

# Body Fat Distribution in Trunk and Legs Are Associated With Cardiometabolic Risk Clustering Among Chinese Adolescents Aged 10-18 Years Old

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## Research article

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# Abstract

**Background:** The association between total fat, body fat distribution and cardiometabolic risk factors are highly controversial among adolescents. The aim of the present study was to evaluate the association of body fat distribution with cardiometabolic risk factors clustering among Chinese adolescents.

**Methods:** In this cross-sectional study a total of 1175 adolescents aged 10 to 18 years underwent a comprehensive assessment of cardiometabolic risk factors. Body fat analysis was performed with Bioelectrical impedance analysis.

**Results:** Individuals with the CVRFs  $\geq 1$  or CVRFs  $\geq 2$  had higher indices of body fat distribution such as body fat mass(BFM) compared to those with normal CVRFs (all  $P < 0.001$ ). The prevalence of CVRFs  $\geq 1$ , CVRFs  $\geq 2$  increased with increasing of the quartile of BFM, TBFM, ABFM, LBFM, PBF, VFL compared to normal subjects. After adjusted for age and sex, the study indicated an linear relationship between TBFM( $\beta = 0.693$ , 95%CI:0.363,1.023), LBFM( $\beta = -1.471$ , 95%CI:-2.768,-0.175) and CVRFs z-score. Logistic regression models suggested TBFM was associated with CVRFs  $\geq 1$  and CVRFs  $\geq 2$  by higher odds. Lower odds of LBFM was associated with CVRFs  $\geq 2$ .

**Conclusions** A significant association between body fat mass of trunk(TBFM), body fat mass of leg(LBFM) and cluster of cardiometabolic risk factors was showed in the study. It suggested to reduce body fat mass of trunk and increase body fat mass of leg were essential for adolescents to prevent cardiovascular risk factors clustering.

## Background

Childhood obesity is a significant public health problem in the world(1, 2). Cardiovascular disease is the leading cause of death in the world, and the number of deaths caused by cardiovascular disease is expected to increase to 23 million by 2030(3). Obesity in children and adolescents is closely related to metabolic diseases such as hypertension, hyperglycemia and dyslipidemia, which increase the risk of cardiovascular disease in adulthood(4, 5). Studies have demonstrated the association between total fat, body fat distribution and cardiometabolic risk factors are highly controversial among adolescents(6).

Body mass index(BMI) does not reflect fat distribution, and distinguish between lean body and fat(7). Studies indicated that the accumulation of visceral fat was more closely related to a greater cardiovascular risk and metabolic disorders rather than the subcutaneous fat among children and adolescents(8).

Waist circumference, waist-to-hip ratio and waist-to-height ratio, which are used to distinguish the abdominal obesity, but it is not enough to reflect the visceral fat accumulation(7, 9). Moreover, these manually measured indicators are prone to bias.

Recently, the computed tomography (CT) and dual-energy x-ray absorptiometry (DXA) have been developed as standard method to precisely evaluate abdominal fat distribution and body composition

respectively. However, it has the disadvantages high cost and great radiation hazard(10). On the contrary, bioelectrical impedance analysis (BIA) was able to accurately and rapidly distinguish between lean body weight and fat content, trunk fat and limb fat mass, with relatively little radiation(11).

We aimed to evaluate the association between body fat distribution in different regions and cardiovascular metabolic risk factors clustering of adolescents by bioelectrical impedance analysis (BIA).

## Methods

### Participants

Participants were recruited from a cross-sectional population-based survey. The study conducted a stratified, randomly clustered sampling design to select subjects on junior and senior high schools in China from 2017 to 2019. A total of 3 junior schools, 2 senior high school were chosen for different age subgroups. Exclusion individuals who had physical disabilities, deformities, congenital genetic diseases and diseases related to cardiovascular metabolism. The study protocols were approved by the Ethics Review Committee of Ningxia Medical University(No.2016 – 123). Informed consent was obtained from a parent or guardian on behalf of any participants under the age of 16, the child above the age of 16 sign an informed consent by themselves.

