Original Article

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Body Fat Distribution and Its Association with Cardiovascular Risk Factors in Adolescent Iranian Girls

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Abstract

Objective: The relationships between body fat distribution, lipid profile and blood pressure, have not been studied extensively in young population. This study was designed to evaluate the association between measures of adiposity and established cardiovascular risk factors in adolescent girls.

Methods: A total of 477 adolescent girls aged 15 to 18 years were recruited from Mashhad high schools. Socio-demographic characteristics were assessed using a self-administered questionnaire. Anthropometric assessments, blood pressure measurement and biochemical assessment were performed. Total and regional fat mass were determined by bio-impedance analysis. Cardiovascular disease risk factors were assessed in relation to body fat measures with adjustment for confounder factors including age and family socioeconomic status.

Findings: The prevalence of overweight and obesity was 14.6% and 3.4% respectively; 16% of study population had greater fat mass compared to its ideal distribution. The majority of cardiovascular risk factors, especially systolic and diastolic blood pressure, triglyceride concentration, CRP and fasting blood sugar were significantly higher in group with a high body fat when compared to those with normal and low values. All anthropometric indices showed significant correlation with fat mass, fat free mass, total and regional body fat percent (P<0.001). After adjustment for age and family socioeconomic status, a high fat mass especially, truncal fat, was positively associated with triglyceride and blood pressure.

Conclusion: Adiposity, especially truncal adiposity, which can be assessed by simple measures such as Body Mass Index (BMI) and Waist Circumference (WC) may predispose adolescent girls for demonstration of metabolic abnormalities and consequently cardiovascular diseases.

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Key Words: Body composition; Hyperlipidemia; Obesity; Girls; Trunk fat

Introduction

Recent studies indicate that the process of atherosclerosis starts at an early age, and is positively associated with obesity. According to the WHO, the global prevalence of overweight and obesity has reached epidemic proportions [1]. There is increasing evidence for enhancing the

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prevalence of type 2 diabetes and cardiovascular risk factors in parts of Asia in which the mean Body Mass Index (BMI) is lower than in the United States. Among teenagers, risk factors for childhood overweight were associated with greater shifts in the upper parts of the children's BMI distribution than in the middle and lower parts [2]. Daniel et al (1999) suggested that fat distribution may be important in determining risk of cardiovascular disease. For both adults and children, a more central distribution of fat is associated with type 2 diabetes mellitus, a worse cardiovascular disease risk profile, and other adverse outcomes [3]. An android fat pattern with distribution of excess fat in the upper body region, particularly the abdomen, has been associated with increased risk when compared to the gynacoid pattern, with increased fat particularly in the hips and thighs[4,5].

Bioelectrical Impedance Analyses (BIA) provides a direct and precise measure of lean body mass and total fat mass. This method also allows quantification of fat mass in anatomically defined regions of interest, which allows more precise evaluation of the impact of fat distribution [6,7].

CRP (C-reactive protein) is thought to be a useful additional biomarker for the evaluation of risk for cardiovascular disease. The high correlation between high sensitive CRP (hsCRP) and cardiovascular disease was established in large epidemiological studies in healthy people [8]. Although the prevalence of obesity and metabolic syndrome has previously been reported to be high in adolescent girls [9], limited research is done dealing with the association of fat distribution with metabolic risk factors in adolescents. Therefore, the purpose of this present study was to evaluate the association between adiposity and fat distribution on established cardiovascular risk factors in adolescent girls. The dependent variables were lipid and lipoprotein concentrations, systolic and diastolic blood pressures, fasting blood sugar and inflammatory marker.

Subjects and Methods

This cross-sectional study was conducted among 622 adolescent girls aged 15–18 years, recruiting from May to July 2007, in Mashhad, Iran. The data collection was carried out in high schools from five different educational districts throughout Mashhad using multi-stage sampling technique. Subjects were chosen if they were healthy and excluded with congestive heart disease, renal disease and endocrine abnormalities (polycystic ovary syndrome) going through their past medical history obtaining in self administered questionnaire. The participation in this study was confirmed via getting informed consent from subjects and their parents. The Ethics Committee of the Mashhad Medical University approved the protocol. Demographic data were collected by completing a self administered questionnaire. Among 622 subjects that completed the questionnaire and were assessed for anthropometric measurement, 538 participated in the biochemical assessment and of these 477 completed body composition measurement respectively. Therefore our analyses were conducted on the 477 subjects for whom we had full information.

