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RESEARCH ARTICLE

# Prevalence of different metabolic phenotypes of obesity in Iranian children and adolescents: the CASPIAN V study

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## Abstract

**Background** Pediatric metabolic disorders are a major health problem. The prevalence of child and adolescent metabolic disorders particularly obesity has globally shown a growing pattern. The aims of this study were to estimate the prevalence of different metabolic phenotypes of obesity in children and adolescents.

**Methods** This multi-centric cross-sectional study was conducted in 2015 in 30 provinces of Iran. Participants consisted of 4200 school students aged 7–18 years, studied in a national school-based surveillance program (CASPIAN- V) in Iran. Metabolic syndrome (MetS) and obesity was defined according to ATP III and WHO criteria respectively. Subjects were classified into four different metabolic phenotypes of obesity; metabolically healthy nonobese (MHNO), metabolically healthy obese (MHO), metabolically non-healthy non-obese (MNHNO) and metabolically non-healthy obese (MNHO). Moreover students were classified in four different phenotypes of obesity; normal; only abdominal obesity (AO), only generalized obesity (GO) and combined obesity (CO).

**Results** The prevalence (95% confidence interval) of different metabolic phenotypes of obesity, MHO 10.35 (9.1, 11.8), MNHNO 3.31 (2.6, 4.2) and MNHO 2.19 (1.6, 2.9) was found in boys, while the prevalence of these phenotypes was significantly lower in girls (7.74 (6.6, 9.1), 3.11 (2.4,5.1) and 1.41 (0.9,2.1) respectively). The prevalence of only AO, only GO and CO was 12.17% (11.6, 12.7), 2.51% (2.3,2.8), and 8.86% (8.4,9.3), respectively. Based on gender differences, the prevalence of AO was significantly higher among girls than boys (12.4% of girls vs. 11.9% of boys).

**Conclusions** Healthy lifestyle education and program interventions are necessary for children with different metabolic phenotypes of obesity, as there is a high probability that they may suffer from poor health in the future.

**Keywords** Different phenotypes of obesity · Different metabolic phenotypes of obesity · Children and adolescents

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## Introduction

Childhood obesity has become a public health concern in all over the world (1). Obesity is an independent risk factor for cardiovascular disease (CVD) and CVD risks as well as morbidity and mortality among children (2). Studies showed that obesity led to clustering of cardiovascular risk factors or metabolic syndrome (MetS) (3, 4). The MetS includes the clustering of abdominal obesity, insulin resistance, dyslipidemia, and elevated blood pressure and is associated with other comorbidities (5). According to the findings of a nationwide survey, the prevalence of MetS in children have been reported to be 2.5%. Iran is facing a double burden of the diseases and is in a rapid epidemiological transition state (2, 6).

A combination of obesity and metabolic syndrome leads to development of different obesity phenotypes that may have different risks for future health outcomes such as cardiovascular disease (CVD), type- 2 diabetes, and all-cause of mortality (7).

Although cardiometabolic disorders usually exist among obese children [phenotypically obese metabolically abnormal (POMA)], studies have shown that some obese individuals have no associated metabolic abnormality. The term phenotypically obese metabolically normal (POMN) has been used to describe them. At the same time, there are normal weight subjects with a clustering of cardiometabolic abnormalities who may be at elevated risk for insulin resistance and elevated risk of cardiovascular disease, i.e. phenotypically normal metabolically obese (8, 9).

A study showed that 63.1% of normal weight Chinese adolescents and all obese subjects had at least one CVD risk factor. Although that study focused on the clustering of risk factors among obese adolescents, the authors found that 15.5% of normal weight boys and 18.8% of normal weight girls had metabolic syndrome (10).

In children and adolescents, a direct relationship between obesity and the prevalence of MetS has been reported (11, 12); however, data about phenotypes of obesity and metabolic phenotype is rather limited. Therefore the main objective of this study is to find Prevalence of different phenotypes of obesity and different metabolic phenotypes of obesity in a large nationally representative sample of Iranian children and adolescents.

## Methods

The present study was conducted on the data of "the fifth survey of the school-based surveillance system entitled **C**hildhood and **A**dolescence **S**urveillance and **P**revention of **A**dult **N**on-communicable Disease (CASPIAN-V) study" (2014–2015), conducted in 30 provinces of Iran. Details on the study protocol have been discussed previously (13), and here we briefly point to the essential details related to the current study topic.

## Study population and sampling

Using multistage stratified cluster sampling method, the study participants were selected from students aged 7–18 years in primary and secondary schools in urban and rural of 30 provinces.

For proportional to size sampling along with the student's residence area (urban or rural), educational levels (primary and secondary) considered with equal sex ratio (14).

Achieving the desired number of samples was obtained using cluster sampling in each province with equal cluster sizes. Clusters were determined at school levels. The size of each cluster was 10 students; meaning that a total of 10 statistical units (including 10 students and their parents) would be considered in each cluster. The sample size of main survey included 480 students in each province (48 clusters of 10 students), i.e. a total of 14,400 students at national level. In each province, 14 out of 48 clusters were randomly selected for biochemical tests. Therefore, sample size of current study was estimated to be 4200.

## Procedure and measurements of data gathering

### Questionnaires

Data for students gathered through Persian-translated version of questionnaire was developed based on the World Health Organization-Global School Student Health Survey (WHO-GSHS) (15). The validity and reliability of questionnaires has been assessed through previous assessments (16). More over demographic information including Age, sex, family history of diseases and metabolic risk factors, complementary data on family characteristics, namely household size, order of students and socioeconomic variables questioned through parents' questionnaires.

### Physical measurements

Under standard protocols and by using calibrated instruments, a team of trained health care experts performed the physical examination. Weight measured in light clothing to the nearest 0.1 kg on a SECA digital weighing scale (SECA, Germany). Height was assessed without shoes to the nearest 0.1 cm while the students were standing and the shoulders were in normal position (17).

Body mass index (BMI) was calculated by dividing weight (kg) to height squared ($m^2$). We used the WHO growth charts to categorize BMI (15).

Waist circumference was measured using a non-elastic tape at a point midway between the lower border of the rib cage and the iliac crest at the end of normal expiration to the nearest

0.1 cm. Hip circumference was measured at the widest part of the hip at the level of the greater trochanter to the nearest 0.1 cm.

Blood pressure was measured in the sitting position on the right arm using a mercury sphygmomanometer with an appropriate cuff size. It was measured 2 times at 5-min intervals; systolic and diastolic pressures were recorded and the average was registered (18).