### Anthropometry

Body height was measured to the nearest 0.1 cm with subjects in light clothing without shoes(ZH7082). Weight was assessed to the nearest 0.1 kg with an electronic scale(RGT-140). WC was measured to the nearest 0.1 cm midway between lowest rib and iliac crest at the end of normal exhalation. Height and waist circumference were measured at least twice continuously, and the error of twice measurement should not exceed 0.5 cm, and the average value were calculated; the weight was measured twice continuously, accurate to 0.1 kg, and the error of twice measurement was not more than 0.5 kg, and the average value was taken, and the mean value of each of these was used to calculate body mass index (BMI)(weight/height<sup>2</sup>, kg/m<sup>2</sup>) and Waist circumference height ratio(WHtR) (waist circumference/height). Body composition indicators included percentage of body fat(PBF); body fat mass(BFM); body fat mass of trunk(TFFM); body fat mass of arm(ABFM); body fat mass of t leg(LBFM); Visceral Fat Level(VFL) were measured using a body composition analyzer (Inbody 370). All measurements were obtained by trained health professionals who followed a standard protocol.

### Biochemical analysis

Venous blood samples were collected after an at least a 12-hour overnight fast. Fasting plasma glucose (glucose oxidase method), and triglyceride(TG), total cholesterol(TC), high density lipoprotein(HDL-C) and low density lipoprotein(LDL-C) were directly measured using the 7060C automatic biochemical analyzer(Hitachi, Tokyo, Japan). were detected by enzymatic methods.

### Cardiometabolic risk factors cluster definitions

Systolic blood pressure and or diastolic blood pressure  $\geq$  90th percentile for age and sex were defined as hypertension(12). Fast plasma glucose (FPG) was defined according to the American Diabetes Association criteria as FPG  $\geq$  5.6 mmol/L. Serum lipid levels were classified according to the criteria endorsed by the Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in children and Adolescents as follows: high TC,  $\geq$  5.18 mmol/L; high LDL-c,  $\geq$  3.37 mmol/L; high TG,  $\geq$  1.13 mmol/L for 0–9 years and  $\geq$  1.5 mmol/L for 10–19 years; low HDL-c,  $<$  1.04 mmol/L(13). We defined subjects have at least one cardiometabolic risk factors clustering as CVRFs  $\geq$  1, and subjects have at least two cardiometabolic risk factors clustering as CVRFs  $\geq$  2.

## Statistical analysis

All data are given as mean  $\pm$  standard deviation() for continuous variables, Categorical variables are presented as number(%) depending on whether or not normally distributed variables. Comparison of variables among groups were performed by using the Student's t-test for continuous variables or the chi-squared test for categorical variables. Multiple Linear Regression analyze the association between body fat distribution indexes and CVRFs z-score. Binary logistic regression analyses were used to analysis for the association between body fat distribution indexes and CVRFs  $\geq$  1/ CVRFs  $\geq$  2. Statistical analysis was performed by using SPSS for Windows 25.0 (SPSS Inc., Chicago, IL, USA), a 2-tailed  $P < 0.05$  was considered statistically significant.

## Results

A total of 1175subjects were included in the analysis, the mean age was 14.8 years old, and 54.4% were boys. Table 1 described the characteristics of subjects stratified by gender. The boys had higher WC, FPG, SBP, CVRFs z-score, lower WHtR, BFM, ABFM, TBFM, LBFM, VFL,, TC, HDL cholesterol compared to girls (all  $P < 0.05$ ). The proportion of individuals with CVRFs  $\geq$  1 and CVRFs  $\geq$  2 were 49.4% and 15.2%, respectively.