Anthropometric parameters including height, weight, waist and hip circumference were measured. Weight was measured while subjects wore only light clothing using a digital weighing scale (Seca 881 digital floor scale), height was assessed without shoes using a height-meter (Seca 214 portable stadiometer) [10]. Waist circumference (at the smallest point between lower costal and 10th rib border) and hip circumference (at the level of the greatest posterior protuberance of the buttocks corresponding anteriorly to the level of the symphysis pubis) were determined using a non-elastic fiberglass measuring tape [10,11]. Blood pressure (BP) was measured in the right arm while the subject was seated in a relaxed position using a mercury sphygmomanometer (Hader Aneroid Guage-W/Balanced inflation system adult size) [12].

Anthropometric indices including; body mass index (BMI)=weight (kg) / height $(m)^2$, waist to hip ratio (WHR) and waist to stature ratio (WSR) were calculated. Overweight and obesity were defined as BMI-Z score 1SD and 2SD more than median for age and sex group [13]. Central obesity was defined with waist circumference above 95th percentile according to CASPIAN study [14]. WHR in the range of 0.8-1 was defined as a strong cardiovascular risk factor [15].

Body composition parameters were assessed using BIA, TANITA Body Composition Analyzer (Model BC-418 MA, Japan) at Mashhad Ghaem Hospital. Stepping on the weighing platform with bare feet, anterior and posterior electrodes touched subject feet. The hand grips were squeezed by the subject, after stabilizing the body weight figure on the display [7]. The parameters measured included fat mass, fat free mass, total body water, total body fat percentage and the percentage of fat in different parts of body (trunk, arms and leg). Subjects were categorized to low, normal and high groups based on the amount of fat mass or fat free mass.

A total of 10 ml fasting venous blood was collected from subjects in Mashhad Ghaem Hospital. Biochemical parameters including fasting blood sugar (FBS), triglyceride (TG), total cholesterol (TC), HDL-cholesterol (HDL-c) and high sensitive C-reactive protein (hs-CRP) were assessed in the laboratory of Bu-Ali medical research center in Mashhad. Enzymatic colorimetric method was used to determine FBS, TC and TG. The coefficients of variations (%CV) for these measurements were 2.8-3.1%, 0.29-0.43% and <4%, respectively. Low density lipoprotein cholesterol (LDL-c) and high density lipoprotein cholesterol (HDL-c) were also determined by homogenous enzymatic assay (CV=2.4-8.4%). A Parsazmun Kit was used to determine the concentration of hsCRP using photometric method by applying HEPES and Borate buffer as reagents (CV<1%) [16,17].

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) 15.0. The normality of data was checked and transformation was done for not normal data. Descriptive statistics, including mean and SD were calculated for continuous variables. The dependent variables were established cardiovascular risk factors, including lipid and lipoprotein concentrations, blood pressure, and CRP. One-way ANOVA was done to compare the mean of mentioned variables among different categorization of body fat composition. The relationships between body composition, anthropometric variables and risk factors were assessed using correlation coefficient. For HDL-c and FBS, non-parametric test was done. In order to evaluate the independence of correlates of risk factor variables, after adjusting for age and socioeconomic status of family, linear regression analysis was used, except for CRP, response of which was observed by exponential regression. Statistical significance level was considered as *P* less than 0.05.

Findings

Mean age of the subjects was 16.4±0.9 years. Using BMI Z-score for age and gender (WHO 2007), 14.6% (BMI Z-score 1 SD>median), 3.4% (BMI Z-score 2 SD>median) of subjects were defined as overweight and obese respectively. WC larger than 95th percentile for Iranian adolescent girls (CASPIAN study) was present in 9.5% of subjects. WHR, more than 0.8, as a cardiovascular risk factor was shown in 10% of subjects. Waist-to-height ratio, which was determined as another criterion for abdominal obesity, was higher than 0.5 in more than 10% of study subjects. The mean body fat percentage was 21.3%±7.1 and total fat mass was 11.6±6.2 kg (Table 1).