## Laboratory analysis

Selected students for blood sampling were referred to the predefined laboratory. After 12-h overnight fasting 6 mL venous blood sample was collected. All collection tubes were centrifuged at 2500–3000 x g for 10 min. Immediately after centrifugation, serum samples were aliquot into 200 μl tubes and stored at −70 °C. Using a comprehensive by cold chain program, all of samples were transferred to Isfahan Mahdieh Laboratory. Alanine aminotransferase (ALT), Fasting blood glucose (FBG), triglycerides (TG), total cholesterol (TC), low- density lipoprotein-cholesterol (LDL-C) and high-density lipoprotein-cholesterol (HDL-C) were measured enzymatically by Hitachi auto-analyzer (Tokyo, Japan) (19, 20) .

## Definitions

Demographic information: Through an interview with parents or child, demographic information was asked for all students in the sampled classes of the selected schools. Family based characteristics including: family history of chronic diseases (hypertension, dyslipidemia, diabetes, and obesity), parental level of education (the highest total years of schooling), possessing a family private car and type of home (rented/owned), dietary behaviors, PA, and sedentary lifestyle.

Metabolic Syndrome (MetS) was defined according to ATP III criteria modified for children and adolescents as clustering of at least three of the five cardiometabolic risk factors including abdominal obesity (AO), elevated BP, elevated FPG, high serum TG and low serum HDL (21).

Fasting blood glucose (FBG) ≥ 100 mg/dl, serum triglycerides (TG) ≥ 100 mg/dl, and HDL-C < 40 mg/dl (except in boy 15-18y mg/dl <45 mg/dl) were considered as abnormal (21). HTN defined as systolic and/or diastolic BP that is ≥95th age-sex specific percentile (22). AO was defined as WHtR>0.5.

Generalized obesity (GO) according to WHO growth curve as BMI > 95th for age-sex specific percentile (15). Subjects were classified into four groups in terms of AO and GO: normal (5th < BMI < 85th percentile and WHtR<0.5), only AO (WHtR>0.5 and BMI < 95th percentile), only GO (BMI > 95th and WHtR<0.5), combined obesity (CO) (BMI > 95th and WHtR>0.5).

Participants were classified in four different phenotypes according to GO and MetS. 1) MHO (metabolically healthy obese): without MetS and BMI > 95th, MNHNO (metabolically non-healthy non-obese): having metabolic syndrome and 5th < BMI < 85th, MNHO (metabolically non-healthy obese): having metabolic syndrome and BMI > 95th and MHNO (metabolically healthy nonobese): without metabolic syndrome and 5th < BMI < 85th.

Screen time (ST): The ST behavior of the children was assessed through the questionnaire that asked them to report the average number of hours//day they spent on watching TV/VCDs, personal computer (PC), or electronic games (EG) in time of week days and weekends.

Socioeconomic status (SES): Aim to assessment the SES of students, using principle component analysis (PCA) method related questions including parental education, parents' job, possessing private car, school type (public/private), and having personal computer were combined as a unique index (15).

## Ethical concerns

Study protocols were reviewed and approved by ethical committees and other relevant national regulatory organizations. The Research and Ethics council of Isfahan University of Medical Sciences approved the study (Project number: 194049). After complete explanation of the study objectives and protocols, written informed consent and verbal consent were obtained from the parents and students, respectively.

## Statistical analysis

Quantitative variables were reported as percentages (95% CI), and qualitative variables were reported as mean ± CI (95%CI). The Chi-square test was used to analyze qualitative variables, and comparison of means of quantitative variables was done by ANOVA test. In our statistical analysis survey data method (cluster sampling) was considered.

Data were analyzed using STATA package version 11.0 (Stata Statistical Software: Release 11. StataCorp LP. Package, College Station, TX, USA), and $P < 0.05$ was considered as statistically significant.

# Results

Overall, 3843 students (52.3% boys) with mean (SD) age of 12.45 (3.04) years from 4200 invited students (participation rate: 91.5%) were assessed. Table 1 summarizes the prevalence of different phenotypes of obesity (only AO, only GO and CO) and different metabolic phenotypes of obesity according to age, sex and region. According to this table, the prevalence of only AO among girls and boys was 12.17 (11.6.12.7) more than only GO 2.51 (2.3, 2.8) and CO 8.86 (8.4.9.3). The prevalence of only AO was 12.62 (12.13.3), only GO 2.69 (2.4.3), and its combination was 8.86 (8.4.9.3)

**Table 1** Prevalence (95% CI) of different phenotypes of obesity and different metabolic phenotypes of obesity according to sex, age and living area in Iranian children and adolescents: the CASPIAN V study

| | Total | Sex | | Living area | | Age group | |
|---|---|---|---|---|---|---|---|
| | | Girls | Boys | Urban | Rural | 6–12 y | 12–18 y |
| Different phenotypes of obesity | | | | | | | |
| Normal [a] | 76.45 (75.7,77.1) | 77.25 (76.2,78.2) | 75.68 (74.7,76.6) | 74.18 (73.3,75) | 82.13 (80.9,83.2) | 76.17 (75.2,77.1) | 76.77(75.7,77.8) |
| Only abdominal obesity [b] | 12.17(11.6,12.7) | 12.44(11.7,13.2) | 11.9(11.2,12.6) | 12.62 (12,13.3) | 11.03(10.1,12) | 12.16(11.4,12.9) | 12.18(11.4,13) |
| Only generalized obesity [c] | 2.51 (2.3, 2.8) | 2.3 (2,2.7) | 2.72 (2.4,3.1) | 2.69 (2.4,3) | 2.08 (1.7,2.5) | 3.14 (2.8,3.5) | 1.81 (1.5,2.2) |
| Combined obesity [d] | 8.86(8.4,9.3) | 8 (7.4,8.7) | 9.69 (9,10.4) | 10.51(9.9,11.1) | 4.76 (4.1,5.5) | 8.52 (7.9,9.2) | 9.24 (8.6,9.9) |
| *P* Value * | | <0.001 | | <0.001 | | <0.001 | |
| Different metabolic phenotypes of obesity | | | | | | | |
| MHNO [e] | 85.84 (84.8,86.8) | 87.73 (86.1,89,2) | 84.15 (82.6,85.6) | 84.26 (83,85.4) | 90.08 (88.2,91.7) | 84.86 (83.3,86.3) | 86.87 (84.8,86.3) |
| MHO [f] | 9.11 (8.2,10.1) | 7.74 (6.6,9.1) | 10.35 (9.1, 11.8) | 6.58 (5.2,8.2) | 10.07 (9,11.2) | 10.3 (9.1,11.6) | 7.87 (6.7,9.2) |
| MNHNO [g] | 3.21 (2.7,3.8) | 3.11 (2.4,5.1) | 3.31 (2.6,4.2) | 2.16 (1.4, 3.3) | 3.61 (2.9, 4.4) | 3.05 (2.3,3.9) | 3.39 (2.6,4.3) |
| MNHO [h] | 1.82 (1.4,2.3) | 1.41 (0.9,2.1) | 2.19 (1.6, 2.9) | 1.17 (0.7,2) | 2.06 (1.6,2.6) | 1.78 (1.3,2.5) | 1.86 (1.4, 2.3) |
| P value * | | 0.01 | | 0.0001 | | 0.06 | |

