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RESEARCH ARTICLE

Adipocytokine profile of type 2 diabetics in metabolic syndrome as defined by various criteria

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Abstract

Background This study aims to identify which among the metabolic syndrome (MS) definitions are closely associated with pathological levels of leptin, adiponectin, resistin, tumour necrosis alpha (TNF-α) and C-reactive protein (CRP) among type 2 diabetics.

Materials and Methods Three hundred and five (160 males; 145 females) adult type 2 diabetic Saudis participated in this cross-sectional study. Leptin, adiponectin, resistin, TNF-α and CRP were analysed, using enzyme-linked immunosorbent assays (ELISA). Each participant was screened for MS based on the definitions of WHO, AHA/NHLBI and IDF.

Results IDF holds the most identified patients [190 (62.3%)] in both, males [107 (66.9%)], and females [83 (57.2%)]. In males, hyperleptinemia, hypoadiponectinemia and hyperresistinemia were strongest in the AHA/NHLBI-defined MS [odds ratio (95% confidence interval 'CI') of 2.03 (1.05–3.93); 1.31 (0.55–3.1); 1.63 (0.42–6.4) respectively]. The risk of elevated CRP was highest on the WHO definition [odds ratio (95% CI) of 2.04 (0.46–9.04)]. In females, the IDF-defined MS has the strongest association in all four parameters: odds ratio (95% CI), as follows: leptin [2.09 (0.14–30.71)]; adiponectin [6.00 (0.47–76.17)]; resistin [0.47 (0.18–1.23)] and CRP [3.07 (0.21–45.10)].

Conclusion Gender differences exist in assessing the risk of various adipocytokine abnormalities in relation to the various criteria. This study supports the use of IDF definition among females and AHA/NHLBI in males in studies involving MS and obesity, since these definitions hold stronger predicting powers in detecting pathological levels of key adipocytokines.
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Keywords adipocytokines; metabolic syndrome; type 2 DM

Introduction

Metabolic syndrome (MS) is one of the most clinically relevant public health threats ever to have evolved as a consequence of 21st century modernization and global adaptation of the 'Western lifestyle'. It is an important cluster of metabolic abnormalities linked with insulin resistance and cardiovascular disease (CVD) [1]. Several international authorities, including the WHO [2] and the American Heart Association/National Heart, Lung, and Blood Institute have each proposed different criteria which are mostly the ones used today. Despite the fact that the prevalence of MS differs according to ethnic origin [3], there is homogeneity in terms of an increasing incidence

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of diabetes mellitus (DM) [4–6], as well as the very high prevalence of MS among diabetic patients [7,8]. Furthermore, it has been proven that MS, regardless of definition used, increases the risk of untoward cardiovascular events [9], although few articles have been published on this and none in the Middle East.

Turning to adipocytokines and C-reactive protein (CRP), these are bio-active substances produced by the adipose tissue and liver respectively which are known to regulate the metabolism. Of clinical importance among the roster of adipocytokines are, among others, leptin, adiponectin, resistin and tumour necrosis alpha (TNF-α). Leptin is the product of the *ob* gene, with a molecular mass of 16 kDa; it is known to play a key role in the regulation of body weight [10]. Hyperleptinemia is an essential feature of human obesity, and was thought to contribute to the catabolic state leading to the development of cardiac cachexia in the course of chronic heart failure [11]. Adiponectin, for its part, is a 30-kDa collagen-like protein, clinically noted to be anti-atherogenic and anti-diabetic at elevated levels [12]. Resistin is a 12.5-kDa protein which was known to reduce the sensitivity of tissues in rodents to insulin but whose functions in humans remain a puzzle [11]. TNF-α is an inflammatory cytokine which is involved, not only in immune system homeostasis, but also in pathological processes such as chronic inflammation and auto-immunity [13]. Lastly, CRP is a plasma protein related to the class of acute-phase reactants; it was initially used as a marker of inflammation. Later studies suggest, however, that individuals with elevated basal levels of CRP are at an increased risk of DM, hypertension and CVD [14].