Approximately 16% of study population had greater fat mass compared to its normal distribution. Focusing on central obesity, around 13.8% of subjects had high amounts of truncal fat. Among different cardiovascular risk factors in this study, triglyceride concentration was higher than the Esmaillzadeh (2006) cut off point [32] for adolescent girls in 24.5% of subjects. Moreover the concentration of HDL-c cholesterol was lower than normal in approximately 60% of them (Table 2).

All anthropometric indices showed significant correlation with fat mass, fat free mass, body fat percent and its distribution in whole body (P<0.001)(Table 3). BMI showed a strong association with body fat percent (r=0.87 P<0.001), fat mass (r=0.91 P<0.001) and fat free mass (r=0.80 P<0.001) whereas WC showed a much stronger relationship with trunk fat (r=0.858 P<0.001). Mentioning relationship between body fat parameters and waist circumference, by increment of WC to more than 80 cm, body fat measures increased significantly (P<0.001).

There was an increasing trend in BMI from less than 24 kg/m^2 to more than 28 with an increment in fat mass and fat distribution (P<0.001). As

Table 1: Demographic, anthropometric and body composition characteristics of subjects (n=477, girls)

Characteristic	Mean (SD)	Range
Age (year)	16.4 (0.9)	15 - 18
Birth Weight (kg)	2.97 (0.64)	0.7 – 5.2
Height (cm)	157.9 (5.4)	133 - 174
Weight (kg)	51.7 (9.8)	30 – 99.3
BMI (kg/m^2)	20.7 (3.6)	13.5 – 36.9
WC (cm)	69.1 (7.8)	54 - 106
HipC (cm)	93 (7)	74 – 121.5
WC / Hipc	0.74 (0.04)	0.62 – 0.93
WC / Height	0.43 (0.05	0.34 – 0.65
Total Body Fat %	21.3 (7.1)	7.3 – 45.3
Fat Mass (kg)	11.6 (6.2)	2.7 - 45
Fat Free Mass (kg)	39.9 (4.4)	23.8 – 58.5
Total Body Water (kg)	29.2 (3.2)	17.4 – 42.8
Fat Right Leg (%)	28.5 (5.2)	13.9 – 45.5
Fat Left Leg (%)	28.7 (5.2)	12.8 – 47.6
Fat Right Arm (%)	24.7 (8.8)	3.3 – 52.7
Fat Left Arm (%)	25.9 (9)	3.2 – 52.6
Fat Trunk (%)	15.3 (8.7)	3 – 43.9

BMI: Body Mass Index; WC: Waist Circumference; Hipc: Hip Circumference; SD: Standard Deviation

compared to WHR, WC/Height presented much higher correlation with body fat measures. Triglyceride concentration was related to body fat distribution, although this relationship was not strong. Greater truncal fat distribution was associated with higher triglyceride concentration. LDL-c and total cholesterol were not associated with any of the measures of body fat. Systolic and diastolic blood pressures were related to fat mass (r=0.33, 0.25 *P*<0.001) and fat distribution in the body. Systolic blood pressure showed higher association with greater truncal fat comparing diastolic blood pressure. CRP however was weakly related to body fat percent and fat mass (*P*<0.05). HDL-c and FBS did not show any significant correlation with body fat parameters in Chi-square test (Table 3).

After categorizing subjects based on their body fat measures, ANOVA indicated that the mean of the majority of cardiovascular risk factors, especially systolic and diastolic blood pressure and triglyceride concentration, were significantly greater in group with high body fat when compared with normal and low group (Table 4, 5). CRP was significantly increased in subjects with higher levels of fat mass (*P*=0.003) and trunk fat (*P*=0.001) as well as lower level of fat free mass (*P*=0.03). FBS depicted remarkable increase in subjects with high fat free mass when compared with low level (*P*=0.02).