BMI: body mass index; WHtR: waist to height ratio; MHNO: Metabolic healthy non obese; MHO: Metabolic healthy obese; MNHNO: Metabolic non healthy non obese; MNHO: Metabolic non healthy obese

[a] Normal: 5th < BMI < 85th age sex specific percentile and WHtR<0.5

[b] Only abdominal obesity: WHtR>0.5 and 5th < BMI < 85th age sex specific percentile

[c] Only generalized obesity: BMI > 95th age sex specific percentile and WHtR<0.5 and

[d] Combined Obesity: BMI > 95th age sex specific percentile and WHtR>0.5

[e] MHNO: Without metabolic syndrome and 5th < BMI < 85th age sex specific percentile

[f] MHO: Without metabolic syndrome and BMI > 95th age sex specific percentile

[g] MNHNO: having metabolic syndrome and 5th < BMI < 85th age sex specific percentile

[h] MNHO: Having metabolic syndrome and BMI > 95th age sex specific percentile

Metabolic syndrome defined as having at least three components of metabolic syndrome according to modified ATP III criteria for children and adolescents

*$P \leq 0.05$ is considered as significant

in urban areas which was greater than rural areas ($P < 0.001$). Compared to the two age groups 6–12 years and 18–12 years, only AO in both groups was 12.16% and 12.18% respectively, but only GO in the age group of 12–6 years old was 3.14% and in the 18–18 year old group was 1.81%. CO in the age group of 12–18 years old was more than 6–12 years old (9.24% vs. 8.52%).

The prevalence of different metabolic phenotypes of obesity, MHO 10.35 (9.1, 11.8), MNHNO 3.31 (2.6,4.2) and MNHO 2.19 (1.6, 2.9) was found in boys, while the prevalence of these phenotypes was lower in girls (7.74 (6.6, 9.1), 3.11 (2.4,5.1) and 1.41 (0.9,2.1) respectively). In contrast to the prevalence of phenotypes of obesity (only AO and only GO), the percentage of different metabolic phenotypes of obesity (MHO, MNHNO, MNHO) in rural area was higher than urban areas ($P = 0.0001$). Comparing the age range, the prevalence of MHO phenotype in the age group of 6–12 years was higher than 18–12 years old. However, the difference between different metabolic phenotypes of obesity and the two age groups was not statistically significant ($P = 0.06$).

The percentage of girls and boys who had elevated TG and FBS and low HDL had a significant statistical significance in all of the different metabolic phenotypes of obesity (MHO, MNHNO, and MNHO) ($P \leq 0.05$). Also SBP were significant in all groups of only AO, only GO and CO in both sexes ($P \leq 0.05$).

Table 2 shows that the highest prevalence of elevated TG was in girls with MNHNO 90.91 and in boys with MNHO 86.05 (71.7.93.7) phenotype. The prevalence of low HDL 81.82 and the elevated FBS was 25.45 in girls with MNHNO phenotype, which was similar to that of boys (89.23 and 36.92 respectively). The highest percentage of dyslipidemia of 100 and high BP 14.71 was found in both sexes with MNHO phenotype.

By considering the components of metabolic syndrome (TG, HDL, FBS, BP) reveal that the highest component was related to high blood pressure with 9.9 in both genders, but there was no significant relationship with other components. Furthermore, in subjects with 3 or more components of metabolic syndrome, there was a significant difference between only AO, only GO, MNHNO and MNHO phenotypes ($P \leq 0.05$). Both girls and boys with MNHNO and MNHO phenotypes had the highest levels of metabolic syndrome.

Table 3 shows mean (95% CI) cardiometabolic risk factors according to different phenotypes of obesity. The mean of weight, BMI, HC, SBP, DBP in subjects with only generalized obesity was higher that other phenotypes.

Girls with MHO phenotype had the highest mean of weight and BMI compared with other phenotypes. MNHNO and MNHO had the highest mean of TG and FBS and the lowest mean of HDL. There was a significant relationship between weight, BMI, WC, HC, WHtR, TG, HDL, SBP, DBP, FBS with different metabolic phenotypes of obesity (MHO, MNHNO,MNHO) in both sexes ($P < 0.001$). (Table 4).

## Discussion

The findings of present study indicated that, the percentage of girls and boys who had elevated TG and FBS and low HDL had a significant statistical significance in all of the different metabolic phenotypes of obesity (MHO, MNHNO, and MNHO). Also SBP were significant in all groups of only AO, only GO and CO in both sexes. Our results showed that the highest prevalence of elevated TG was in girls with MNHNO 90.91 and in boys with MNHO 86.05 phenotype. The prevalence of low HDL 81.82 and the elevated FBS was 25.45 in girls with MNHNO phenotype, which was similar to that of boys. The highest percentage of dyslipidemia of 100 and high BP 14.71 was found in both sexes with MNHO phenotype. In line with these findings, a study among 6748 non-diabetic subjects mean age 43 years in Seoul, Korea showed that, among the components of metabolic syndrome, the prevalence for hypertriglyceridemia and low HDL-C were markedly higher in metabolically unhealthy groups compared to other components in metabolically healthy groups (24). Although the usefulness of different metabolic phenotypes of obesity in determining cardiometabolic risk factors has been studied in previous studies among adult population and in different groups of patients, few studies in this field were conducted in pediatric populations (9, 25, 26). one study in a large healthy Brazilian population showed that the prevalence of hypertension, diabetes, and dyslipidemia was higher in the metabolically unhealthy groups as compared to the metabolically healthy phenotypes (27). These findings are also consistent with a previous study that indicated metabolically healthy abdominal obese individuals have increased values of blood pressure, FBS, 2-h blood glucose, insulin resistance, and less favorable lipid profiles compared to metabolically healthy non-abdominal obese phenotype at baseline (7).

The findings of the present study indicated that by considering the components of metabolic syndrome (TG, HDL, FBS, BP) reveal that the highest component was related to high blood pressure with 9.9 in both genders, but there was no significant relationship with other components. Furthermore, in subjects with 3 or more components of metabolic syndrome, there was a significant difference between only AO, only GO, MNHNO and MNHO phenotypes ($P \leq 0.05$). Both girls and boys with MNHNO and MNHO phenotypes had the highest levels of metabolic syndrome. The findings are in line with previous study that showed Metabolically unhealthy groups significantly worse mean values in FBS, serum creatinine, TG, HDL-C, fasting insulin, BP and HOMA-IR compared with metabolically healthy groups (24).

