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Lower Level of Physical Activity Predisposes Iranian Adolescent Girls to Obesity and its Metabolic Consequences

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Abstract: Physical activity has been investigated among Asian populations as a factor that influences the clustering of cardiovascular risk factors. However, the magnitude of these associations has not been well studied among adolescents, particularly in Middle East countries. This study aimed to investigate associations between physical activity level, metabolic abnormalities and body composition among adolescent girls in Iran. Socio-demographic and physical activity information were assessed using self-administered questionnaire in 538 adolescent girls aged 15-18 years from Mashhad high schools. Anthropometric, blood pressure and biochemical assessment were performed. Bioelectrical Impedance Analyses was applied to measure total and regional fat mass. The prevalence of overweight, obesity and metabolic syndrome was 14.6, 3.4 and 6.5% respectively. Subjects with lower levels of physical activity had higher anthropometric indices, fat mass, fat free mass and metabolic abnormalities especially systolic blood pressure. There were inverse correlations between physical activity with hypertension, dyslipidemia and body composition parameters. Physical activity was negatively associated with weight (%R = 2.8 B = -0.168, $p<0.0001$), systolic blood pressure (%R = 3.9 B = -0.158, $p<0.0001$), triglyceride concentration (%R = 3.9 B = -0.106, $p<0.018$) and fat free mass (%R = 4.2 B = -0.205, $p<0.0001$) after adjusting for age and socioeconomic status of family. Subjects with metabolic syndrome had lower levels of physical activity (1.37 vs 1.39, $p<0.05$) and higher basal metabolic rate (1426 kcal vs 1360, $p<0.0001$). To avoid increasing risk of cardiovascular diseases, programs to promote greater physical activity should be implemented.

Key words: Adolescence, body composition, cardiovascular abnormalities, girls, obesity, physical activity

INTRODUCTION

Childhood obesity is a major public health problem because of its increasing prevalence and adverse health consequences (Reilly *et al.*, 2003). These trends are likely to result in a significant increase in the rates of coronary artery disease, hypertension, diabetes mellitus and other obesity-related diseases in young and middle-aged adults (Bibbins-Domingo *et al.*, 2007). Physical inactivity and sedentary lifestyles contribute to obesity and may be fundamental sources of energy imbalance (Goran *et al.*, 1999). It also predisposes an individual to other metabolic abnormalities and may thereby ultimately lead to metabolic syndrome. The latter being particularly important in girls due to sex-dependant changes in insulin sensitivity, body fat accumulation, blood pressure and lipid profiles after puberty (Jessup and Harrel, 2005). Girls, at all ages, are usually less active than boys and this difference is particularly prominent during the adolescent period.

Previous studies showed that increased physical activity and decreased sedentary behaviour were protective against relative weight and fatness gains over childhood and adolescence (Must and Tybor, 2005). It is suggested that physical inactivity may be one of the main modifiable risk factors in the etiology of the common complex metabolic disorders (Leon, 1997). Interventions for increasing physical activity have been widely recommended and are essential in reversing the increasing trend of obesity. Although it is well established that the incidence of overweight increases and physical activity declines as much as 50% during adolescence, few studies have examined the role of physical activity in preventing obesity and related metabolic disorders among young people (Kimm *et al.*,

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2001; 2002). Previous studies in a similar study population showed a high prevalence of metabolic syndrome and its components (Mirhosseini *et al.*, 2009). Recognising the importance of the influence of physical activity on the development of metabolic syndrome, this study was designed to examine the association between physical activity level with body composition and metabolic syndrome components including hypertension, dyslipidemia and glucose intolerance in adolescent girls. The significance of this study is that all different aspects resulted from sedentary lifestyle including obesity, cardiovascular markers rise up and fat accumulation in body put together and evaluated in a high risk population.

MATERIALS AND METHODS

A cross-sectional study was conducted among 622 adolescent girls (15-18 years) from Mashhad, Iran, from May to July 2007. Body composition assessment and blood sampling was conducted on 538 subjects. Recruitment of healthy adolescent girls was carried out in high schools from five different educational areas throughout Mashhad using multi-stage sampling technique. First stage was stratified sampling in five zones of educational division of Mashhad, second stage was a cluster sampling to select one high school in each zone and third stage was a convenient sampling to select students in each high school. Subjects were excluded if they suffered from congestive heart disease, renal disease and endocrine abnormalities (poly cystic ovary syndrome) as identified using self report of past medical history. Written informed consent from adolescents and their parents were obtained. The Medical Ethics Committee of the Mashhad Medical University approved the protocol.