All anthropometric parameters and related indices increased significantly in subjects with greater body fat composition. Evaluating the cardiovascular risk factors, the number of these

Table 2: Cardiovascular risk factor characteristics of study subjects (n=477, girls)

Risk Factor	Mean (SD)	Range	Abnormal Value (%)	Cut off points
hsCRP (mg/l)	1.3 (2.6)	0.23 – 5	3.7	≥ 5
TC (mg/dl)	154 (30)	78 – 200	21	>170
HDL-c (mg/dl)	36.6 (5.1)	23 - 49	56.9	< 37
LDL-c (mg/dl)	98.2 (26.1)	37 – 270.6	NA	NA
Cholesterol /HDL	4.2 (0.8)	2 – 8.6	6.9	> 5.5
FBS (mg/dl)	75.1 (11.4)	40.4 – 124.2	16.7	≥ 100
TG (mg/dl)	95.3 (41.8)	26.5 – 302.4	24.5	≥ 114
Systolic BP (mmHg)≠	95.9 (12.6)	60 – 140	7.2	≥ 126
Diastolic BP (mmHg)≠	59.5 (9.3)	40 – 90	24.1	≥ 80

hsCRP: High Sensitive C-Reactive Protein, TC: Total Cholesterol, HDL-C: HDL-Cholesterol, LDL-C: LDL-Cholesterol, FBS: Fasting Blood Sugar, TG: Triglyceride, BP: Blood Pressure, NA: Not Available, ≠<90th Percentile (Age, Gender)

Table 3: Correlation coefficients for association between body fat measures and anthropometric indices

Body Fat Composition	BMI	WC	HipC	WHR	WC/Height	TG≠	LDL-c	TC	Sys BP	Dia BP*	hsCRP
Total Body Fat %	0.87‡	0.79‡	0.80‡	0.46‡	0.73‡	0.19‡	-0.002	0.05	0.21‡	0.29‡	0.10*
Trunk Fat %	0.83‡	0.86‡	0.79‡	0.43‡	0.68‡	0.20‡	-0.006	0.05	0.29‡	0.22‡	0.08
Left Arm Fat %	0.79‡	0.76‡	0.70‡	0.42‡	0.68‡	0.15‡	0.01	0.05	0.26‡	0.17‡	0.08
Left Leg Fat %	0.87‡	0.76‡	0.75‡	0.47‡	0.76‡	0.15‡	-0.003	0.04	0.26‡	0.18‡	0.11*
TBW (kg)	0.80‡	0.76‡	0.83‡	0.36‡	0.61‡						
Fat Free Mass (kg)	-0.80‡	-0.69‡	-0.83‡	-0.36‡	-0.61‡						
Fat Mass (kg)	0.91‡	0.77‡	0.86‡	0.47‡	0.76‡	0.19‡	0.007	0.06	0.33‡	0.25‡	0.10*

*P<0.05, ‡P< 0.001, BMI=Body Mass Index, WC=Waist circumference, HipC=Hip circumference, TG=Triglyceride, LDL-c=LDL-cholesterol, TC=Total cholesterol, BP=Blood pressure, ≠ Log transformed; TBW: Total Body Water

parameters increased significantly with increasing body fat composition (P<0.001). In subjects with one risk factor, percentage of total body fat was 20.5%. By increasing the number of risk factors, subjects with four criteria had 34.3% total body fat.

After adjusting for age and socioeconomic status of family (based on family salary), total body fat percent was significantly associated with plasma triglyceride (P<0.001, %R=3.5), hsCRP (P=0.008, %R=1.5), systolic (P<0.001, %R=8.5) and diastolic blood pressure (P<0.001, %R=4.2). Fat mass and truncal fat also followed the same pattern. The fat distribution in upper and lower segments explained a relatively small but significant proportion of the variance of triglyceride, systolic and diastolic blood pressure. Anthropometric indices, especially BMI and WC were independent correlates of triglyceride (P=0.001, %R=2.2/ P<0.001, %R=2.4), hsCRP (P=0.009, %R=1.3/ P=0.01, %R=1.2), systolic (P<0.001, %R=12.4/ P<0.001, %R=10.4) and diastolic blood pressure (P<0.001, %R=8/ P<0.001, %R=8.4) respectively. Exponential regression showed that CRP was associated to values more than 30 kg/m² and 90 cm for BMI and WC respectively. In regression models, HDL-c, LDL-c and TC also FBG were not significantly related to body fat and its distribution.