Our results showed that the mean of weight, BMI, HC, SBP, DBP in subjects with only generalized obesity was higher that other phenotypes. And girls with MHO phenotype

**Table 2** Prevalence (95% CI) of cardiometabolic risk factors according to different phenotypes of obesity and different metabolic phenotypes

| | Different phenotypes of obesity | | | | Different metabolic phenotypes of obesity | | | |
|---|---|---|---|---|---|---|---|---|
| Sex | Normal [a] (*n* = 2938) | Only abdominal obesity [b] (*n* = 101) | Only generalized Obesity [c] (*n* = 450) | Combined obesity [d] (*n* = 312) | MHNO [e] (*n* = 3202) | MHO [f] (*n* = 340) | MNHNO [g] (*n* = 120) | MNHO [h] (*n* = 68) |
| Girls | | | | | | | | |
| Elevated TG | 28.46 (26.2,30.8) | 29.57 (23.7,36.2) | 40 (28.2,53.1) | 23.93 (17.1,32.4) | 26.11 (24,28.3)* | 19.71 (13.9,27.1)* | 90.91 (81.1,95.9)* | 76 (56.8,88.4)* |
| Elevated TC | 4.87 (3.9,6.1) | 4.35 (2.4,7.7) | 6 (2.1,16.2) | 4.27 (1.8,9.8) | 4.9 (3.9,6.1) | 5.11 (2.5,10.2) | 3.64 (0.9,13.5) | 4 (0.5,24) |
| Elevated LDL | 18.57 (16.7,20.6) | 16.09 (11.9,21.3) | 14 (6.8,26.5) | 20.51 (14, 23) | 18.38 (16.6,20.3) | 20.44 (14.7,27.8) | 10.91 (5,22.3) | 8 (1.9,27.5) |
| Low HDL | 25.56 (23.3,28) | 23.91 (18.7,30) | 34 (22,48.4) | 32.48 (24,42.2) | 23.15 (21.1,25.4)* | 25.5 (18.2,34.5)* | 81.82 (69.3,90)* | 76 (55.6,88.9)* |
| Dyslipidemia | 53.67 (51.1,56.2) | 53.04 (46.6,59.4) | 60 (46.2,72.4) | 62.39 (53.4,70.6) | 51.71 (49.3,54.1)* | 55.47 (46.6,64)* | 100* | 100* |
| High SBP | 2.8 (2.4,3.2)* | 2.34 (1.5,3.6)* | 10.53 (6.8,15.9)* | 7.55 (5.6,10)* | 1.55 (1,2.3)* | 4.38 (2,9.4)* | 5.45 (1.7,15.8)* | 8 (2,27.3)* |
| High DBP | 8.9 (8.2,9.7)* | 10.67 (8.8,12.9)* | 15.13 (10.5,21.3)* | 19.82 (16.7,23.4)* | 6.9 (5.8,8.2)* | 9.49 (5.7,15.4)* | 38.18 (27,50.8)* | 56 (35.5,74.6)* |
| High BP | 10.06 (9.3,10.9)* | 11.25 (9.3,13.5)* | 19.74 (14.7,25.9)* | 21.98 (18.6,25.8)* | 7.48 (6.3,8.8)* | 12.41 (7.9,18.8)* | 38.18 (27, 50.8)* | 56 (35.5,74.6)* |
| Elevated FBS | 3.46 (2.7,4.4) | 4.78 (2.7,8.3) | 2 (0.3,13) | 3.42 (1.3,8.6) | 2.9 (2.2,3.8)* | 0.73 (0.1,5)* | 25.45 (16,37.9)* | 16 (6.4,34.6)* |
| MetS | 1.38 (0.9,2.2)* | 15.8 (11.6,21.1)* | 6.67 (2.1,18.9)* | 18.8 (12.6,27.1)* | 0 | 0 | 100* | 100* |
| Boys | | | | | | | | |
| Elevated TG | 26.54 (24.4,28.8) | 27.27 (21.6,33.7) | 25.49 (15.4,39.1) | 30.26 (23.9,37.4) | 24.29 (22.3,26.4)* | 17.24 (12.5,23.2)* | 83.08 (71,90.8)* | 86.05 (71.7,93.7)* |
| Elevated TC | 5.32 (4.3,6.5) | 4.09 (2.1,7.7) | 1.96 (0.3,12.7) | 3.59 (1.7,7.3) | 5.27 (4.3,6.4) | 2.46 (1,5.7) | 4.61 (1.5,13.3) | 6.98 (2.3,19.4) |
| Elevated LDL | 16.56 (14.8,18.4) | 18.64 (14,24.7) | 15.69 (8.1,28.2) | 19.49 (14.5,25.6) | 17.08 (15.4,18.9) | 16.75 (12.2,22.5) | 15.38 (8.5,26.2) | 27.91 (16.1,43.8) |
| Low HDL | 33.51 (31.4,35.6) | 30 (24.3,36.4) | 25.49 (15.3,39.2) | 32.82 (26.7,39.6) | 31.01 (29,33.1)* | 22.17 (17.4,27.9)* | 89.23 (78.6,94.9)* | 74.42 (60,84.9)* |
| Dyslipidemia | 56.9 (54.5,59.3) | 59.09 (52.5,65.4) | 54.9 (40.6,68.4) | 58.46 (51.4,65.2) | 55.66 (53.3,58)* | 48.77 (41.9,55.7)* | 98.46 (89.7,99.8)* | 100* |
| High SBP | 2.27 (1.9,2.7)* | 2.88 (1.9,4.2)* | 4.21 (2.1,8.1)* | 8.13 (6.4,10.3)* | 2.12 (1.5,2.9)* | 3.94 (2,7.6)* | 10.77 (5.2,20.9)* | 18.6 (9.9,32.3)* |
| High DBP | 8.96 (8.3, 9.7)* | 12.14 (10.1,14.5)* | 15.26 (11.1,20.7)* | 19.01 (16.3,22)* | 7.08 (6,8.3)* | 13.3 (9.3,18.6)* | 41.54 (29.8,54.3)* | 44.19 (29.9,52.4)* |
| High BP | 9.85 (9.1,10.6)* | 13.22 (11.,15.6)* | 16.32 (11.9,21.9)* | 20.61 (17.8,23.7)* | 7.8 (6.7,9.1)* | 13.79 (9.7,19.2)* | 44.62 (32.7,57.2)* | 46.51 (32,61.6)* |
| Elevated FBS | 4.93 (3.9,6.2) | 4.54 (2.3,8.7) | 3.92 (0.9,14.5) | 3.59 (1.7,7.3) | 3.63 (2.8,4.6)* | 1.97 (0.7,5.1)* | 36.92 (26.2,49.1)* | 11.63 (4.8,25.4)* |
| MetS | 2.13 (1.5,3)* | 15.28 (11.1,20.6)* | 1.96 (0.3,12.7)* | 21.54 (15.9,28.4)* | 0 | 0 | 100* | 100* |
| Total | | | | | | | | |
| Elevated TG | 27.47 (25.9,29.1) | 32.67 (24.2,42.4) | 28.44 (24.2,33.2) | 27.88 (23.1,33.9) | 25.17 (23.7,26.7)* | 18.24 (14.4,22.8)* | 86.67 (79,91.8)* | 82.35 (71.2,89.8)* |
| Elevated TC | 5.1 (4.4,5.9) | 4.22 (2.7,6.5) | 3.96 (1.6,9.2) | 3.85 (2.2,6.6) | 5.09 (4.4,5.8) | 3.53 (2.1,5.9) | 4.16 (1.7,9.6) | 5.88 (2.2,14.7) |

