Indicators of the metabolic syndrome in obese adolescents

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Abstract

Introduction: To assess the prevalence of metabolic risk indicators for the metabolic syndrome (MS) in a sample of obese Egyptian adolescents and to compare anthropometric and biochemical parameters in subjects with one or two parameters of the MS with those who meet MS criteria.

Material and methods: A descriptive, cross-sectional study was conducted on 300 obese adolescents, with a mean age of 15.45 ± 2.54 years. Variables examined included body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR), systolic and diastolic blood pressure (BP), fasting blood glucose, cholesterol, triglycerides (TG), high-density lipoprotein (HDL), low-density lipoproteins (LDL), insulin and insulin resistance (IR) measured by Homeostasis Model Assessment-Insulin Resistance (HOMA-IR). Receiver operating characteristic (ROC) curve analysis was used to determine the predictive powers of anthropometric parameters associated with increased risk for the MS.

Results: The overall prevalence of the MS was 20%. Individuals meeting 3 or more MS criteria had significantly higher levels of BP, TG, glucose, insulin, and HOMA-R and low HDL levels compared with those who had 1 or 2 MS criteria. Area under the curve (AUC) for identifying the MS risk factors was the highest for WHR, followed by WC and BMI in both genders (p < 0.001).

Conclusions: The most prevalent metabolic risk factors that compose the MS were arterial hypertension, low HDL and hypertriglyceridemia; BMI tended to be the weakest index for identifying MS risk factors, while WHR was the best predictive index in both genders.

Key words: obesity, metabolic risk factors, adolescents, anthropometry.

Introduction

Obesity in children and adolescents is a major public health problem which is increasing worldwide, thus increasing the likelihood of the metabolic syndrome (MS). Metabolic syndrome is essentially considered as a product of an interaction between multiple genetic and environmental factors, though its pathogenesis is not clearly determined. Metabolic syndrome is defined as a clustering of interrelated metabolic risk factors that increase the risk of cardiovascular morbidity and mortality [1]. These factors include insulin resistance or glucose intolerance, central/abdominal obesity, hypertension and dyslipidemia, particularly decreased
high-density lipoprotein cholesterol (HDL-C) and hypertriglyceridemia [2]. Insulin resistance and leptin may be important pathogenic factors in hypertensive patients with severe obesity [3]. The prevalence of the MS varies among different populations. A remarkably high prevalence of the MS has been reported in Western communities, Asians, Africans and in Arabs [4, 5]. The recorded high prevalence of the MS and its key cardiovascular risk factors (15–60%) among the Middle East population mandates the need for national and international prevention programs to combat MS [6]. The criteria for diagnosis of the MS include obesity (particularly increased waist circumference (WC)), high fasting triglycerides, low levels of HDL-C, hypertension, elevated fasting blood glucose and insulin resistance [7–9]. Homeostasis Model Assessment-Insulin Resistance (HOMA-IR) is an indirect marker of insulin resistance [10]. Lack of congruent diagnostic criteria has resulted in reporting of variable prevalence of the disease in different studies [11]. For example, the thresholds of the WC diagnostic of abdominal obesity in most studies are derived from European data [8]. There is a need to develop national guidelines for the definition of abdominal obesity. This study is an attempt to highlight the usefulness of the proxy markers of the MS focusing on a sample of obese Egyptian adolescents.

The aim of this study is to assess indicators of the MS and evaluate the prevalence of the different components of the MS in individuals meeting 1 or 2 MS criteria with those who meet 3 or more MS criteria.