Table 1  
Characteristics of the study population

Variables	All	Boys	Girls	t/ $\chi^2$	P value
N (%)	1175(100)	639(54.4)	536(45.6)		
Age (years)	14.8 ± 1.9	14.9 ± 1.9	14.6 ± 2.0	2.631	0.008
Height (cm)	167.5 ± 8.7	171.5 ± 8.7	162.8 ± 5.9	20.118	< 0.001
Weight (kg)	58.6 ± 13.2	61.9 ± 14.2	54.7 ± 10.5	9.983	< 0.001
BMI (kg/m <sup>2</sup> )	20.7 ± 3.7	20.9 ± 3.9	20.6 ± 3.4	1.674	0.094
WC (cm)	73.5 ± 11.9	74.3 ± 14.0	72.7 ± 9.1	2.122	0.034
WHtR	0.44 ± 0.08	0.43 ± 0.09	0.44 ± 0.06	-2.070	0.039
Body fat distribution indexes					
BFM (kg) <sup>a</sup>	12.10(7.80,18.00)	9.30(6.10,15.80)	14.35(10.83,18.88)	-11.009	< 0.001
ABFM(kg) <sup>a</sup>	0.80(0.50,1.20)	0.50(0.35,1.00)	1.00(0.70,1.30)	-13.988	< 0.001
TBFM(kg) <sup>a</sup>	5.50(3.10,8.70)	0.40(2.20,7.70)	6.65(4.70,9.00)	-9.942	< 0.001
LBFM(kg) <sup>a</sup>	2.00(1.45,2.90)	1.60(1.20,2.50)	2.40(1.90,3.10)	-12.008	< 0.001
VFL <sup>a</sup>	5.00(3.00,7.00)	3.00(2.00,6.00)	5.00(4.00,8.00)	-9.786	< 0.001
PBF(%)	22.39 ± 9.06	18.15 ± 8.50	27.43 ± 6.85	-20.722	< 0.001
Cardiometabolic risk factors					
FPG (mmol/L)	4.67 ± 0.42	4.72 ± 0.45	4.61 ± 0.36	3.931	< 0.001
TC (mmol/L)	3.63 ± 0.70	3.56 ± 0.71	3.71 ± 0.67	-3.765	< 0.001
TG (mmol/L) <sup>a</sup>	0.95(0.76,1.24)	0.92(0.73,1.23)	0.95(0.76,1.21)	-0.885	0.376
SBP (mmHg)	114 ± 11	116 ± 11	110 ± 10	9.221	< 0.001
DBP (mmHg)	69 ± 8	69 ± 8	69 ± 8	-1.076	0.282
LDL-C (mmol/L)	1.91 ± 0.62	1.88 ± 0.64	1.95 ± 0.59	-1.814	0.070
HDL-C (mmol/L)	1.25 ± 0.24	1.20 ± 0.23	1.32 ± 0.23	-8.303	< 0.001
CVRFs ≥1 (n,%) <sup>b</sup>	467(49.4)	261(51.4)	206(47.1)	1.688	0.194
CVRFs ≥2 (n,%) <sup>c</sup>	144(15.2)	87(17.1)	57(13.0)	3.031	0.082
CVRFs z-score <sup>d</sup>	-0.29 ± 3.47	-0.003 ± 3.64	-0.63 ± 3.23	2.784	0.005

Variables	All	Boys	Girls	t/ $\chi^2$	P value
BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio; PBF, percentage of body fat; BFM, body fat mass; TFFM, body fat mass of trunk; ABFM, body fat mass of arm; LBFM, body fat mass of leg; VFL, Visceral Fat Level; FPG,; TC, total cholesterol; TG, triglyceride; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure. <sup>a</sup> Skewed distributions were logarithmically transformed for statistical tests. <sup>b</sup> Subjects have at least one cardiometabolic risk factors. <sup>c</sup> Subjects have at least two cardiometabolic risk factors. <sup>d</sup> CVRFs z-score = FPG z-score + TC z-score + logTG z-score + LDL z-score + HDL z-score* (-1) + SBP z-score + DBP z-score.					

Comparison of body fat distribution indexes among different clustering of CVRFs were shown in figure. Individuals with CVRFs  $\geq 1$  had higher BFM, TBFM, ABFM, LBFM, PBF, VFL compared to those with no CVRFs. Equally, subjects with CVRFs  $\geq 2$  had higher level of all body fat distribution indexes than those with CVRFs  $< 2$  (all  $P < 0.001$ ).

Prevalence of the cluster of cardiometabolic risk factors according to categories of different body fat distribution indexes by quartile were provided in Table 2. Prevalence of individuals with CVRFs  $\geq 1$  and CVRFs  $\geq 2$  compared to those in normal subjects increased with the quartile of all body fat distribution indexes. The prevalence of cardiovascular metabolic risk factors was the highest in the fourth percentile group (all  $P < 0.05$ ).