**Table 2** (continued)

| | Different phenotypes of obesity | | | | Different metabolic phenotypes of obesity | | | |
|---|---|---|---|---|---|---|---|---|
| Elevated LDL | 17.53 (16.2,18.9) | 17.33 (14.1,21.2) | 14.85 (9,23.6) | 19.87 (15.8,24.6) | 17.71 (16.5,19) | 18.24 (14.5,21.1) | 13.33 (8.1,21.1) | 20.59 (11.9,33.1) |
| Low HDL | 29.7 (28.2, 31.2) | 26.7 (22.8,31.4) | 29.7 (21.5,39.4) | 32.7 (27.7,38.1) | 27.2 (25.8,28.9)* | 23.53 (19.3,28.4)* | 85.83 (78.4,91)* | 75 (63.6,83.7)* |
| Dyslipidemia | 55.34 (53.5,57.1) | 56 (51.1,60.7) | 57.43 (47.4,66.9) | 59.94 (54.6,65.1) | 53.75 (52,55.5)* | 51.47 (46.1,56.8)* | 99.17 (94.3,99.9)* | 100 * |
| High SBP | 2.53 (2.3,2.8)* | 2.6 (1.9,3.5)* | 7 (4.8,10.1)* | 7.9 (6.5,9.4)* | 1.84 (1.4,2.3)* | 4.12 (2.4,7)* | 8.33 (4.6,14.7)* | 14.71 (8.2,24.9)* |
| High DBP | 8.9 (8.4,9.5)* | 11.4 (9.9,13)* | 15.2 (11.9,19.2)* | 19.37 (17.3,21.6)* | 6.99 (6.2,7.9)* | 11.76 (8.8,15.6)* | 40 (31.5, 49.2)* | 48.53 (36.5,60.8)* |
| High BP | 9.9 (9.4,10.5)* | 12.2 (10.8,13.8)* | 17.8 (14.4,21.9)* | 21.22 (19.1,23.5)* | 7.65 (6.8,8.5)* | 13.24 (10.1,17.2)* | 41.67 (33.1,50.8)* | 50 (37.8,62.2)* |
| Elevated FBS | 4.22 (3.5,5) | 4.7 (3,7.2) | 2.97 (0.9,8.8) | 3.5 (1.9,6.3) | 3.28 (2.7,4)* | 1.47 (0.6,3.5)* | 31.67 (24.1,40.3)* | 13.24 (7,23.6)* |
| MetS | 1.77 (1.3,2.3)* | 15.54 (12.4,19.2)* | 4.17 (1.5,10.7)* | 20.51 (16.2,25.6)* | 0 | 0 | 100* | 100* |

MetS: metabolic syndrome; FBS, fasting blood sugar; TC, total cholesterol; TG, triglycerides; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI: body mass index; WHtR: waist to height ratio; MHNO: Metabolic healthy non obese; MHO: Metabolic healthy obese; MNHNO: Metabolic non healthy non obese; MNHO: Metabolic non healthy obese

[a] Normal: 5th < BMI < 85th age sex specific percentile and WHtR<0.5

[b] Only abdominal obesity: WHtR>0.5 and 5th < BMI < 85th age sex specific percentile

[c] Only generalized obesity: BMI > 95th age sex specific percentile and WHtR<0.5 and

[d] Combined Obesity: BMI > 95th age sex specific percentile and WHtR>0.5

[e] MHNO: Without metabolic syndrome and 5th < BMI < 85th age sex specific percentile

[f] MHO: Without metabolic syndrome and BMI > 95th age sex specific percentile

[g] MNHNO: having metabolic syndrome and 5th < BMI < 85th age sex specific percentile

[h] MNHO: Having metabolic syndrome and BMI > 95th age sex specific percentile

Dyslipidemia: at least one of thecomponents (TG, HDL, LDL, TC) are abnormal; Low HDL: HDL < 40 mg/dL (except in boys 15 ± 19 y old, that cut-off was <45 mg/dL); High LDL: LDL > 110 mg/dL; High TG: TG > 100 mg/dL; High TC: TC > 200 mg/dL; HighFBS: FBS > 100 mg/dL; High blood pressure: BP > 90th (adjusted by age, sex, height); Metabolic syndrome: ATP-III criteria.* $P \leq 0.05$ is considered as significant

**Table 3** Mean (95% CI) of cardiometabolic risk factors according to different phenotypes of obesity in Iranian children and adolescents