Demographic data were collected using a self-administered questionnaire. Anthropometric assessments were carried out using standard protocol (ISAK) which included height, weight, waist and hip circumferences. Height was measured barefoot using a height-meter (Seca 214 portable stadiometer) and weight was measured using a digital weighing scale (Seca 881 digital floor scale) with the subjects wore only light clothing. 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 corresponds interiorly to the level of the symphysis pubis) was determined using non-elastic fiberglass measuring tape (Daniels *et al.*, 2000; ISAK, 2001). Blood Pressure (BP) was recorded on the right arm with the patient sitting upright using sphygmomanometers (Hader Aneroid Guage-W/ Balanced inflation system adult size). The onset of the first Korotkoff phase and Korotkoff phase disappearance were used to determine systolic and diastolic blood pressure (NHLBI Task, 1987). Body mass index [BMI = weight (kg)/height (m) ^{2}], Waist to Hip Ratio (WHR) and Waist to Stature Ratio (WSR) were determined. Overweight among subjects were defined as BMI-Z score 1SD more than median and obesity as BMI-Z score 2 SD more than median for age and sex group (Onis *et al.*, 2007). Central obesity was defined with waist circumference above 90th percentile (WC = 80 cm) of WC Iranian charts (Esmaillzadeh *et al.*, 2006A).

Physical Activity Level (PAL) of subjects was assessed using a standard questionnaire modified from the SHHS/MONICA questionnaire (Vasconcellos and Anjo, 2003) which was coded using the Human Energy Requirement proposed by James and Schofield (1990). The questionnaire was divided into sections concerned with time spent on activities during school time, non-school time and in bed. Total Energy Expenditure (TEE) was calculated by adding the number of minutes for which the person was sleeping and the energy used up when the person is active, moderately active and inactive during school and leisure times (which are the minute of that activity multiplying by Integrated Energy Index (IEI). IEI was considered 1.61, 2.52 and 4.39 for inactive, moderately active and active subjects respectively. Basal Metabolic Rate (BMR) was calculated using the following equation; BMR = 0.062 x weight + 2.036 (FAO/WHO/UNU equations). PAL was calculated by dividing total energy expenditure over 24 h (TEE) to basal metabolic rate over 24 h (BMR) for same person. Physical Activity Level (PAL) classified subjects to inactive ($PAL<1.5$), moderately active ($1.5<PAL<2$) and active ($PAL>2$) (Vasconcellos and Anjo, 2003).

Body composition parameters studied were 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). They were assessed using Bioelectrical Impedance Analyses (BIA) and applying TANITA Body Composition Analyzer (type BC-418 MA, Germany) in Mashhad Ghaem hospital. Subjects were asked to step on the weighing platform with bare feet; subjects touched the electrodes with placing heels on the posterior electrodes and the front part of the feet in contact with the anterior electrodes. After stabilizing the body weight figure on the display, the hand grips were grabbed. The instrument was operated, analyses were done and the results printed on roll papers (Greives, 2007).

A total of 10 ml fasting venous blood was taken for biochemical assessment which comprised of fasting blood sugar, triglyceride, total cholesterol, HDL-cholesterol and high sensitive C-reactive protein in Mashhad Ghaem hospital, Iran. Fasting Blood Sugar (FBS) was determined using Enzymatic Colorimetric determination via Glucose Oxidase and Peroxidase reactions. Total Cholesterol (TC) was measured by Enzymatic Colorimetric determination using Cholesterol Esterase, Cholesterol Oxidase and Peroxidase reactions. Triglyceride (TG) was determined via ESPAS (N-Ethyl-N-sultorpropyl-n-anisidine) enzymatic determination by using Pars Azmoon Kits (Pars Azmoon Inc. Iran). LDL-C and HDL-C were also determined by enzymatic methods (Hadaegh *et al*., 2007; Nazrul Hasnain, 2006). All analyses were carried out using a Selectra 2 auto-analyzer (Vital Scientific, Spankeren, Netherlands).