Table 2  
Prevalence according to categories of different body fat distribution indexes

Variables	CVRFs < 1	CVRFs ≥1	$\chi^2$	P value	CVRFs < 2	CVRFs ≥2	$\chi^2$	P value
BFM								
Q <sub>1</sub> <sup>*</sup>	152(60.3)	100(39.7)	72.953	< 0.001	231(91.7)	21(8.3)	70.425	< 0.001
Q <sub>2</sub> <sup>*</sup>	134(61.5)	84(38.5)			203(93.1)	15(6.9)		
Q <sub>3</sub> <sup>*</sup>	122(54.5)	102(45.5)			194(86.6)	30(13.4)		
Q <sub>4</sub>	70(27.9)	181(72.1)			173(68.9)	78(31.1)		
TBFM								
Q <sub>1</sub> <sup>*</sup>	154(62.1)	94(37.9)	79.808	< 0.001	229(92.3)	19(7.7)	81.083	< 0.001
Q <sub>2</sub> <sup>*</sup>	141(61.0)	90(39.0)			214(92.6)	17(7.4)		
Q <sub>3</sub> <sup>*</sup>	116(53.5)	101(46.5)			190(87.6)	27(12.4)		
Q <sub>4</sub>	67(26.9)	182(73.1)			168(67.5)	81(32.5)		
ABFM								
Q <sub>1</sub> <sup>*</sup>	124(58.2)	89(41.8)	61.546	< 0.001	192(90.1)	21(9.9)	54.309	< 0.001
Q <sub>2</sub> <sup>*</sup>	148(64.6)	81(35.4)			213(93.0)	16(7.0)		
Q <sub>3</sub> <sup>*</sup>	122(51.5)	115(48.5)			206(86.9)	31(13.1)		
Q <sub>4</sub>	84(31.6)	182(68.4)			190(71.4)	76(28.6)		
LBFM								
Q <sub>1</sub> <sup>*</sup>	133(61.0)	85(39.0)	61.425	< 0.001	202(92.7)	16(7.3)	61.628	< 0.001
Q <sub>2</sub> <sup>*</sup>	128(61.8)	79(38.2)			191(92.3)	16(7.7)		
Q <sub>3</sub> <sup>*</sup>	135(52.9)	120(47.1)			221(86.7)	34(13.3)		
Q <sub>4</sub>	82(30.9)	183(69.1)			187(70.6)	78(29.4)		
PBF								
Q <sub>1</sub> <sup>*</sup>	131(57.2)	98(42.8)	42.784	< 0.001	205(89.5)	24(10.5)	40.631	< 0.001

Variables	CVRFs < 1	CVRFs ≥1	$\chi^2$	P value	CVRFs < 2	CVRFs ≥2	$\chi^2$	P value
Q <sub>2</sub> <sup>*</sup>	141(61.6)	88(38.4)			212(92.6)	17(7.4)		
Q <sub>3</sub> <sup>*</sup>	119(51.3)	119(48.7)			197(84.9)	35(15.1)		
Q <sub>4</sub>	87(34.1)	168(65.9)			187(73.3)	68(26.7)		
VFL								
Q <sub>1</sub> <sup>*</sup>	87(62.1)	53(37.9)	51.620	< 0.001	131(93.6)	9(6.4)	50.708	< 0.001
Q <sub>2</sub> <sup>*</sup>	128(65.6)	67(34.4)			188(96.4)	7(3.6)		
Q <sub>3</sub> <sup>□</sup>	71(48.3)	76(51.7)			123(83.7)	24(16.3)		
Q <sub>4</sub>	75(33.5)	149(66.5)			161(71.9)	63(28.1)		
* Compared with Q <sub>4</sub> , P<0.05. □Compared with Q <sub>3</sub> , P<0.05.								

After adjusted for age and sex, we found TBFM was positively associated with CVRFs z-score ( $\beta = 0.693, 95\% \text{ CI: } 0.363, 1.023$ ), and LBFM was inversely associated with CVRFs z-score ( $\beta = -1.471, 95\% \text{ CI: } -2.768, -0.175$ ), both  $P < 0.05$ , in Table 3.

Table 3  
Multivariable associations of body fat distribution indexes with CVRFs z-score

Variables	Unstandardized Coefficients B	Standardized Coefficients Beta	t	95%CI	P value
TBFM	0.693	0.836	4.123	0.363 to 1.023	< 0.001
ABFM	1.090	0.208	1.126	-0.811 to -2.992	0.261
LBFM	-1.471	-0.489	-2.229	-2.768 to -0.175	0.026
VFL	-0.075	-0.081	-0.438	-0.410 to 0.260	0.661
Model adjusted for age and sex.					

