Generalized or Abdominal Obesity: Which One Better Identifies Cardiometabolic Risk Factors among Children and Adolescents? The CASPIAN III Study

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Summary

Objectives: We investigated the association of generalized and abdominal obesity with cardiometabolic risk factors in children and adolescents.

Methods: Data were obtained from a surveillance system entitled CASPIAN-III study in school students aged 10–18 years in Iran. Data of subjects with normal body mass index (BMI) or above (BMI $\geq$ 5th percentile) were analyzed. The associations of obesity with cardiometabolic risk factors were tested using logistic regression models.

Results: In the sample of 4641 children and adolescents, overweight/obese children were more likely to have metabolic syndrome and cardiometabolic risk factors compared with their normal weight counterparts. Among these parameters, elevated TG had the strongest association with degree of obesity (overweight: OR = 2.28 [95% CI 1.59–3.26]; obesity: OR = 5.63 [95% CI 4.27,7.43]). Combined

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generalized and abdominal obesity increased the risk of high blood pressure, elevated triglyceride and total cholesterol.
Conclusions: Combined type of generalized and abdominal obesity is a predictor of cardiometabolic risk factors.

Key words: generalized obesity, abdominal obesity, children, metabolic syndrome, cardiometabolic risk, Iran.

Introduction

Obesity is increasing rapidly among children and adolescents in developed and developing countries [1, 2]. Some studies in adults and fewer in children showed associations between obesity with cardiometabolic risk factors [3, 4]. On the other hand, adolescence obesity and its associated cardiovascular risk and comorbidities have substantial tracking into adulthood [1, 5]. Therefore, the diagnosis of childhood and adolescence obesity can provide an early identification of cardiovascular risk.

Although measures of abdominal obesity, such as waist circumference, waist to hip ratio and waist to height ratio (WHtR), are more often associated with cardiovascular risk than with generalized obesity in adults [6–14], this association in children and adolescents is yet to be elucidated. A previous study that assessed the association between fat distribution and cardiovascular risk in children showed that both types of obesity are linked to high blood pressure in Italian children [15]. However, the sensitivity and specificity of these measures to detect high blood pressure was low in Brazilian adolescents, although the clustered use of both types of obesity improved the sensitivity [16]. Recently, a study in Chinese children and adolescents revealed that abdominal obesity is more strongly associated with MetS and its components than the generalized obesity. In addition, combination of these types of obesity was even the best predictor [17].

These conflicting results suggest that superiority of generalized obesity or abdominal obesity for predicting cardiometabolic risk factors in children and adolescents is debated. The purpose of this study was to investigate the association of generalized and abdominal obesity with cardiometabolic risk factors in a nationally representative sample of Iranian adolescents.

Subjects & methods

The methodology has been explained elsewhere [18]. In brief, CASPIAN is a national school-based survey entitled the 'Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease'. This program is surveillance of the risk behaviors and risk factors of chronic diseases among children and adolescents. The data for the current study were obtained from the CASPIAN-III study (2009–10), which was conducted in 27 provinces of Iran. A total of 5570 students aged 10–18 years were selected by multistage random cluster sampling from eligible schools.

Study protocols were approved by ethical committees. A written informed consent and verbal consent was obtained from the parents and students; respectively. Demographic and health-related information were collected using self-administered questionnaires or by trained health care professionals. Data of 4641 adolescents with a normal body mass index (BMI) or above (BMI$\geq$5th percentile) who had complete records were analyzed.

Anthropometric and biochemical measurements

Weight and height were measured, and BMI was calculated. Waist circumference was measured at a point midway between the lower border of the rib cage and the iliac crest at the end of normal expiration, and WHtR was calculated. Using a mercury sphygmomanometer, systolic (SBP) and diastolic (DBP) blood pressure were measured three times at 2-min intervals, and the average was considered as the actual value.

Fasting serum levels of blood sugar (FBS), total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-C) and triglycerides (TG) were measured using enzymatic method (Pars Azmoon, Tehran, Iran) in the central provincial laboratory in Tehran. Low-density lipoprotein-cholesterol (LDL-C) was calculated according to Friedewald's formula [19].

Diagnostic criteria

BMI 5th–85th percentile was considered as normal weight, 85th–95th percentile as overweight and higher than 95th percentile of the study population as generalized obesity. Abdominal obesity was defined as WHtR > 0.5 [20]. Based on both adiposity indexes, the sample was stratified into: (i) normal adolescents (without overweight/obesity and abdominal obesity); (ii) overweight/obesity; (iii) abdominal obesity; (iv) only general overweight/obesity (subjects with abdominal obesity removed); (v) only abdominal obesity (subjects with general obesity removed); and (vi) both general overweight/obesity and abdominal obesity.