Overweight and obesity were characterized according to WHO BMI Z-score for age and gender (WHO, 2007). Metabolic syndrome was defined based on NCEP ATP(III) criteria (2001) (Cook *et al*., 2003) following these criteria; central obesity with waist circumference above 90th percentile (WC = 87 cm) of WC Iranian charts (Esmaillzadeh *et al*., 2006B), a systolic or diastolic blood pressure above the 90th percentile (SBP = 126 mmHg, DBP = 80 mmHg) for age and sex according to the National Heart, Lung and Blood Institute and the 1987 update on the Second Task Force Report on Hypertension in Children charts, triglyceride level above the 90th paediatric percentile (TG =114 mg/dL) from NHANES III (1988-1994), low HDL-cholesterol level below the 5th percentile (HDL-C = 37 mg/dL) (Hickman *et al*., 1998; Cruz *et al*., 2004) or impaired glucose tolerance (FBS = 100 mg/dL) (Chi *et al*., 2006; Tamsma *et al*., 2005).

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) 15.5.0. Descriptive statistics, including mean and SD for continuous variables were calculated. Appropriate transformations were performed for continuous variables that were not normally distributed. ANOVA was done to compare variables including; body fat composition, anthropometric indices and metabolic abnormalities among different levels of physical activity. Univariate relationships between physical activity level and different variables were assessed using spearman correlation analysis. Multiple linear regression models were applied to express the factors affected by the level of physical activity. The stepwise model was used whereas weight, systolic blood pressure, triglyceride concentration and fat free mass were the parameters entered the model with adjustment for age and socioeconomic status of family. In these analyses, the values for triglyceride and CRP were included after logarithmic transformation.

RESULTS

Based on BMI Z-score for age and gender, 14.6% (BMI Z-score 1 SD > median) and 3.4% (BMI Z-score 2 SD > median) of subjects were defined as overweight and obese, respectively. Waist circumference larger than 80 cm was identified in 9.5% of subjects. Based on NCEP ATP (III) (2001) 6.5% of subjects had metabolic syndrome (Table 1 and 2). Among different metabolic abnormalities, 24.5% suffered from hypertriglyceridemia (>114 mg/dL) whereas 43.1% had low HDL-C (<37 mg/dL). Hypercholesterolemia (>100 mg/dL) was detected in approximately half of subjects.

According to the James and Schofield classification (James and Schofield, 1990), 59.5% of the subjects were inactive with PAL less than 1.5; whilst 25.2% and 15.3% of subjects were classified as moderately and active persons, respectively. In this study, there was no significant difference between physical activity level in subjects with metabolic syndrome (1.37±0.57) and those without (1.39±0.57). However, PAL was negatively correlated to all anthropometric indices, body composition parameters and cardiovascular biomarkers (Table 3).

Table 1: Anthropometric characteristics, body fat components and physical activity level of study subjects (n = 538)

Characteristic	Mean±SD	Range
Age (year)	16.4±0.9	15-18
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
HiC (cm)	93±7	74-121.5
WC/Hic	0.74±0.04	0.62-0.93
WC/Stature	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
PAL	1.39±0.56	0.4-2.92
BMR (Kcal)	1362.7±98.7	1108.2-1828.1
TEE (Kcal)	1892±756.3	534.8-3633.6

WC = Waist Circumference, HiC = Hip Circumference, Stature = Height, PAL = Physical Activity Level, BMR = Basal Metabolic Rate, TEE = Total Energy Expenditure, SD = Standard Deviation

Table 2: Metabolic abnormalities description of study subjects (n = 538)

Characteristic	Mean±SD	Range	Normal value	Abnormal value (%)
hs CRP (mg/l)	1.3±02.6	0.23-45.1	0-5	3.7
TC (mg/dl)	154.0±30.0	78-328.8	100-200	21.0
HDL-c (mg/dl)	36.6±05.1	23-49	>37	56.9
LDL-c (mg/dl)	98.2±26.1	37-270.6	NA	N.A
Cholesterol/HDL	4.2±00.8	2-8.6	< 5.5	6.9
FBS (mg/dl)	75.1±11.4	40.4-124.2	70-100	16.7
TG (mg/dl)	95.3±41.8	26.5-302.4	70-120	24.5
Systolic BP (mmHg)	95.9±12.6	60-140	<90th percentile (age, gender)	7.2
Diastolic BP (mmHg)	59.5±09.3	40-90	<90th percentile (age, gender)	24.1

