception and health-related factors among Iranian children and adolescents: the CASPIAN-V study. J Pediatr Endocrinol Metab 30(10):1033–1040. https://doi.org/10.1515/jpem-2017-0149
28. Mohammadpour-Ahranjani B, Abdollahi M, Angoorani P, Adab P (2011) Weight status and psychological health among children in Tehran. Proc Nutr Soc. https://doi.org/10.1017/s0029665111000255
29. Wang Y (2001) Cross-national comparison of childhood obesity: the epidemic and the relationship between obesity and socioeconomic status. Inter J Epidemiol 30(5):1129–1136. https://doi.org/10.1093/ije/30.5.1129
30. Karyani AK, Matin BK, Soltani S, Rezaei S, Soofi M, Salimi Y et al (2019) Socioeconomic gradient in physical activity: findings from the PERSIAN cohort study. BMC Public Health 19(1):1312. https://doi.org/10.1186/s12889-019-7715-z
31. Voltas N, Arija V, Aparicio E, Canals J (2016) Longitudinal study of psychopathological, anthropometric and sociodemographic factors related to the level of Mediterranean diet adherence in a community sample of Spanish adolescents. Public Health Nutr 19(10):1812–1822. https://doi.org/10.1017/S1368980015003560
32. Archero F, Ricotti R, Solito A, Carrera D, Civello F, Di Bella R et al (2018) Adherence to the Mediterranean diet among school children and adolescents living in northern Italy and unhealthy food behaviors associated to overweight. Nutrients 10(9):1322. https://doi.org/10.3390/nu10091322
33. Wilkinson RG, Marmot M. Social determinants of health: the solid facts: World Health Organization; 2003
34. Scaglione R, Di Chiara T, Cariello T, Licata G (2010) Visceral obesity and metabolic syndrome: two faces of the same medal? Intern Emerg Med 5(2):111–119. https://doi.org/10.1007/s11739-009-0332-6
35. Licata G, Argano C, Di TC, Parrinello G, Scaglione R (2006) Obesity: a main factor of metabolic syndrome? Panminerva Med 48(2):77–85 **PMID: 16953145**
36. González-Cortés CA, Téran-García M, Luevano-Contreras C, Portales-Pérez DP, Vargas-Morales JM, Cubillas-Tejeda AC et al (2019) Neck circumference and its association with cardiometabolic risk factors in pediatric population. Medicina 55(5):183. https://doi.org/10.3390/medicina55050183
37. Freedman DS, Kahn HS, Mei Z, Grummer-Strawn LM, Dietz WH, Srinivasan SR et al (2007) 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 86(1):33–40. https://doi.org/10.1093/ajcn/86.1.33
38. Malden D, Lacey B, Emberson J, Karpe F, Allen N, Bennett D et al (2019) Body fat distribution and systolic blood pressure in 10,000 adults with whole-body imaging: UK Biobank and Oxford BioBank. Obes. https://doi.org/10.1002/oby.22509
39. Fernandes J, Lofgren IE (2011) Prevalence of metabolic syndrome and individual criteria in college students. J Am Coll Health 59(4):313–321. https://doi.org/10.1080/07448481.2010.508084
40. Tabrizi A, Gholipour M (2016) Determination of obesity indices cut-off points for predicting metabolic syndrome in inactive college students. Iran J Diabetes Obes. 8(4):157–163