Subjects were classified as having metabolic syndrome (MetS) if they had at least three of the

followings: TG $\geq$150 mg/dL (1.7 mmol/L); HDL-C $\leq$ 40 mg/dL (1.03 mmol/L); Impaired fasting glucose (IFG) defined as FBS $\geq$100 mg/dL (5.6 mmol/L); WHtR > 0.5; and either SBP or DBP > 90th percentile for their age, sex and height [21]. TC $\geq$ 200 mg/dL (5.18 mmol/L) and LDL-C $\geq$130 mg/dL (3.36 mmol/L) was considered as abnormal. Prehypertension and hypertension were considered as the average systolic or diastolic blood pressure between 90th and 95th percentile, and $\geq$95th percentile; respectively. Dyslipidemia was defined if any of aforementioned serum lipids (TC, TG, LDL or HDL) were abnormal.

Statistical analyses

Data was analyzed using the statistical software SPSS version 16.0 for windows. The mean differences of continuous variables between genders or living areas (urban/rural) and BMI categories (normal weight/overweight/obese) were assessed by Student *t*-test and analysis of variance, respectively. The prevalence rates were compared across groups by chi-square test. Logistic regression analyses adjusted for age, sex and living area were used to assess associations between different types of obesity and MetS as well as cardiometabolic risk factors. *P*-values < 0.05 were considered as statistically significant.

Results

Participants were 4641 school students (2315 girls and 2326 boys) with mean age of 14.8 $\pm$ 2.4 years (Table 1). Numbers in tables may not add up to the total numbers due to missing data in some variables. Overall, 70.6% of the participants were from urban and 29.4% from rural areas.

Prevalence of obesity and metabolic disorders

As shown in Table 1, the overall prevalence of overweight and obesity among boys and girls was approximately 27 and 19%, respectively ($p < 0.001$). In addition, the prevalence was higher in urban than in rural areas, approximately 26 vs. 15% ($p < 0.001$). Abdominal obesity was slightly more prevalent in girls than in boys (20 vs. 18%; $p = 0.044$), and much more prevalent in urban participants compared with rural subjects (21 vs. 12%; $p < 0.001$). The prevalence of IFG, hypertension and MetS was significantly higher among girls than boys ($p < 0.01$); however, elevated TC was significantly more prevalent in boys than in girls (6.7 vs. 5.1%; $p = 0.036$). IFG, hypertension, elevated TC and LDL-C were significantly more prevalent in urban than rural residents ($p < 0.05$). In addition, MetS prevalence in urban participants was around two times higher than in rural adolescents (5.6 vs. 2.7%; $p = 0.001$).

Prevalence of abdominal obesity and metabolic disorders according to BMI categories

The prevalence of abdominal obesity was 7, 40 and 83% in normal weight, overweight and obese participant; respectively ($p < 0.001$). The difference in cardiometabolic risk factors prevalence across normal weight, overweight and obese groups were statistically significant ($p < 0.001$) except for IFG and elevated LDL-C. The prevalence of MetS was significantly higher in obese subjects than in their normal weight counterparts (20.0 vs. 1.8%) (Table 2).

Anthropometric measures and metabolic disorders according to BMI categories

The mean WHtR increased with greater BMI categories (*p-trend*< 0.001). Among cardiometabolic risk factors, mean SBP (but not DBP), FBS, TG and TC significantly increased, and HDL-C decreased according to higher BMI categories (Table 3).

Table 4 shows that among all types of obesity, adolescents with combined overweight/generalized and abdominal obesity had the highest prevalence of all cardiometabolic risk factors and MetS.

Association of different types and degrees of obesity with metabolic disorders

Logistic regression models show that overweight and obesity were associated with cardiometabolic risk factors. Among them, elevated TG had the strongest association with degree of obesity [overweight: OR = 2.28 (95% CI 1.59, 3.26); obesity: OR = 5.63 (95% CI 4.27, 7.43)]. Compared with normal weight adolescents, overweight and obese adolescents were more likely to have MetS [overweight: OR = 6.70 (95% CI 4.06, 11.06); obesity: OR = 14.74 (95% CI 9.58, 22.68)] (Table 5).