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

Table 3: Association between physical activity level and anthropometric indices, metabolic abnormalities and body composition (expressed as 'r')

Parameter	Weight	BMI	WC	HipC	WC/HipC	WC/Stature	sysBP
PAL	-0.17**	-0.15**	-0.15**	-0.13**	-0.11**	-0.13**	-0.12**
Parameter	Cholesterol	TG	Fat mass	Fat free mass	Body water	% leg fat	% arm fat
PAL	-0.1*	-0.1*	-0.15**	-0.21**	-0.21**	-0.13**	-0.09

PAL = Physical Activity Level, BMI = Body Mass Index, WC = Waist Circumference, HipC = Hip Circumference, Stature = Height, sysBP = systolic Blood Pressure, TG = Triglyceride, *p<0.05, **p<0.01

Table 4: Mean comparison between different levels of physical activity regarding anthropometric indices, metabolic abnormalities and body fat composition

	PAL			
Parameters	Active	MA	Inactive	p-value
BMI*	19.8	20.3	21.0	0.005
WC*	67.5	68.2	69.9	0.006
HiC*	91.8	92.2	93.7	0.016
Total body fat (%)*	19.5	21.0	21.9	0.031
Fat mass*	10.0	11.1	12.2	0.017
Fat free mass*	38.8	39.2	40.5	0.001
Fat trunk (%)*	13.3	14.9	16.1	0.042
Systolic BP*	93.0	96.0	96.4	0.050
Diastolic BP	58.2	59.7	60.3	0.214
Triglyceride	87.9	94.9	96.2	0.103
Total cholesterol	147.4	153.3	155.4	0.073
HDL-C	35.9	36.9	36.8	0.335
LDL-C	93.9	97.4	98.6	0.269
hs-CRP	1.0	1.1	1.2	0.563

ANOVA and Tukey test was done. *Significant level <0.05. PAL = Physical Activity Level (PAL<1.5 = inactive, 1.5<PAL<2 = Moderately active, PAL>2 = Active) BMI = Body Mass Index, WC = Waist Circumference, HiC = Hip Circumference, BP = Blood Pressure, hs-CRP = high sensitive C-reactive protein. MA = Moderately Active

Systolic blood pressure (p = 0.05), percentage of body fat (p = 0.03), fat mass (p = 0.01), trunk fat (p = 0.04), as well as all anthropometric indices were inversely associated with physical activity levels (Table 4). Cardiovascular markers including; triglyceride, total cholesterol, LDL-C and CRP were higher in inactive subjects as compared to active subjects although this difference was not significant (Table 4). Basal Metabolic Rate (BMR) was significantly higher in subjects with metabolic syndrome (1426 kcal) as compared to non metabolic syndrome (1360 kcal) (p<0.0001). Furthermore, basal metabolic rate showed positive relationship with blood pressure (r = 0.37, p<0.01) and triglyceride concentration (r = 0.145, p<0.01). BMR correlated positively with BMI (r = 0.89, p<0.001) and WC (r = 0.83, p<0.001). PAL was also related to socioeconomic status as indicated by monthly family salary (%R = 1.1 B = -0.105, p<0.009). Families with high socioeconomic status had children with low level of physical activity. Multiple regression analysis, after adjustment for socioeconomic status and age showed that body weight (%R = 2.8 B = -0.168, p<0.0001), systolic blood pressure (%R = 3.9 B = -0.158, p<0.0001), triglyceride (%R = 3.9 B = -0.106, p<0.0001) and fat free mass (%R = 4.2 B = -0.205, p<0.0001) were indices significantly associated with PAL (Table 5).

Table 5: Association of health variables and socioeconomic status with physical activity level

	Variables	%R	Coefficient (β)	p-value
PAL	Weight	2.8	-0.168	0.0001
	Sys blood pressure	3.9	-0.158	0.0001
	Triglyceride	3.9	-0.106	0.0180
	Fat free mass	4.2	-0.205	0.0001
	Family SES	1.1	-0.105	0.0090

PAL = Physical Activity Level, SES = Socioeconomic Status. Multiple Regression Model was done for adjusting of confounding factors (age)

DISCUSSION

The purpose of the present study was to determine the association between body composition and metabolic abnormalities with physical activity level in a large group of post-pubertal adolescent girls representing this population in Mashhad, Iran. As the prevalence of adolescent obesity was high (18%) and this follows an increasing trend, a better understanding of the association between body fat and cardiovascular risk factors with physical activity will be needed to support the progress in behavioural interventions to reduce and prevent this public health challenge.