Body fat distribution indexes predicted the risks of development cardiometabolic risk factors clustering was given in Table 4. The increase in TBFM by 1 standard deviation was associated with higher odds rates of CVRFs  $\geq 1$  (OR = 1.426, 95% CI: 1.126, 1.820,  $P = 0.004$ ) and CVRFs  $\geq 2$  (OR = 2.111,

95%CI:1.558,2.861,  $P < 0.001$ ), as well as the decrease in LBFM by 1 standard deviation was associated with CVRFs  $\geq 2$  (OR = 0.194, 95%CI:0.057,0.659,  $P = 0.009$ ).

Table 4

Results of the logistic regression analysis for the association between body fat distribution indexes and cardiometabolic risk factors

Variables	CVRFs $\geq 1$			CVRFs $\geq 2$		
	Coefficients <i>B</i>	OR(95%CI)	<i>P</i>	Coefficients <i>B</i>	OR(95%CI)	<i>P</i>
TBFM	0.335	1.426(1.116,1.820)	0.004	0.747	2.111(1.558,2.861)	< 0.001
ABFM	-0.040	0.961(0.179,5.147)	0.963	0.241	1.272(0.204,7.935)	0.796
LBFM	-0.624	0.536(0.195,1.470)	0.225	-1.641	0.194(0.057,0.659)	0.009
VFL	-0.017	0.983(0.767,1.260)	0.892	-0.129	0.879(0.652,1.185)	0.398
Model adjusted for age and sex.						

## Discussion

It is well known that obesity is a potential risk factor for many cardiovascular diseases, and cardiovascular disease is still the leading cause of death worldwide(14). This study was conducted in the northwest of China from children and adolescent aged 10 ~ 18 years to assessing the prevalence of cardiometabolic risk factors.

A representative study from US adolescents suggested 49% of the overweight and 61% of the obese adolescents had one CVRFs risk factors. The prevalence was 49.4% for subjects at least one cardiometabolic risk, and more than 15% of the adolescents had two risk factors clustering in our study. It is lower than the developed countries, still can not be ignored.

Our results suggested the girls had higher all body fat distribution indexes than boys, and they are related to CVRFs with gender differences, this did agree with the study in China consisted of 8460 children and adolescents, It found that trunk fat mass and abdominal fat mass were positively associated with all cardiometabolic risk factor, in contrast, arm fat was not significantly associated with all risk factors (15). While our study found the same results in cardiometabolic risk factors clustering. It suggested that body fat mass of trunk was positively associated with CVRFs clustering, in contrast, body fat mass of leg was inversely associated with CVRFs clustering. There were no statistically significant association of body fat mass of arm and CVRFs clustering. Recently, a mount of studies showed an related relationship between body fat distribution indexes and cardiometabolic risk factors like blood lipids. This phenomenon still exists in middle-aged men and women(16) and 5 ~ 18 year-olds children and adolescents(17). Studies have shown that a central fat distribution seemed to be an independent risk factor for high TG concentrations in children(18). A cohort study shows subjects who had greater trunk FM development

while adolescence and emerging adulthood, they will have higher metabolic risk at 36 years of age(19). However, the present findings suggested fasting glucose levels did not relate to regional fat in boys that did agree with a prior study(17, 20), the puberty girls in this study are susceptible to changes in hormone levels are different from the boys. This shows that the control of trunk fat in adolescence has important public health significance for the prevention of cardiovascular disease in adulthood.

Recently, Some studies in adults showed the stronger associations between abdominal obesity with cardiometabolic risk factors rather than generalized obesity, and there was paradox in children and adolescent about this view(21, 22). The bioelectrical impedance analysis(BIA) could not discriminate visceral fat and subcutaneous fat, the trunk fat mass could explain the level of visceral fat to a certain extent.