| | Total | Normal [a] ($n = 2938$) | Abdominal obesity [b] ($n = 101$) | Generalized obesity [c] ($n = 450$) | Combined Obesity [d] ($n = 312$) | *P* value |
|---|---|---|---|---|---|---|
| Girls | | | | | | |
| Weight (kg) | 40.4 (40.2,40.6) | 37.6 (37.3,39.2) | 41.7 (40.7,42.6) | 56.5 (53.6,59.4) | 60.1 (58.6,61.6) | <0.001 |
| Height (cm) | 144.9 (144.7145.1) | 144.9 (144.6145.2) | 142.6 (141.6143.6) | 147.8 (145.2150.4) | 148.1 (146.8149.4) | <0.001 |
| BMI (kg/m$^2$) | 18.5 (18.4,18.6) | 17.3 (17.2,17.4) | 19.6 (19.4,19.9) | 25.4 (24.5,26.2) | 26.8 (26.4,27.2) | <0.001 |
| WC (cm) | 65.8 (65.5,66) | 62.4 (62.2,62.5) | 76 (75.4,76.6) | 66.1 (63.9,68.3) | 82.6 (81.8,83.5) | <0.001 |
| HC (cm) | 79.3 (79.1,79.6) | 77.1 (76.8,77.4) | 82.4 (81.5,83.3) | 84.4 (81.1,87.7) | 95.4 (94.1,96.7) | <0.001 |
| WHtR | 0.45 (0.45,0.45) | 0.43 (0.43,0.43) | 0.53 (0.53,0.54) | 0.44 (0.43,0.45) | 0.56 (0.55,0.57) | <0.001 |
| TG (mg/dL) | 89 (87.1,91) | 88.9 (86.7,91.2) | 89.5 (83.8,95.1) | 99.5 (86.5112.6) | 85.6 (79,92.3) | 0.32 |
| TC (mg/dL) | 152.9 (151.8154.1) | 155.2 (153.9156.6) | 153.5 (150.2156.7) | 152 (145.2158.8) | 153.1 (148.2158) | 0.58 |
| LDL (mg/dL) | 90.9 (89.8,91.8) | 91.2 (90.1,92.3) | 89.3 (86.5,92.1) | 87.9 (82.1,93.7) | 90.9 (86.9,94.9) | 0.51 |
| HDL (mg/dL) | 46.1 (45.7,46.6) | 46.3 (45.7,46.8) | 46.3 (44.9,47.7) | 44.1 (41.6,46.7) | 45.1 (43.1,47.1) | 0.29 |
| SBP (mm Hg) | 98.8 (98.5,99) | 98 (97.7,98.2) | 98.7 (97.9,99.5) | 104.2 (102.3106.1) | 105 (103.9106.2) | <0.001 |
| DBP (mm Hg) | 63.6 (63.4,63.8) | 63.1 (62.8,63.3) | 63.9 (63.2,64.5) | 65.8 (64.3,67.3) | 67.4 (66.4,68.4) | <0.001 |
| FBS (mg/dL) | 91.2 (90.8,91.6) | 91.3 (90.8,91.8) | 91.7 (90.4,93.1) | 89.9 (87.3,92.5) | 90 (87.8,92.2) | 0.45 |
| Boys | | | | | | |
| Weight (kg) | 42.4 (42.1,42.6) | 38.9 (38.7,39.2) | 43.2 (42.1,44.3) | 56.6 (52.9,60.4) | 63.5 (62,65) | <0.001 |
| Height (cm) | 148.1 (144.7145.1) | 148 (147.7148.3) | 145.6 (144.4146.8) | 148.1 (145.4150.9) | 152.1 (150.7153.5) | <0.001 |
| BMI (kg/m$^2$) | 18.5 (18.4,18.6) | 17 (16.9,17.1) | 19.3 (19.1,19.5) | 25.6 (23.4,27.5) | 26.6 (26.2,27) | <0.001 |
| WC (cm) | 67.6 (67.4,67.9) | 63.7 (63.5,63.9) | 77.6 (76.9,78.4) | 65.1 (63.5,66.8) | 87 (86.1,87.9) | <0.001 |
| HC (cm) | 78.9 (78.7,79.1) | 76.5 (76.2,76.7) | 81.7 (80.9,82.6) | 80.3 (77.9,82.7) | 94.7 (93.8,95.7) | <0.001 |
| WHtR | 0.45 (0.45,0.46) | 0.43 (0.42,0.43) | 0.53 (0.53,0.54) | 0.44 (0.43,0.45) | 0.57 (0.56,0.58) | <0.001 |
| TG (mg/dL) | 87.1 (85.1,89.2) | 86.5 (84.4, 88.7) | 88.5 (82.6,94.4) | 83.3 (71.9,94.8) | 91.8 (84.4,99.2) | 0.4 |
| TC (mg/dL) | 154.8 (153.6156) | 152.5 (151.1153.9) | 153.7 (149.8157.6) | 150.9 (142.9158.8) | 156.5 (152.8160.1) | 0.27 |
| LDL (mg/dL) | 89.3 (88.4,90.2) | 89.1 (88,90.2) | 89.4 (86.3,92.5) | 85.8 (78.9,92.8) | 92.1 (89.1,95.1) | 0.23 |
| HDL (mg/dL) | 46.2 (45.8,46.6) | 446.1 (45.6,46.6) | 46.6 (45.1,48) | 48.3 (45.1,51.6) | 46 (44.6,47.3) | 0.4 |
| SBP (mm Hg) | 99.5 (99.3,99.8) | 98.7 (98.4,98.9) | 100.2 (99.4101) | 101.7 (100.3103.1) | 105.2 (104.2106.1) | <0.001 |
| DBP (mm Hg) | 64.1 (63.9,64.3) | 63.4 (63.2,63.7) | 64.5 (63.8,65.2) | 65.6 (64.3,66.9) | 68 (67.2,68.8) | <0.001 |
| FBS (mg/dL) | 92.1 (91.5,92.6) | 92 (91.3,92.6) | 93.5 (92.2,94.9) | 90.6 (87.2,94.1) | 91.4 (90.2,92.7) | 0.26 |
| Total | | | | | | |
| Weight (kg) | 41.4 (41.2,41.6) | 38.3 (38.1,38.4) | 42.5 (41.7,43.2) | 56.5 (54.2,58.9) | 62 (60.1,63.1) | <0.001 |
| Height (cm) | 146.6 (146.4146.7) | 146.5 (146.3146.7) | 144.1 (143.3144.9) | 148 (146.1149.9) | 150.3 (149.3151.3) | <0.001 |
| BMI (kg/m$^2$) | 18.5 (18.4,18.6) | 17.2 (17.1,17.2) | 19.5 (19.3,19.6) | 25.5 (24.4,26.6) | 26.7 (26.4,27) | <0.001 |
| WC (cm) | 66.7 (66.6,66.9) | 63 (62.9,63.2) | 76.8 (76.3,77.3) | 65.5 (64.1,66.9) | 85.1 (84.4,85.7) | <0.001 |
| HC (cm) | 79.1 (79,79.3) | 76.8 (76.6,77) | 82.1 (81.4,82.7) | 82.2 (80.1,84.2) | 95 (94.2,95.8) | <0.001 |
| WHtR | 0.46(0.45,0.46) | 0.43 (0.43,0.43) | 0.53 (0.53,0.54) | 0.44 (0.43,0.45) | 0.57 (0.56,0.57) | <0.001 |

**Table 3** (continued)

| | Total | Normal [a] ($n = 2938$) | Abdominal obesity [b] ($n = 101$) | Generalized obesity [c] ($n = 450$) | Combined Obesity [d] ($n = 312$) | *P* value |
|---|---|---|---|---|---|---|
| TG (mg/dL) | 88 (86.6,89.5) | 87.7 (86.1,92) | 92.6 (91.7,93.6) | 90.3 (88.1,92.4) | 90.9 (89.7,92.1) | 0.74 |
| TC (mg/dL) | 153.8 (153,154.7) | 153.8 (152.9154.8) | 153.6 (150.9156.2) | 151.4 (145.8157) | 155.2 (152.3158.2) | 0.65 |
| LDL (mg/dL) | 90 (89.4,90.1) | 90.1 (89.3,90.9) | 89.3 (87.2,91.5) | 86.9 (82,91.8) | 91.7 (89.3,94) | 0.26 |
| HDL (mg/dL) | 46.2 (45.9,46.5) | 46.2 (45.8,46.5) | 46.4 (45.3,47.5) | 46.3 (44.2,48.4) | 45.7 (44.5,46.8) | 0.77 |
| SBP (mm Hg) | 99.2 (99,99.3) | 98.3 (98.1,98.5) | 99.4 (98.9100) | 102.8 (101.7104) | 105.1 (104.4105.9) | <0.001 |
| DBP (mm Hg) | 63.8 (63.7,64) | 63.2 (63.1,63.4) | 64.2 (63.7,64.6) | 65.7 (64.7,66.7) | 67.7 (67.1,68.3) | <0.001 |
| FBS (mg/dL) | 91.6 (91.3,92) | 91.6 (91.2,92) | 92.6 (91.7,93.6) | 90.3 (88.1,92.4) | 90.9 (89.7,92.1) | 0.14 |