In this study the prevalence of overweight (14.6%), obesity (3.4%) and metabolic syndrome (6.5%) was consistent with some earlier studies in Iran (Azizi *et al.*, 2003 and Shahbazpour, 2003 and Esmaillzadeh *et al.*, 2006B). A low level of physical activity was seen in 60% of subjects which demonstrated significant correlation with increasing in weight, BMI and WC. A previous study compared correlates of physical activity among African-American and white girls of different weight groups to guide future interventions and also showed differences in physical activity level with their weight status (Dianne *et al.*, 2006). However, it was not clear whether regular activity was protective against weight gain. Berkey *et al.* (2003) found that an increase in physical activity over a one year period was associated with a decrease in relative BMI (Berkey *et al.*, 2003). Some studies confirmed this protective effect of physical activity (Rowlands *et al.*, 1999; Bernard *et al.*, 1995), whereas other studies have not found a clear association (Crespo *et al.*, 2001; Dwyer *et al.*, 1998). The differences in study sample characteristics (age, gender and obesity status), study designs (cross-sectional vs longitudinal) and statistical approaches could explain this discrepancy. A few weak correlations in this study also can be explained by weight status of subjects and large distribution of some determined parameters in them.

In this study, the relationship between body composition components and the level of physical activity and basal metabolic rate was determined. With decreasing level of physical activity, a higher total body fat, fat mass and fat free mass were observed. Subjects with greater body fat tend to have greater fat free mass as well (Lohman *et al.*, 2006). The correlation of all body composition components were inversely related to physical activity level. Subjects with greater body fat had a lower level of physical activity. The regression model showed that more active persons had less fat mass and fat free mass and this fact have been confirmed in earlier studies (Lohman *et al.*, 2006; Mcmurray *et al.*, 2000; Obarzanek *et al.*, 1994). In this study, total energy expenditure was also determined which needs to account for body mass as well as physical activity. Less physical activity and more sedentary behaviour led to a decrease in the total energy expenditure ($r = 0.98$, $p<0.0001$) which in turn predisposed adolescent girls to weight gain and obesity. Using family salary per month as a surrogate for socioeconomic status, in families with high socioeconomic status, the easy access to motor vehicle for conveyance, spending more time watching television and operating computers, resulted in decrease of physical activity and energy expenditure. This explains the higher prevalence of obesity in these families.

This study also examined the association between metabolic abnormalities including; blood pressure, dyslipidemia, hypertension, glucose intolerance and C - reactive protein status with the level of physical activity. Most of cardiovascular risk factors such as blood pressure, triglyceride, cholesterol and LDL-C concentration as well as CRP decreased in active persons with higher level of physical activity, although this difference was statistically significant only for systolic blood pressure. This study strongly depicted the relevance of low physical activity level with overweight and obesity. An early report from this population demonstrated significant association between obesity and cardiovascular risk factors especially blood pressure and triglyceride concentration (Mirhosseini *et al.*, 2009). Therefore, increase in physical activity level was independently associated with decrease in hypertension and hyperlipidemia. Earlier studies also depicted this fact that adolescent girls with high level of triglyceride and low level of HDL-c had lower level of physical activity during childhood (Ventura *et al.*, 2006; Franks *et al.*, 2004). Hence, most components of metabolic syndrome exhibit inverse relationship to the level of physical activity. Apparently, sedentary lifestyle is a predisposing factor in prevalence of metabolic syndrome and consequently future cardiovascular diseases. It was also confirmed by other researches that low level of physical activity was associated with metabolic syndrome in adolescent girls (McMurray *et al.*, 2008).

The results of this study provide important information regarding the association between body composition and metabolic abnormalities with physical activity. Adolescents with lower level of physical activity had higher body weight, systolic blood pressure, fat mass, fat free mass, triglyceride and cholesterol concentration which are metabolites related to metabolic syndrome. Further studies are required to ascertain the exact amount of physical activity needed to prevent the development of obesity, metabolic syndrome and to provide evidence-based physical activity recommendations to the public.

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