Likewise, the risk of having MetS was greatly higher in adolescents with abdominal obesity vs. their normal counterparts (without abdominal obesity) [OR = 35.3 (95% CI 21.3, 58.4)]. In addition, the likelihood of having cardiometabolic risk factors increased in participants with this type of obesity compared with those without abdominal obesity. Being only overweight did not affect the likelihood of cardiometabolic risk factors. However, the risk of hypertension, elevated TG and low HDL-C increased $\approx$1.5 to 2 times when overweight and abdominal obesity were clustered. It seems that generalized obesity and abdominal obesity had cumulative effect on risk of raised TG [OR = 5.22 (95% CI 3.95, 6.89)].

Discussion

In this study, associations of different types of obesity and their combinations were assessed on cardiometabolic risk factors in adolescents. We found a higher prevalence of overweight and obesity among boys and a higher prevalence of abdominal obesity, IFG, hypertension and MetS among girls. In

TABLE 1

Prevalence (%) of obesity, metabolic syndrome and cardiometabolic risk factors according to the sex and living area: the CASPIAN-III study

	Boys			Girls			All			All		
	Urban ($n=1600$)	Rural ($n=600$)	p value	Urban ($n=1573$)	Rural ($n=662$)	p value	Boys ($n=2326$)	Girls ($n=2315$)	p value	Urban ($n=3173$)	Rural ($n=1322$)	p value
Overweight (85th < BMI < 95th)	14.1	10.3	0.021	10.7	3.7	<0.001	13.0	8.9	<0.001	12.4	6.9	<0.001
Obesity (BMI > 95th)	14.8	11.7	0.069	12.0	5.0	<0.001	13.8	9.8	<0.001	13.4	8.2	<0.001
Abdominal obesity (WHtR > 0.5)	19.2	14.6	0.010	23.4	10.5	<0.001	17.8	19.6	0.044	21.3	12.5	<0.001
Overweight only (85th < BMI < 95th)	9.2	7.6	0.234	3.4	1.8	0.039	8.7	2.9	<0.001	6.3	4.7	0.035
Obesity only (BMI > 95th)	3.2	2.9	0.757	0.7	0.6	0.67	3.1	0.7	<0.001	1.9	1.7	0.680
Abdominal obesity only (WHtR > 0.5)	6.2	5.2	0.370	7.1	4.5	0.022	5.8	6.4	0.432	6.6	4.8	0.023
Generalized obesity and abdominal obesity	9.9	7.8	0.119	10.2	4.2	<0.001	9.2	8.4	0.439	10.0	6.0	<0.001
Overweight and abdominal obesity	3.2	1.7	0.044	6.1	1.7	<0.001	2.7	4.8	<0.001	4.6	1.7	<0.001
IFG	14.2	7.7	<0.001	20.2	14.4	0.003	12.1	18.4	<0.001	17.2	11.1	<0.001
Prehypertension	2.9	3.3	0.592	6.4	2.5	<0.001	3.0	6.4	<0.001	4.6	2.9	0.011
Hypertension	4.8	5.7	0.393	10.1	5.4	0.001	5.1	8.7	<0.001	7.4	5.6	0.036
High systolic blood pressure	2.6	4.2	0.053	6.2	3.5	0.016	3.0	5.4	<0.001	4.4	3.9	0.476
High diastolic blood pressure	2.5	2.4	0.857	5.9	2.5	0.001	2.5	4.9	<0.001	4.2	2.4	0.006
Elevated TG	8.1	10.5	0.096	9.2	7.9	0.384	8.8	8.8	0.827	8.6	9.2	0.567
Elevated TC	7.4	5.8	0.207	6.1	2.7	0.002	6.7	5.1	0.036	6.8	4.3	0.003
Elevated LDL-C	7.0	5.2	0.215	5.5	3.4	0.111	6.5	4.9	0.099	6.3	4.3	0.049
Low HDL-C	30.3	39.5	<0.001	35.3	41.9	0.011	33.0	37.3	0.071	32.7	40.7	<0.001
Dyslipidemia	39.9	47.4	0.012	43.0	49.6	0.031	42.1	44.9	0.148	41.4	8.5	0.001
MetS component (n)												
0	49.5	43.4		36.4	37.1		47.7	36.6		43.0	40.3	
1	33.9	39.0		40.9	47.9		35.3	42.9		37.4	3.4	
2	12.8	14.8	0.132	15.3	12.5	0.003	13.3	14.5	<0.001	14.0	13.6	0.001
3	3.5	2.9		5.7	2.5		3.3	4.7		4.6	2.7	
4	0.4	0.0		1.6	0.0		0.3	1.2		1.0	0.0	
5	–	–	–	0.1	0.0		0.0	0.07		0.1	0.0	
MetS	3.9	2.9	0.384	7.4	2.5	<0.001	3.6	5.9	0.003	5.6	2.7	0.001

Abbreviation: BMI, body mass index; WHtR, waist to height ratio; IFG, impaired fasting glucose; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; MetS, metabolic syndrome.