**Material and methods**

A descriptive cross-sectional study was conducted on 300 obese adolescents with body mass index (BMI) greater than the 97th percentile for age and gender according to the National Egyptian Growth Curves of Children and Adolescents [12]. One hundred and twenty males (40%) and 180 females (60%) were included, of mean age 15.45 ±2.54 years (range: 17–21 years). The data were collected from June 2011 to July 2012 and were extracted from a project entitled “Obesity among Youth: Lifestyle and Genetic Factors” funded by the Science and Technology Development Fund (STDF), Egypt. This study protocol was approved by the ethical committee board of the National Research Centre of Egypt (No. 10/223). Informed written consent was obtained from all participants. All individuals were clinically evaluated and anthropometric data were collected. The components of the MS that were observed are WC, body mass index (BMI), impaired blood glucose, HDL, systolic and diastolic blood pressure (BP), hypertriglyceridemia, cholesterol and insulin resistance measured by HOMA. Metabolic syndrome was diagnosed by the occurrence of 3 or more of the following risk factors according to the 2007 International Diabetes Federation (IDF) [13]: WC greater than the 90th percentile for age and gender; TG ≥ 150 mg/dl, HDL < 40 mg/dl, BP ≥ 130/85, basal blood glucose ≥ 100 mg/dl. Weight was measured with the patients in light clothing and without shoes. Height was measured with the patients standing with their backs leaning against the stadiometer of the same scale. Body mass index was calculated as weight in kilograms divided by height in meters squared (kg/m²). Waist circumference and hip circumference (HC) were measured in cm using a plastic, non-stretchable tailor’s tape. Waist circumference was measured with light clothing at a level midway between the lower rib margin and the iliac crest standing and breathing normally. Hip circumference was measured at the level of the widest circumference over the buttocks (at the greater trochanter). Subsequently the waist hip ratio (WHR) was calculated as WC divided by HC. Blood pressure was measured with the patients sitting with their left arm at heart level using a professional Riester sphygmomanometer manufactured in Japan. Several measurements were made, from which an average BP measurement was obtained. Laboratory tests were performed with patients fasting for 12 h. All the subjects underwent plasma glucose and HOMA-IR, which was calculated using relevant formulae. Normal fasting blood glucose was defined as levels ranging from 60 mg/dl to 100 mg/dl; HOMA-IR greater than 3.5 was considered as pathological [10]. This study was performed according to the Helsinki declaration and was approved by the Ethical Research Committee of the National Research Centre, Egypt.

**Statistical analysis**

SPSS 16.0 software was used for statistical analysis. Quantitative variables were given as mean and standard deviation, and dichotomous variables as a percentage. Quantitative variables from patients with or without prediabetes were compared using Student’s t-test for independent samples. A value of p < 0.05 was considered statistically significant. Receiver operating characteristic (ROC) curve analyses was used to calculate the area under ROC curves between MS risk factors and anthropometric measurements. Each value of an anthropometric index was used as a cutoff value to calculate its sensitivity (defined as the percentage of subjects having MS risk) and specificity (defined as the percentage of subjects without MS risk) in predicting MS risk factors, after adjusting for age. The optimal cutoff value was...
denoted by the Youden index, which is the value that had the highest sum of sensitivity and specificity [14]. A plot of the sensitivity versus 1 – specificity was used to display the trade-off between true positives and false positives across discriminating cutoff points.

Results

The prevalence of the MS according to the IDF criteria in the total sample of obese adolescents was 20% (60/300). Males and females were analyzed together because homogeneity of the effect was observed by gender. They presented 2 or more features of the MS (hypertension, obesity, dyslipidemia and altered glucose tolerance). Metabolic syndrome was more common in females (22.2%, 40/180) than in males (16.6%, 20/120), with no statistically significant difference. The prevalence of the different components of the MS based on IDF criteria is shown in Figure 1. Table I shows a comparison of anthropometric, clinical and biochemical data in obese adolescents with 1 or 2 MS criteria and those with complete MS. The results showed that patients with the MS had significantly elevated values of blood glucose, BP (systolic and diastolic), TG and insulin resistance, and HOMA-IR, and a decreased value of HDL-C. The area under the receiver operating characteristic curve (and 95% confidence interval) for BMI was 0.711 (0.597–0.825) and 0.740 (0.610–0.869); for WC 0.809 (0.741–0.877) and 0.829 (0.742–0.915); for WHR 0.834 (0.770–0.899) and 0.833 (0.753–0.913) in females and males respectively, Figure 2 (females), Figure 3 (males) and Table II.

