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

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Abstract

Background

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

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 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.

Conclusions

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

Background

Metabolic syndrome (MetS) in adults is generally defined as a coexistence 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 use the adult definitions with modified cutoff points for each component which could be the cause of controversial findings across epidemiologic studies as well as the low prevalence of MetS in some populations (3). In this regard, using a continuous score has been suggested in children and adolescents 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 associated 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 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 (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 the strength and sign of directional relationships for complicated causal schemes with multiple dependent variables (16). 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 (17). 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 was 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 the most correlation was observed between ZBMI and ZMAP ($r = 0.228$ for boys and $r = 0.219$ for girls). ZWC in both sexes was positively correlated with ZMAP, SES and ST. There was a negative correlation between ZWC and age in girls. ZWC showed the most correlation with ZMAP in both genders ($r = 0.544$ for girls and $r = 0.571$ for boys).

Table 1: General characteristics and continuous metabolic syndrome score components according to sex				
variable	n = 3844))Total	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	Boy(n: 2013)	1	0.236*	0.039	0.155*	-0.003	-0.01	0.007	0.069**	0.001
	Girl(n: 1831)	1	0.291*	0.006	0.186*	0.003	0.004	0.002	0.018	0.011
ZHDL	Boy(n: 2013)		1	0.024	-0.013	0.058*	-0.031	0.005	0.007	0.00
	Girl(n: 1831)		1	-0.012	-0.006	-0.066*	0.002	0.025	0.06*	0.056*
ZMAP	Boy(n: 2013)			1	0.018	0.018	0.050*	0.024	0.228*	0.239*
	Girl(n: 1831)			1	0.02	0.008	-0.029	-0.012	0.219*	0.226*
ZFBS	Boy(n: 2013)				1	-0.006	0.004	0.008	-0.006	0.001
	Girl(n: 1831)				1	0.008	0.06*	-0.013	-0.006	0.022
Age	Boy(n: 2013)					1	-0.09*	0.054*	-0.048*	0.006
	Girl(n: 1831)					1	-0.020	0.032	-0.008	-0.05*
SES	Boy(n: 2013)						1	0.049*	0.039	0.053*
	Girl(n: 1831)						1	0.32	0.039	0.08*
ST	Boy(n: 2013)							1	0.005	0.07*
	Girl(n: 1831)							1	0.006	0.001*
ZBMI	Boy(n: 2013)								1	0.571*

		ZTG	ZHDL	ZMAP	ZFBS	AGE	SES	ST	ZBMI	ZWC
	Girl (n: 1831)								1	0.544*
ZWC	Boy(n: 2013)									1
	Girl (n: 1831)									1
*Statistically significant 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										

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 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 .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.

Table 3: Direct effect of each variable on continuous metabolic risk score components according to sex				
	Boy		Girl	
	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
* Statistically significant 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				

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

Model		χ^2	df	CFI	GFI	NFI	RMSEA	AGFI
ZBMI	Boy	173.29	26	0.95	0.97	0.97	0.076	0.95
	Girl	236.8	27	0.93	0.96	0.95	0.077	0.92
ZWC	Boy	177.02	28	0.96	0.97	0.97	0.066	0.95
	Girl	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								

Discussion

We assessed the relationship between anthropometric measures with cMetS risk score components in a large, nationally representative sample of children and adolescents using the structural equation modeling. 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 with its single dependent variable (7). We previously in a liner regression model documented that higher anthropometric indices are associated with higher cMetS risk score in children and adolescents (18). 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 (19). 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 (19–21). 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.

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 (22). During the last decades, because of a rapid nutritional transition in Iran, the trend toward high-calorie diet and sedentary lifestyle has increased (23, 24). It has been shown that in Iran similar to some 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 (25–27).

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 in consistent with several population studies which documented the close correlation between central obesity and MetS components (28–30). 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 years (31). 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 excess adiposity underlying the development of adiposity-related hypertension (32).

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 developed by unhealthy diet, lack of exercise, overweight and central obesity (33, 34).

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 and ZTG in both sexes, but the effect of ZWC was stronger than ZBMI on these variables. 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.

Abbreviations

BMI	body mass index
cMetS	continuous metabolic syndrome
DBP	diastolic blood pressure
FBG	Fasting blood glucose
HDL-C	high density lipoprotein-cholesterol
SBP	systolic blood pressure
ST	screen time
SES	socioeconomic status
TG	triglyceride
MAP	mean arterial pressure
WC	waist circumference

Declarations

Ethics declarations and consent to participate

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.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

The concept of this study was proposed by H.-S.E., M.Q., This study was designed R.H., M.Q., R.K., Data collection or processing was done by R.H., M.E.M., Z.M., P.A., H.-S.E., S.H., H.Z., M.T., Analysis or interpretation was performed by H.-S.E., M.Q., P.A., Z.M. Literature search was done by H.-S.E., M.Q., P.A. This study was written by H.-S.E., P.A. All authors have read and approved the manuscript.

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Figures

Figure1: Path analysis diagrams of association of anthropometric measures and general characteristics with continuous metabolic risk score components according to sex

Figure 1

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