Although many studies have been carried out regarding adipocytokines and MS [15,16], to our knowledge there has been no or very little documentation of the associations of these adipocytokines and inflammatory markers with various definitions of MS. This study, therefore, aims to identify which among the various definitions of MS is closely associated with pathological levels of leptin, adiponectin, resistin, TNF-α and CRP among type 2 diabetic males and females from Saudi Arabia.

Materials and methods

The subjects were known type 2 diabetic Saudis, 160 males and 145 females, between 20 and 80 years old, all recruited from the roster of diabetic patients attending the out-patient department of the Diabetes Center, King Abdul-Aziz University Hospital, Riyadh, Kingdom of Saudi Arabia. There is no conflict of interest. This study was conducted in accordance with the guidelines set by the Ethics Committee of the College of Medicine, King Saud University, by which it was approved. Written and informed consents were individually obtained from all the participants prior to inclusion and the commencement of the study. Exclusion criteria covered diabetic patients with existing co-morbidities such as CHD, debilitating diabetic complications secondary to poor glycemic control, and patients who were pregnant or lactating. All subjects were given a generalized questionnaire, which collected patient information, past medical history, present medications, duration of diabetes and other pertinent personal details relevant to the study.

Anthropometric measurements

BP was measured using the conventional mercury sphygmomanometer after the participants had rested for at least 15 min. The average of two readings was recorded. Body mass index (BMI) was calculated as the quotient of weight (kg) divided by height squared (m^2). Waist and hip circumferences were measured in centimeters by a standardized tape measure, after which the waist-to-hip ratio was calculated.

Laboratory measurements and assays

Blood was withdrawn from each participant after an overnight fast, and parameters such as fasting plasma glucose and lipid profile were measured, using routine laboratory procedures. Adiponectin and resistin were measured using the sandwich enzyme-linked immunosorbent assay (ELISA) by Linco (Linco Ltd, USA). TNF-α and leptin were quantified using ELISA kits from RnD (RnD Systems, Ltd, UK). Insulin was analysed by a solid phase enzyme amplified sensitivity immunoassay (Medgenix INS-ELISA, Biosource, Belgium). CRP was measured using ELISA by Immunodiagnoztik (Immunodiagnoztik AG, Germany).

Metabolic syndrome

Subjects were carefully screened for the presence of the components of MS, as defined by WHO, AHA/NHLBI and IDF. For definition purposes, IDF criteria consist of five factors with abdominal obesity defined as waist circumference $\geq$94 cm for men and $\geq$80 cm for women, plus two other factors required for diagnosis. These include BP $\geq$130–$\geq$85 mmHg; fasting glucose of $\geq$5.6 mmol/L or with pre-existing diabetes; fasting triglycerides of $\geq$1.7 mmol/L; and high density lipoprotein (HDL) cholesterol of $<$1.04 mmol/L for men and $<$1.3 mmol/L for women. The updated AHA/NHLBI definition also has five components, but instead of the above, requires any three risk factors. These include a higher cut-off for waist circumference: $\geq$102 cm for men and $\geq$88 cm for women; the rest conform to the IDF definition. Lastly, the WHO criteria have six components, including urinary albumin excretion rate $\geq$20 µg/min. The other criteria are BMI $\geq$30 kg/m^2 and/or waist-hip ratio (WHR) $\geq$0.9 for men and $\geq$0.85 for women; a more elevated BP at $\geq$140/90 mmHg or on antihypertensive medications; with diabetes, impaired glucose tolerance or insulin resistance; and with triglycerides $\geq$1.7 mmol/L

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and/or HDL <0.91 mmol/L for men and <1.01 mmol/L for women. The WHO definition focused more on diabetes and therefore impaired glucose intolerance or insulin resistance plus any two or more risk factors are required for its diagnosis.