BMI, body mass index; WC, waist circumference; HC: hip circumference; FBS, fasting blood sugar; TC, total cholesterol; TG, triglycerides; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI: body mass index; WHtR: waist to height ratio;

a Normal: 5th < BMI < 85th age sex specific percentile and WHtR<0.5

b Only abdominal obesity: WHtR>0.5 and 5th < BMI < 85th age sex specific percentile

c Only generalized obesity: BMI > 95th age sex specific percentile and WHtR<0.5 and

d Combined Obesity: BMI > 95th age sex specific percentile and WHtR>0.5

*$P \leq 0.05$ is considered as significant

had the highest mean of weight and BMI compared with other phenotypes. Rolland-Cachera et al. hypothesized that the trajectory of persistently high BMI could correspond to MHO phenotype (28). Previous study among adolescents' age 12–18 years and adults' age 19–85 years in Boston showed that the prevalence of MHO phenotype was higher in girls than in boys both in the group with overweight/obesity and only obesity (29). But a study among 313 boys age 13.0–17.9 years in Czech Republic demonstrated that higher BMI *z* scores in metabolically unhealthy compared with their healthy counterparts (23).

In the present study, MNHNO and MNHO had the highest mean of TG and FBS and the lowest mean of HDL. There was a significant relationship between weight, BMI, WC, HC, WHtR, TG, HDL, SBP, DBP, FBS with different metabolic phenotypes of obesity (MHO, MNHNO, MNHO) in both sexes. Some studies in participants age 30–60 years (30), and 153 obese and non-obese women aged 19–48 year (31) have shown MHO-like phenotypes are in fact intermediate conditions that show higher levels of insulin resistance, lipid profile, blood pressure, and intima-media thickness although within normal values when compared to healthy non-obese individuals (30, 31).

Li and colleagues found that 63.1% of normal weight Chinese adolescents and all obese subjects had at least one CVD risk factor. Although that study focused on the clustering of risk factors among obese adolescents, the authors found that 15.5% of normal weight boys and 18.8% of normal weight girls had metabolic syndrome (10).

The main limitation of this study is the cross-sectional nature of the findings. The strength of the study is that to our knowledge, the concepts of different metabolic phenotypes of obesity among children have not been described in the pediatric literature from a national sample of children and adolescents. In addition, this study had a large sample size, and adds information to the very limited number of published data from a nationally representative sample of children and adolescents.

## Conclusion

Findings that highlight the importance of both obesity and metabolic syndrome in predicting future health outcomes. Therefore Healthy lifestyle education and program interventions are necessary for children with different metabolic phenotypes of obesity, as there is a high probability that they may suffer from poor health in the future.

**Table 4** Mean (95% CI) of cardiometabolic risk factors according to different metabolic phenotypes of obesity in Iranian children and adolescents