Discussion

According to previous knowledge regarding the relatively high prevalence of obesity, metabolic syndrome and its components in adolescent

Table 4: Mean comparison of cardiovascular risk factors and anthropometric indices among different categories of Fat Mass (kg)

Parameter	Low (<5kg) (10.3%)	Normal (5-17 kg) (73.8%)	High (17-27 kg) (12.8%)	Very high (>27 kg) (3.1%)	P value
Systolic BP (mmHg)*	90.41	95.03	101.56	110.67	< 0.0001
Diastolic BP (mmHg)*	58.16	59.18	61.97	69.33	< 0.0001
FBS (mg/dl)	78.68	75.71	74.54	79.14	0.1
TG (mg/dl)*	85.63	92.54	102.1	108.78	0.05
TC (mg/dl)	146.99	152.81	153.81	161.27	0.3
HDL–c (mg/dl)	36.16	36.66	36.87	37.67	0.8
LDL–c (mg/dl)	93.8	98	93.66	103.14	0.3
hs-CRP (mg/l)*	1.04	1.1	1.57	1.60	0.003
BMI (kg/m²)*	16.70	19.93	26	31.48	< 0.0001
WC (cm)*	61.66	67.59	79.53	90.8	< 0.0001
HiC (cm)*	85.35	92.12	102.18	111.83	< 0.0001
WC/HipC*	0.72	0.73	0.77	0.81	< 0.0001
WC/Height*	0.39	0.42	0.49	0.56	< 0.0001

- ANOVA & Tukey test was done. * Significance level P<0.05
BP: Blood pressure, FBS: Fasting blood sugar, TG: Triglyceride, TC: Total cholesterol, hs-CRP: High sensitive C-reactive protein, BMI: Body Mass Index, WC: Waist circumference, HipC: Hip circumference

Table 5: Mean comparison of cardiovascular risk factors and anthropometric indices among different categories of Fat Free Mass

Parameter	Low (<34kg) (6.9%)	Normal (34-45kg) (80%)	High (>45kg) (13.2%)	*P* value
Systolic BP (mmHg)*	88.79	95.26	103.33	< 0.0001
Diastolic BP (mmHg)*	55.45	59.41	64.05	< 0.0001
FBS (mg/dl)*	71.42	76.08	77.74	0.02
TG (mg/dl)*	80.46	93.35	101.69	0.04
TC (mg/dl)	150.33	153.01	155.49	0.7
HDL – c (mg/dl)	36.03	36.69	36.82	0.7
LDL – c (mg/dl)	98.21	96.92	98.77	0.8
hs-CRP (mg/l)*	0.89	1.1	1.46	0.03
BMI (kg/m²)*	16.79	20.11	26.59	< 0.0001
WC (cm)*	61.65	67.88	81.44	< 0.0001
HiC (cm)*	85.1	92.2	104.51	< 0.0001
WC/HiPC*	0.72	0.73	0.77	< 0.0001
WC/Height*	0.4	0.43	0.5	< 0.0001

- ANOVA & Tukey test was done. * Significance level P<0.05
- Fat Free Mass (FFM, kg) categorization: Low=FFM<34, Normal=34<FFM<45, High=FFM > 45
BP=Blood pressure, FBS=Fasting blood sugar, TG=Triglyceride, TC=Total cholesterol, hs-CRP=High sensitive C-reactive protein, BMI=Body Mass Index, WC=Waist circumference, HiPC=Hip circumference

girls [9], this study was designed to measure indices of adiposity and highlight their association with metabolic abnormalities as the cardiovascular risk factors. Regarding to the association of obesity risk factors with higher BMI in adolescents [2], this study clarified that increment in total body fat especially truncal fat (central obesity), which can be assessed by anthropometric indices preferably body mass index, waist circumference and WC/Height, were significantly related to increase in cardiovascular risk factors which was demonstrated by triglyceride concentration, CRP, systolic and diastolic blood pressure rise up in this study. These results suggest that body fat including abdominal fat is an important determinant of cardiovascular risk factor status in adolescent girls. This is of particular importance in young population because their mean weight was relatively normal accompanied low truncal fat mass. The gradual deposition and distribution of fat while these adolescents become adults will be of importance regarding greater fat accumulation in trunk and increasingly unfavorable cardiovascular risk status [3].