Statistics

SPSS for Windows Version 11.5 (Chicago, Illinois) was utilized for the statistical evaluation. Variables exhibiting non-Gaussian distribution, such as leptin, adiponectin, resistin and CRP were logarithmically transformed. The remaining variables were presented as means ± standard error of the mean (SEM). An independent *t*-test was done on the continuous variables, and the Mann–Whitney *U* test for variables not normally distributed as mentioned previously. *K* statistics were used to assess the measure of agreement between the three definitions of MS. The odds-ratio was used to assess risk. A *p*-value of <0.05 was considered statistically significant.

Results

A total of 305 (160 males and 145 females) adult type 2 diabetic Saudis participated in this cross-sectional study. In Table 1 subject information reveals that the male participants were significantly older, with higher waist circumference, WHR and diastolic BP than the females (*p*-value 0.0001 in all three parameters). Female subjects, conversely, had significantly higher BMI and systolic BP (*p*-value 0.0001 in both parameters). Furthermore, the metabolic parameters show that the females have significantly higher fasting serum glucose, HDL cholesterol, leptin and CRP levels than their male counterparts (*p*-values 0.007, 0.008, 0.0001 and 0.0001 respectively). No significant inter-gender variation was detected in the other measured parameters. Table 2 shows the high prevalence of the individual components of MS, according to its definition among Saudi type 2 diabetics. MS, as defined by the IDF criteria, applies to the greatest number of identified patients [190 cases (62.3%)] and in both, males [107 (66.9%)], and females [83 (57.2%)] (Tables 3–5), compared with the definitions of AHA/NHLBI and WHO. Using *K* statistics, we found a close agreement between IDF and AHA/NHLBI was 0.91 ($p < 0.0001$); between IDF and WHO it was 0.84 ($p < 0.0001$); and between WHO and AHA/NHLBI it was 0.81 ($p < 0.0001$) (not shown in the table).

Specific cut-offs of clinical significance were used for the comparison and associations of the different adipocytokines and CRP with the various definitions of MS.

Leptin

The normal range is 3–7 ng/mL in males, and 15–20 ng/mL in females. Hyperleptinemia was defined as >7 ng/mL for males, and >20 ng/mL for females [1]. In all cases, AHA/NHLBI had the highest percentage of cases with hyperleptinemia [98 individuals (61.3% of those defined as MS according to AHA/NHLBI definition)]. In males, the WHO definition had the highest prevalence [61 (57.5%)]. In females, the IDF definition had the highest prevalence [50 (60.2%)] and frequency (Tables 3–5).

Adiponectin

The normal mean for males is 9.8 ± 2.9 μg/mL and for females 16.6 ± 5.0 μg/mL. In both cases, hypoadiponectinemia was defined as <6 μg/mL [16]. Overall, the incidence of hypoadiponectinemia was highest in males using the IDF definition [36 (18.9%)] as well as in

Table 1. Clinical and metabolic characteristics of male and female diabetic subjects

Parameter	Males	Females	*p*–value
N (%)	160	145	
Age (years)	54.8 ± 10.28	49.46 ± 8.87	**0.0001**
BMI (kg/m^2)	28.75 ± 33.20	33.20 ± 5.73	**0.0001**
Waist circumference (cm)	121.6 ± 23.6	107.0 ± 19.7	**0.0001**
WHR	1.38 ± 0.36	1.08 ± 0.31	**0.0001**
Systolic BP (mmHg)	115.46 ± 23.16	128.27 ± 22.70	**0.0001**
Diastolic BP (mmHg)	93.96 ± 13.02	83.64 ± 14.46	**0.0001**
Fasting Glucose (mmol/L)	8.62 ± 1.13	9.89 ± 3.78	**0.007**
Insulin (ng/mL)	20.33 ± 16.41	23.13 ± 28.34	0.30
HDL-C (mmol/L)	1.07 ± 0.69	1.40 ± 1.14	**0.008**
LDL-C (mmol/L)	2.85 ± 0.86	2.94 ± 0.86	0.43
Triglycerides (mmol/L)	2.09 ± 1.39	2.06 ± 2.15	0.90
Total Chol (mmol/L)	4.84 ± 0.98	5.08 ± 1.13	0.09
Leptin ng/mL #	10.12 (0.84–58.1)	28.85 (4.0–122.0)	**0.0001**
Adiponectin μg/mL #	11.96 (1.5–110.1)	11.21 (2.1–41.7)	0.49
Resistin ng/mL #	14.46 (5.4–103.9)	15.65 (5.5–57.0)	0.23
CRP μg/mL #	2.97 (0.04–39.0)	5.77 (0.07–41.6)	**0.0001**
TNF-α pg/mL	4.71 ± 2.54	4.47 ± 1.96	0.53