TABLE 2
Prevalence (%) of abdominal obesity, metabolic syndrome and cardiometabolic risk factors according to BMI categories: the CASPIAN-III study

Metabolic disorders	Normal weight ($n=3689$)	Overweight ($n=451$)	Obesity ($n=501$)	p value[a]
Abdominal obesity (WHtR > 0.5) (%)	7.5	40.31	82.63	<0.001
IFG	15.1	16.4	15.0	0.797
Prehypertension	3.5	5.1	7.3	<0.001
Hypertension	5.5	9.1	14.4	<0.001
High systolic blood pressure	3.1	6.2	10.8	<0.001
High diastolic blood pressure	3.1	4.9	6.5	<0.001
Elevated TG	6.3	11.9	25.5	<0.001
Elevated TC	5.1	7.5	10.2	<0.001
Elevated LDL-C	5.4	7.3	6.2	0.382
Low HDL-C	34.2	41.7	42.2	0.001
Dyslipidemia	40.8	54.4	56.2	<0.001
MetS component (n)				
0	48.3	28.6	6.8	
1	40.0	39.7	35.7	
2	9.9	21.2	37.5	
3	1.7	9.1	16.0	<0.001
4	0.2	1.4	3.7	
5	0.0	0.0	0.3	
MetS	1.9	10.4	20.0	<0.001

Abbreviation: WHtR, waist to height ratio; IFG, impaired fasting glucose; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein.
[a]p values for trend tests across BMI categories

TABLE 3
Anthropometric measures and cardiometabolic risk factors according to BMI categories: the CASPIAN-III Study

	Normal weight ($n=3689$)		Overweight ($n=451$)		Obesity ($n=501$)		p value[a]
	Mean	SD	Mean	SD	Mean	SD	
Weight (kg)	46.4	12.0	58.9	13.5	67.7	16.7	<0.001
Height (m)	154.97	13.93	156.28	12.94	154.90	14.56	0.580
Waist (cm)	67.7	19.9	76.2	10.7	84.6	13.0	<0.001
BMI (kg/m^2)	18.9	2.3	23.7	2.1	27.8	3.5	<0.001
WHtR	0.44	0.12	0.49	0.05	0.55	0.6	<0.001
Systolic blood pressure (mmHg)	103.2	13.4	106.6	14.4	110.7	14.2	0.042
Diastolic blood pressure (mmHg)	65.8	10.7	67.2	10.7	69.5	10.8	0.982
FBS (mmol/L)	4.85	0.75	4.89	1.09	4.92	0.67	<0.001
TG (mmol/L)	1.01	0.43	1.15	0.53	1.41	0.74	<0.001
TC (mmol/L)	3.80	0.81	3.96	0.88	4.05	0.86	0.026
LDL-C (mmol/L)	2.15	0.70	2.34	0.69	2.28	0.66	0.451
HDL-C (mmol/L)	1.21	0.38	1.12	0.30	1.12	0.30	<0.001

Abbreviation: WHtR, waist to height ratio; SD, standard deviation; FBS, fasting blood glucose; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.
[a]p values for trend tests across BMI categories.

addition, the prevalence of obesity, cardiometabolic risk factors and MetS was higher in urban than rural participants.