Consistent with other studies, the results of current study showed a significant increase in CRP among subjects who had a greater body fat composition when compared to low and normal group [18-20]. Increments in BMI and WC were positively associated with hsCRP, a biomarker of the inflammatory process in adolescent girls. CRP concentrations within the high-normal range have been shown to predict cardiovascular disease and development of metabolic abnormalities in children and adolescents [19-21].

These results are consistent with Thomas et al (2004) and Novotny et al (2006) who have shown that for a given level of BMI, subscapular skinfold (central body fat measure) remains a significant and independent predictor of coronary heart disease risk in adolescents [22,23]. Obesity, especially abdominal adiposity has been shown to be important determinants of insulin resistance and diabetes in youth [21,24,25]. This fact was confirmed by significant increase in fasting blood sugar among subjects with high levels of trunk fat in our study, although late occurrence of changing in fasting blood sugar during insulin resistance in adolescents made the related correlations not much strong. The mechanism by which truncal fat deposition influences cardiovascular risk factors can be related to lower insulin sensitivity, which was likely to be present in 16% of study population as assessed by fasting hyperglycemia. Visceral adipocytes are less responsive to the action of insulin in obese subjects. Insulin resistance leads to increased delivery of fatty acids to the liver which is a determinant of triglyceride production [26].

The relationship between insulin sensitivity to blood pressure in obese adolescents was shown by Rocchini (1989, 1993) [27,28]. Increased circu-lating levels of insulin are related to blood pressure elevation due to the effect of insulin in excretion of sodium and water, leading to increased circulating blood volume. The relationship between increased body fat with elevated triglyceride, CRP and blood pressure also the association of lipid, blood pressure and inflammatory marker CRP alterations with measures of central obesity such as waist circumference and anthropometric indices which was demonstrated in this study, has been confirmed in both adults and children by other researchers [11,21,29,30]. However most of these studies have used less direct anthropometric measures such as waist and hip circumferences. These measurements can be useful but are subject to variability due to differences in measurements and observer bias. Body composition analyze using BIA has the advantages of indirect measurement of fat and fat free mass and the ability to evaluate differences in fat deposition by region which leads to more precise measurement of fat mass and a better understanding of the role of fat distribution, the issue that was mentioned in this research.

As more central deposition of fat has been shown to be associated with high blood pressure and less favorable lipid and lipoprotein levels, it is important to find simple, useful measures of fat deposition for possible use in clinical settings. This study showed significant relationship between body fat measures, especially trunk fat, with waist circumference and body mass index. Also these two anthropometric indices were significantly associated with triglyceride, CRP and blood pressure elevation. Moreover Bei-Fan et al (2002) showed in a meta-analysis on the relationship between BMI, waist circumference and risk factors of related chronic diseases such as type 2 diabetes, and lipoprotein disorders, that the prevalence of hypertension, diabetes, dyslipidemia and clustering of risk factors all increased in youth with increasing levels of BMI or waist circumference [31]. Therefore in conditions where BIA or DXA are not available for direct measurement of body fat composition, waist circumference preferably, and body mass index are useful measures for body fat composition status. These two indices which are so easily accessible can be a reliable tool for screening adolescents in order to estimate their body fat composition.

Conclusion

We found that total body fat particularly central fat was significantly associated with plasma triglycerides, CRP, systolic and diastolic blood pressure in adolescents. Waist circumference and body mass index associated with cardiovascular risk factors. These findings, for which a direct measure of fat distribution by region was used, suggest that prevention of central adiposity will be important in the planning of clinical intervention strategies to lower cardiovascular risk for young people.

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Conflict of Interest: None

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