| | Total | MHNO [a] ($n = 3202$) | MHO [b] ($n = 340$) | MNHNO [c] ($n = 120$) | MNHO [d] ($n = 68$) | $P$ value |
|---|---|---|---|---|---|---|
| Girls | | | | | | |
| Weight (kg) | 40.4 (40.2,40.6) | 38.4 (37.9,38.9) | 60.6 (57.2,63.9) | 40.9 (37.7,44.1) | 58.4 (52.1,64.7) | <0.001 |
| Height (cm) | 144.9 (144.7145.1) | 145.2 (144.7145.7) | 148.3 (145.4151.1) | 146.5 (143.2149.9) | 148.6 (143,154.3) | 0.12 |
| BMI (kg/m$^2$) | 18.5 (18.4,18.6) | 17.6 (17.4,17.7) | 26.9 (26,27.8) | 18.5 (17.6,19.5) | 25.7 (24.5,27) | <0.001 |
| WC (cm) | 65.8 (65.5,66) | 64.5 (64.1,64.9) | 77.5 (75.2,79.8) | 73.1 (69.9,76.4) | 82 (77.7,86.3) | <0.001 |
| HC (cm) | 79.3 (79.1,79.6) | 78.2 (77.7,78.7) | 91.9 (88.7,95.1) | 81 (77.9,84.2) | 97.3 (92.3102.3) | <0.001 |
| WHtR | 0.45 (0.45,0.45) | 0.44 (0.44,0.45) | 0.52 (0.51,0.53) | 0.5 (0.48,0.52) | 0.55 (0.53,0.57) | <0.001 |
| TG (mg/dL) | 89 (87.1,91) | 84.6 (82.6,86.6) | 81.5 (75.9,87.2) | 146.4 (131,161.7) | 135.6 (115.5155.7) | <0.001 |
| TC (mg/dL) | 152.9 (151.8154.1) | 155.2 (153.8156.5) | 153.3 (148.8157.8) | 149.8 (143.7155.8) | 149.9 (140.8158.9) | 0.31 |
| LDL (mg/dL) | 90.9 (89.8,91.8) | 91.2 (90.1,92.3) | 90.8 (87.1,94.6) | 84 (78.4,89.6) | 85.6 (78.2,92.9) | 0.07 |
| HDL (mg/dL) | 46.1 (45.7,46.6) | 46.6 (46.1,47) | 46.2 (44.4,47.9) | 36.5 (35,37.9) | 37.2 (34.8,39.6) | <0.001 |
| SBP (mm Hg) | 98.8 (98.5,99) | 97 (96.5,97.5) | 103.8 (101.6105.9) | 103.9 (101,106.8) | 105.8 (100.4111.2) | <0.001 |
| DBP (mm Hg) | 63.6 (63.4,63.8) | 62.7 (62.3,63.1) | 65.4 (63.8,67) | 69.4 (66.8,72) | 74.6 (69.9,79.3) | <0.001 |
| FBS (mg/dL) | 91.2 (90.8,91.6) | 91.1 (90.6,91.5) | 88.8 (87.3,90.4) | 97.5 (94,101.1) | 96.5 (91.1101.8) | <0.001 |
| Boys | | | | | | |
| Weight (kg) | 42.4 (42.1,42.6) | 39.7 (39.3,40.2) | 58.6 (55.8,61.4) | 42.2 (37.9,46.5) | 70.7 (60.7,80.7) | <0.001 |
| Height (cm) | 148.1 (147.9148.4) | 148.3 (147.8148.8) | 148.6 (145.7151.5) | 147.3 (142.3152.2) | 154.6 (143,154.3) | 0.17 |
| BMI (kg/m$^2$) | 18.5 (18.4,18.6) | 17.4 (17.3,17.5) | 25.6 (25,26.1) | 18.5 (17.7,19.4) | 29.5 (24.5,34.5) | <0.001 |
| WC (cm) | 67.6 (67.4,67.9) | 65.2 (64.9,65.6) | 79 (77,81.1) | 70.1 (67.4,72.8) | 88.1 (84.2,92) | <0.001 |
| HC (cm) | 78.9 (78.7,79.1) | 77.6 (77.2,78.1) | 90 (87.9,92.1) | 81 (77.7,84.2) | 95.8 (91.8,99.8) | <0.001 |
| WHtR | 0.46 (0.45,0.46) | 0.44 (0.34,0.44) | 0.53 (0.52,0.54) | 0.48 (0.46,0.49) | 0.57 (0.55,0.59) | <0.001 |
| TG (mg/dL) | 87.1 (85.1,89.2) | 84.6 (82.6,86.6) | 79.4 (74,84.5) | 142.3 (124.6160) | 140.3 (122.3158.3) | <0.001 |
| TC (mg/dL) | 152.9 (151.8154.1) | 152.8 (151.5154.1) | 154 (150.5157.4) | 150.6 (143.6157.7) | 161.5 (151.9171.2) | 0.19 |
| LDL (mg/dL) | 89.3 (88.4,90.2) | 89.3 (88.3,90.4) | 90.2 (87.2,93.3) | 86.1 (80.4,91.8) | 93.6 (85.8101.4) | 0.38 |
| HDL (mg/dL) | 46.2 (45.8,46.6) | 46.6 (46.1,47) | 47.9 (46.5,49.2) | 36.1 (34.1,38) | 39.9 (37.4,42.3) | <0.001 |
| SBP (mm Hg) | 99.5 (99.3,99.8) | 98.5 (98,99) | 103.6 (101.8105.4) | 106 (102.2109.8) | 109.4 (100.4114) | <0.001 |
| DBP (mm Hg) | 64.1 (63.9,64.3) | 62.8 (62.4,63.2) | 66.9 (65.5,68.2) | 71.5 (68.3,74.6) | 72.5 (69.1,76) | <0.001 |
| FBS (mg/dL) | 92.1 (91.5,92.6) | 91.8 (91.2,92.3) | 90.6 (89.2,91.9) | 102.2 (98.1106.2) | 94.6 (91.1,98.1) | <0.001 |
| Total | | | | | | |
| Weight (kg) | 41.4 (41.2,41.6) | 39.1 (38.7,39.4) | 59.4 (57.2,61.6) | 41.6 (38.9,44.3) | 66.2 (59.3,73.1) | <0.001 |
| Height (cm) | 146.6 (146.4146.7) | 146.8 (146.4147.1) | 148.5 (146.4150.9) | 146.9 (143.8150) | 152.4 (148.2156.5) | 0.02 |
| BMI (kg/m$^2$) | 18.5 (18.4,18.6) | 17.5 (17.4,17.5) | 26.1 (25.6,26.6) | 18.5 (17.9,19.1) | 28.1 (24.9,31.3) | <0.001 |
| WC (cm) | 66.7 (66.6,66.9) | 64.8 (64.6,65.1) | 78.4 (76.9,80) | 71.5 (69.5,73.5) | 85.9 (82.8,89) | <0.001 |
| HC (cm) | 79.1 (79,79.3) | 77.9 (77.6,78.2) | 90.8 (89,92.6) | 81 (78.7,83.2) | 96.3 (93.2,99.5) | <0.001 |
| WHtR | 0.46(0.45,0.46) | 0.44 (0.44,0.44) | 0.53 (0.52,0.53) | 0.49 (0.48,0.5) | 0.56 (0.55,0.58) | <0.001 |
| TG (mg/dL) | 88 (86.6,89.5) | 85.6 (84.2,87.1) | 80.3 (76.3,84.2) | 144.2 (132.2156.1) | 138.6 (125.2152) | <0.001 |
| TC (mg/dL) | 153.8 (153,154.7) | 153.9 (153,154.9) | 153.7 (151,156.5) | 150.2 (145.4155) | 157.3 (150.1164.4) | 0.36 |
| LDL (mg/dL) | 90 (89.4,90.1) | 90.2 (89.5,91) | 90.5 (88.1,92.8) | 85.1 (81,89.3) | 90.7 (84.9,96.4) | 0.11 |
| HDL (mg/dL) | 46.2 (45.9,46.5) | 46.6 (46.2,46.9) | 47.2 (46.1,48.2) | 36.2 (35,37.5) | 38.9 (37.1,40.7) | <0.001 |
| SBP (mm Hg) | 99.2 (99,99.3) | 97.8 (97.4,98.1) | 103.7 (102.3105) | 105 (102.7107.4) | 108 (104.5111.6) | <0.001 |
| DBP (mm Hg) | 63.8 (63.7,64) | 62.8 (62.5,63.1) | 66.3 (65.2,67.3) | 70.5 (68.4,72.6) | 73.3 (70.5,76.1) | <0.001 |
| FBS (mg/dL) | 91.6 (91.3,92) | 91.4 (91.1,91.9) | 89.9 (88.8,90.9) | 100 (97.3102.8) | 95.3 (92.3,98.2) | <0.001 |

BMI, body mass index; WC, waist circumference; HC: hip circumference; FBS, fasting blood sugar; TC, total cholesterol; TG, triglycerides; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI: body mass index; WHtR: waist to height ratio; MHNO: Metabolic healthy non obese; MHO: Metabolic healthy obese; MNHNO: Metabolic non healthy non obese; MNHO: Metabolic non healthy obese

[a] MHNO: Without metabolic syndrome and 5th < BMI < 85th age sex specific percentile

[b] MHO: Without metabolic syndrome and BMI > 95th age sex specific percentile

[c] MNHNO: having metabolic syndrome and 5th < BMI < 85th age sex specific percentile

[d] MNHO: Having metabolic syndrome and BMI > 95th age sex specific percentile

*$P \leq 0.05$ is considered as significant

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## Compliance with ethical standards

**Ethics approval and consent to participate** The study was approved by the Research and Ethics Council of Isfahan University of Medical Sciences (Project number: 194049). After explaining the objectives and protocols of the study, written informed consent and verbal consent were obtained from all the children and adolescents, respectively.

**Conflicts of interest** There are no conflicts of interest.

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