Sex-differences in prevalence of obesity vary across different populations. Studies performed in different countries in eastern and western Europe have shown a higher prevalence of obesity in boys [22, 23]. The findings of the present study are consistent with these studies, but not with results of studies performed in other countries in South America and in the Middle East [24–28]. These conflicting results could be explained by lifestyle differences, as well as the age and ethnicity of participants and their various pubertal stages. A national study in 29 988 Iranian children 7–18 years in different ethnicities showed a significant ethnic difference in BMI. Prevalence of

TABLE 4
Prevalence of metabolic syndrome and cardiometabolic risk factors according to the type of obesity: the CASPIAN-III study

Metabolic disorders	Normal BMI & WHtR ($n=2809$)		Type of obesity[a]															
			Overweight (85th < BMI < 95th) ($n=368$)		Obesity (BMI > 95th) ($n=423$)		Abdominal obesity (WHtR > 0.5) ($n=704$)		Overweight only (85th < BMI < 95th) ($n=221$)		Generalized obesity only (BMI > 95th) ($n=71$)		Abdominal obesity only ($n=205$)		Overweight and abdominal obesity ($n=147$)		Generalized and abdominal obesity ($n=352$)	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Prehypertension	354	8.4	46	11.1	80	17.2	114	14.1	23	9.1	10	12.3	21	8.0	23	14.0	70	18.2
Hypertension	167	5.4	38	9.1	67	14.4	96	11.8	17	6.7	10	12.3	18	6.8	21	12.8	57	14.8
IFG	421	15.3	58	16.4	60	15.0	99	15.1	30	13.8	11	15.5	22	11.8	28	20.4	49	14.8
Elevated TG	159	5.7	44	12.0	108	25.5	151	21.4	21	9.5	11	15.5	31	15.1	23	15.6	97	27.6
Elevated TC	138	4.8	28	7.5	44	10.2	72	98	17	7.7	3	4.2	20	9.0	11	7.3	41	11.4
Elevated LDL-C	101	5.1	20	7.3	19	6.2	39	7.5	11	6.7	3	6.0	14	9.0	9	8.3	16	6.3
Low HDL-C	822	33.9	141	41.7	155	42.2	251	41.8	80	39.2	26	41.3	61	37.7	61	45.5	129	42.2
MetS	16	0.8	31	10.4	65	20.0	119	22.8	3	1.6	0	0.0	26	18.1	28	25.7	5	24.3

Abbreviation: BMI, body mass index; WHtR, waist to height ratio; IFG, impaired fasting glucose; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; MetS, metabolic syndrome.
[a]Overweight only/obesity only were used when participants were overweight/obese according to BMI, but with normal WHtR. Abdominal obesity only were used for subjects with waist to height ratio >0.5, but with normal BMI.

TABLE 5
Logistic regression models of metabolic syndrome and cardiometabolic risk factors according to the type of obesity: the CASPIAN-III study

Metabolic disorders	Type of obesity[a]															
	Overweight (85th < BMI < 95th) ($n = 368$)		Obesity (BMI > 95th) ($n = 423$)		Abdominal obesity (WHtR > 0.5) ($n = 704$)		Overweight only (85th < BMI < 95th) ($n = 221$)		Overweight and abdominal obesity ($n = 147$)		Generalized obesity only (BMI > 95th) ($n = 71$)		Abdominal obesity only ($n = 205$)		Generalized and abdominal obesity ($n = 352$)	
	OR[b]	95% CI	OR[b]	95% CI	OR[b]	95% CI	OR[b]	95% CI	OR[b]	95% CI	OR[b]	95% CI	OR[b]	95% CI	OR[b]	95% CI
Prehypertension	1.63	1.02,2.62	2.38	1.59,3.55	1.68	1.19,2.37	1.37	0.74,2.52	1.38	0.71,2.68	2.16	0.85,5.48	0.95	0.51,1.77	2.17	1.43,3.30
Hypertension	1.91	1.30,2.80	3.32	2.42,4.56	2.14	1.64,2.81	1.25	0.74,2.10	1.79	1.08,2.99	3.09	1.54,6.22	0.95	0.57,1.56	2.88	2.07,4.01
IFG	1.14	0.84,1.54	1.01	0.75,1.36	0.92	0.72,1.17	1.03	0.69,1.54	1.25	0.81,1.93	1.27	0.66,2.46	0.70	0.44,1.10	0.94	0.68,1.30
Elevated TG	2.28	1.59,3.26	5.63	4.27,7.43	4.40	3.46,5.61	1.16	0.72,1.86	2.15	1.34,3.46	2.16	1.11,4.18	1.86	1.24,2.79	5.22	3.95,6.89
Elevated TC	1.43	0.94,2.18	1.93	1.34,2.76	2.01	1.49,2.72	1.23	0.73,2.08	1.34	0.71,2.52	0.60	0.19,1.93	1.57	0.96,2.56	2.13	1.47,3.07
Elevated LDL-C	1.30	0.79,2.13	1.09	0.66,1.81	1.49	1.01,2.17	1.09	0.57,2.07	1.55	0.76,3.14	0.95	0.29,3.13	1.79	1.00,3.19	1.08	0.63,1.85
Low HDL-C	1.57	1.23,1.99	1.49	1.18,1.88	1.43	1.18,172	1.33	0.98,1.79	1.67	1.16,2.41	1.34	0.79,2.29	1.13	0.81,1.57	1.39	1.08,1.78
MetS	6.70	4.06,11.06	14.74	9.58,22.68	35.32	21.4,58.4	0.37	0.12,1.18	7.32	4.48,11.97	–	–	4.91	3.06,7.88	11.59	7.91,16.98