Discussion

The prevalence of obesity is increasing substantially, and obesity is one of the major contributors to the incidence of various diseases due to its pathophysiological link to other cardiovascular risks such as hypertension and diabetes [15]. The predominant underlying risk factors for the MS appear to be abdominal obesity, insulin resistance and other associated conditions that can be physical inactivity, aging, and hormonal imbalance [16]. Central obesity is characterized by increased visceral adipose tissue and appears to contribute more to the development of MS risk than general adiposity [17]. Presence of one or more metabolic abnormalities among obese subjects can be attributed to a sedentary lifestyle and dietary habits, which are important predictors of obesity and metabolic abnormalities. Central adiposity is an important indicator of the MS due to its link to dyslipidemia, hyperinsulinaemia, hypertension, and impaired fibrinolytic capacity [18]. The phenotype of obesity varies in different ethnic groups [19]. As compared to white Caucasians, adult Asian Indians have lower height, weight, BMI, WC, and fat free mass, but higher body fat and abdominal adiposity [20]. A quarter of the world’s adults have the MS [21]. People with the MS have a five-fold greater risk of developing type 2 dia-

Table I. Comparison of anthropometric, clinical and biochemical data

| Variables                  | 1 or 2 MS parameters | MS parameters (≥ 3) |
|----------------------------|----------------------|--------------------|
| Systolic blood [mm Hg]     | 113.06 ±12.89        | 126.32** ±15.44    |
| Diastolic blood pressure [mm Hg] | 73.96 ±8.65           | 81.76** ±12.18     |
| Glucose [mg/dl]            | 92.30 ±13.10         | 105.12** ±40.70    |
| Cholesterol [mg/dl]        | 187.18 ±46.40        | 192.76 ±46.96      |
| Triglycerides [mg/dl]      | 90.28 ±37.10         | 147.71** ±81.65    |
| HDL-C [mg/dl]              | 56.60 ±17.88         | 41.41** ±17.81     |
| LDL-C [mg/dl]              | 115.68 ±38.87        | 119.64 ±38.10      |
| Insulin [µIU/ml]           | 39.81 ±26.99         | 75.00** ±37.86     |
| HOMA-IR                    | 9.57 ±7.34           | 19.65** ±10.00     |

HDL-C – high-density lipoprotein cholesterol, LDL-C – low-density lipoprotein cholesterol, HOMA-IR – homeostasis model assessment for insulin resistance, MS – metabolic syndrome; **p < 0.01.
People have become more sedentary and consume more calories through non-healthy fast foods, leading to increased incidence of the MS. In our study, MS prevalence was 20%. Other studies have reported similar MS prevalence rates ranging from 10% to 21% [1, 23, 24]. More than one-third of the adults in the United States could be characterized as having the MS [25]. The prevalence of this syndrome is 19% in Mongolia, 21% in Jordan, 17% in Palestine [5, 6], 24.2% in Malaysia, 21.17% in Taiwan, 12.2% in Singapore, 12% in Japan, 14.8% in China, 28.8% in India, and 28.6% and 27.8%, respectively, in male and female Koreans [26]. The prevalence of the MS in Iranian subjects aged 25 to 30 years was 35.9%. Another study reported that prevalence of the MS reaches 50% in severely obese youngsters [4]. The current literature data suggest that the incidence of the MS is increasing rapidly all over the world, but its prevalence varies among populations [27, 28]. Our results are in accordance with some of these studies. Differences in population characteristics and dietary habits may be considered as the main sources of this variation. According to the area under the curves (AUCs) in our study, the BMI was the weakest index compared with other obesity indices for MS diagnosis in both genders. Waist hip ratio was better than WC and BMI for predicting the MS risk in both genders. Although different studies agreed upon the five metabolic risk factors that compose the MS, they basically differ with respect to the diagnosis of central obesity [1, 13]. Waist circumference and WHR are important indicators of central obesity and were independently associated with three MS components (HDL-C, TG, and SBP). Therefore, WC and WHR are stronger indicators of abdominal obesity and development of the MS. Waist hip ratio is so far the most widely used index of central fat distribution due to its benefits in routine monitoring and assessment in patients. Studies in Europeans [29], Asians [30], Africans [10], and Arab communities [31] were done by using ROC analysis to compare the performance of obesity indices for identifying such risks. Our results are in agreement with some of these studies [32–34]. Metabolic syndrome increased with age but increased even more dramatically as BMI increased [35]. In our study the MS was more common in females (22.2%, 40/180) than males (16.6%, 20/120), but