Our study shows the subjects with clustering of CVRFs at least one had higher Trunk fat mass and limb fat mass compared to normal adolescents. The prevalence of CVRFs increased with the percentile of all body fat mass. Previous study found that central fat includes trunk and android fat(23), and the findings indicate that higher fat mass in the he trunk and android fat plays an important role in the progression of CVRFs in children and adolescents(24). Other findings suggested that arms and legs fat mass confer differential cardiometabolic risk in subjects. A study from College students suggested that the leg fat has a protective effect, and arm fat has no effect(25). Another study consisted 391 children aged 5 to 18 years showed that the proportion of leg mass has lower CVRFs(17). In this study, we found that The increase of TBFM was associated with higher odds rates of CVRFs  $\geq 1$  and CVRFs  $\geq 2$ , as well as the decrease of LBFM was associated with CVRFs  $\geq 2$ . Thus, not only TBFM, LBFM are associated with CVRFs independently, but also with clustering of CVRFs.

## Conclusion

Nearly half of the adolescents had at least one cardiovascular risk, and more than 15% of the subjects had two risk factors. In addition, the body fat mass of trunk and body fat mass of leg plays an important role in identifying cardiometabolic risk clustering as an indirect indicator of abdominal fat.

## Abbreviations

BMI

body mass index; WHtR:waist circumference height ratio; glucose oxidase method:fasting plasma glucose; TG:triglyceride; TC:total cholesterol; HDL-C:high density lipoprotein; LDL-C:low density lipoprotein; PBF:percentage of body fat; VFL:visceral Fat Level; BFM:body fat mass; TBFM:body fat mass of trunk; LBFM:body fat mass of leg; ABFM:body fat mass of arm; CVRFs:number of cluster of cardiovascular risk factors; SD:standard deviation.

## Declarations

**Ethics approval and consent to participate** The study protocols were approved by the Ethics Review Committee of Ningxia Medical University (No.2016-123). Informed consent was obtained from a parent or guardian on behalf of any participants under the age of 16, the child above the age of 16 sign an informed consent by themselves.

**Consent for publication** Not applicable.

**Availability of data and material** Not applicable.

**Competing interests** The authors declare that they have no conflict of interest.

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### **Authors' contributions**

Study concepts: Q Y, W D

Study design: Q Y, P M, H Z, R C, Y D, W D

Data collection: Q Y, P M, H Z, R C, Y D, W D

Data analysis: Q Y

Manuscript: Q Y

Manuscript review: W D

**All authors have read and approved the manuscript.**

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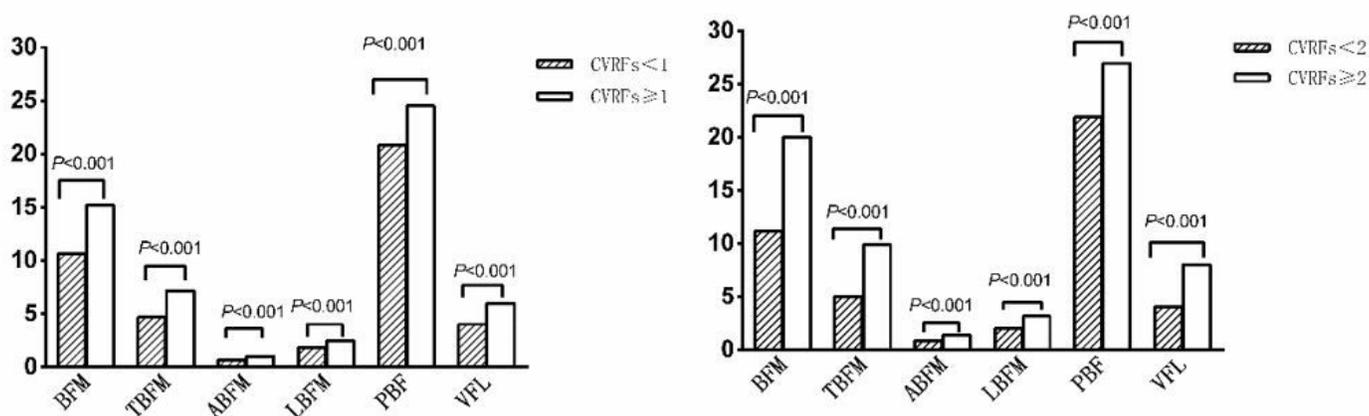
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## Figures



**Figure 1**

Comparison of body fat distribution indexes among different clustering of cardiometabolic risk factors (Median/mean, kg)