Abbreviation: BMI, body mass index; WHtR, waist to height ratio; IFG, impaired fasting glucose; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; MetS, metabolic syndrome.
[a]Overweight only/obesity only were used when participants were overweight/obese according to BMI, but with normal WHtR. Abdominal obesity only were used for subjects with waist to height ratio >0.5, but with normal BMI.
[b]Adjusted for age, sex and living area.

overweight and obesity was higher in boys than girls [29].

Regarding higher prevalence of obesity and cardiometabolic risk factors in urban than rural areas, the finding is in line with the work of most other groups [17, 30–33], which can be explained by lifestyle behaviors such as physical inactivity and types of foods in residents of cities [34].

This study showed that the prevalence of cardiometabolic risk factors was higher in overweight and obese groups than in normal weight adolescents. Similar results were shown in an Iranian sample of 6- to 18-year-old children and adolescents [35]. In addition, the prevalence of MetS was ≈10 times higher in obese group than in their normal weight counterparts. The prevalence of MetS in obese group (20.0%) was higher than that in Japanese (17.7%) [36], but lower than that reported in the US (27.8%) [37] and China (27.6%) [17]. As obesity was strongly associated with MetS in our sample, it is a useful indicator for screening MetS patients in the target population.

In addition, those with both generalized and abdominal obesity had much higher prevalence of MetS (≈25%) than adolescents with isolated types of obesity (0% in generalized obesity only, and 18% in abdominal obesity). The findings are in line with study in China that found 0% MetS in isolated generalized obesity, 5.9% in isolated abdominal obesity and 27.8% in combined types of obesity [17].

In this study, we found that the association between generalized obesity and abdominal obesity was different for various cardiometabolic risk factors. Even as the relative importance of generalized and abdominal obesity is still debated, abdominal obesity is particularly considered of the atherogenic variety of adiposity, because it appears to promote a cluster of atherogenic risk factors [38, 39].

Similar studies represent that the association between abdominal obesity with most MetS components was stronger than those with generalized obesity [16, 17]. The association was even stronger when general overweight/obesity and abdominal obesity were clustered, than when identified by either of them alone [16]. Being only overweight/obese (with normal WHtR) showed a reduced risk of MetS, although isolated generalized obesity increased the risk of hypertension and elevated TG. On the other hand, the risk of raised TG in isolated abdominal obesity and combined type of obesity was ≈2 times and ≈5 times of that in their normal counterparts. Thus, data from this large sample of Iranian adolescents support that combined type of obesity indicates greater risk than isolated generalized or abdominal obesity.

Conflicting results of similar studies in adolescents indicate between-population differences in prevalence of obesity, MetS and cardiometabolic risk factors, as well as their associations. A systematic review of cohorts in children and adolescents, consisting of both pubertal and prepubertal children, shows a wide variation of values for different cardiometabolic parameters in different countries [40]. It is presumed that genetic profile and dietary habits play a substantial role outside the degree of obesity in affecting cardiometabolic risk parameters.

This study was conducted on a large representative sample of Iranian adolescents using standard protocols. However, the cross-sectional nature of the study by which causality cannot be determined, and lack of data on pubertal status of adolescents were major limitations of this survey.

Findings of this study showed high prevalence of overweight/obesity and cardiometabolic risk factors among adolescents in Iran, particularly in urban participants. We also found a strong association between obesity with MetS and cardiometabolic risk factors.

It seems that Iran has experienced a rapid nutrition transition during the last decade, with urbanization and decreases in physical activity, and increases in calorie and fat intake. Schools have been identified as an important setting to improve lifestyle and children's behavior and subsequently prevent overweight and obesity [41, 42]. Urgent interventions need to be made in Iran through policy makers to legislate supportive policies to encourage physical activity and healthy eating to combat the growing obesity epidemic and related chronic diseases.

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