**Figure 2.** Receiver operating characteristic curves (ROC) for identifying the risk of metabolic syndrome in females

**Figure 3.** Receiver operating characteristic curves (ROC) for identifying the risk of metabolic syndrome in males

**Table II.** Area under receiver operating characteristic curves for identifying the risk of metabolic syndrome by obesity indices

| Gender | Body mass index [kg/m²] (95% confidence intervals) | Waist circumference [cm] (95% confidence intervals) | Waist to hip ratio (95% confidence intervals) |
|--------|--------------------------------------------------|---------------------------------------------------|---------------------------------------------|
| Female | 0.711 (0.597–0.825)                               | 0.809 (0.741–0.877)                               | 0.834 (0.770–0.899)                          |
| Male   | 0.740 (0.610–0.869)                               | 0.829 (0.742–0.915)                               | 0.833 (0.753–0.913)                          |
without a statistically significant difference. In the adult population in Tehran the MS was found in 55% of women and 30.1% of men [4]. The overall prevalence of obesity in the Middle East region was considerably higher among women compared with men [6]. Although the exact explanation of such gender variations is not entirely clear, it has been reported that women are less active compared with men in certain areas [23]. Physical and cultural barriers to physical activity have been reported among women in Egypt and Saudi Arabia. These include climatic conditions of extreme heat in the summer, limited exercise facilities devoted solely for women, lack of physical education or an emphasis on its importance in schools, and absence of women’s participation in organized sports [23].

The most prevalent component of the MS in our study was elevated WC, because all our patients were obese. Impaired blood glucose (IBG) was present in 15% of studied individuals, as insulin resistance is an obesity-related condition that plays a major pathogenic role in the development of the MS. The prevalence of IBG in previous studies was much lower (8.3%) [36–38]. By contrast, insulin resistance was identified in 70% of obese prepubertal children in a study conducted in Lebanon [23]. However, the cumulative risk for the MS appears to cause microvascular dysfunction, which further amplifies insulin resistance and promotes hypertension [39, 40]. Hypertension is an important cardiovascular disease (CVD) risk factor with high global prevalence. It is one of the most commonly identified components of the MS [15]. When hypertension and other metabolic risk factors co-exist in an individual, they potentiate one another, leading to a synergism that increases the total CVD risk well above that which results from the sum of the individual risk factors. Accordingly, MS risk factors should be quantified so that the type and intensity of treatment can be tailored to the degree of MS component risk factors [41]. Different results may be explained by differences in age, dietary habits, genetic or other factors. In our study, the prevalence of low HDL-C was 24%. Insulin resistance may contribute to increased TG levels and may be responsible for decreased HDL-C levels through an increase in the extent of apolipoprotein A1 (ApoA1)/HDL-C degradation as compared to its synthesis [42–44]. High BP found in 25% of observed obese individuals is similar to previous studies [3, 45]. An additional study conducted in Iran reported high BP in 48.9% of individuals over 19 years old [25]. Hypertriglyceridemia was present in 23% of individuals observed in our study. High serum TG was found in 28.6% of a French population and 42.8% of an Iranian population [25]. Finally, it should be noted that prevention and early management of the different MS components in childhood and adolescence are of utmost importance. Efforts should be aimed at preventing obesity, initiating and maintaining healthy eating patterns, and encouraging moderate intensity regular physical activity.

In conclusion, high prevalence of the MS was detected in obese Egyptian adolescents. The present results are in accordance with some Western and Arab studies [5, 6, 29]. The prevalence of the MS varied in the different studies due to lack of congruent diagnosis. Moreover, this study indicates that WHR could be the best predictive index for identifying MS risk in both genders, while BMI tends to be the weakest index. A meta-analysis of 10 studies in different populations (Europeans, Asians, and Africans) also showed the weakness of BMI as a discriminator [46–48]. Differences between populations could depend on several factors such as genetic variables, race, nutritional status, different socioeconomic-cultural characteristics and also lifestyle differences [49–53].

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Conflict of interest

The authors declare no conflict of interest.

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