Data presented as mean (SD) and mean (range) for parameters not normally distributed.

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Table 2. Prevalence of individual components of the metabolic syndrome according to criteria (%)

	Abdominal obesity [a]WC (cm) OR [b]BMI (kg/m^2) OR [c]WHR	Elevated triglycerides (mmol/L)	Low HDL-C (mmol/L)	Elevated blood pressure (mmHg)	Elevated fasting glucose (mmol/L)
IDF	WC ≥94 (men) & ≥80 (women)	≥1.7	<1.04 (men) & <1.3 (women)	≥130 ≥ 85	≥5.6
Total	100	58.4	67.4	79.9	95.3
Male	100	62.6	66.4	94.3	92.5
Female	100	53.0	68.7	72.3	98.8
AHA/NHLBI	WC ≥102 (men) & ≥88 (women)		**The same cut-offs as IDF**		
Total	91.0	61.8	67.1	80.9	93.8
Male	84.7	64.3	68.4	93.8	92.9
Female	96.4	50.0	65.9	68.7	97.6
WHO	*BMI* ≥30 *&/or WHR* ≥0.9 (men) & ≥0.85 (women)	*Same cut-off as IDF* *Same cut-off as IDF*	<0.91 (men) & <1.01 (women)	≥140/90	***With DM, IGT or insulin resistance***
Total	99.1	63.1	57.1	83.5	100
Male	98.1	63.8	61.9	87.6	100
Female	100	62.0	52.3	73.2	100

[a]WC, waist circumference.
[b]BMI, body mass index.
[c]WHR, waist-to-hip ratio.
Total number of participants is 305 (160 men and 145 female).

Table 3. Overall frequencies of patients identified to have metabolic syndrome by various definitions with associated metabolic abnormality. Data presented as the number of cases with metabolic abnormality (%)

N = 305	IDF	AHA/NHLBI	WHO
[a] Metabolic syndrome (MS)	190 (62.3)	181 (59.3)	177 (58.0)
1-Hyperleptinemia	111 (58.4)	98 (61.3)	101 (57.1)
2-Hypoadiponectinemia	36 (18.9)	33 (18.6)	32 (18.1)
3-Hyperresistenemia	15 (7.9)	15 (8.5)	13 (7.3)
4-Elevated CRP	79 (41.6)	74 (40.9)	70 (39.5)

[a]For MS: the percentage was calculated as the number of cases having MS relative to the total number of participants. For each metabolic abnormality (from 1 to 4): the percentage was calculated as the number of cases with this abnormality/the number of MS cases by definition × 100.

Table 4. Frequency of males identified to have metabolic syndrome by various definitions with associated metabolic abnormality (% cases)

N = 160	IDF	AHA/NHLBI	WHO
[a] Metabolic syndrome (MS)	107 (66.9)	83 (57.2)	106 (66.3)
Hyperleptinemia	61 (57.0)	56 (57.1)	61 (57.5)
Hypoadiponectinemia	20 (18.7)	19 (19.4)	19 (17.9)
Hyperresistenemia	7 (6.5)	8 (8.2)	8 (7.5)
Elevated CRP	29 (27.1)	26 (26.5)	30 (28.3)

[a]For MS: the percentage was calculated as the number of cases having MS relative to the total number of participants. For each metabolic abnormality (from 1 to 4): the percentage was calculated as the number of cases with this abnormality/the number of MS cases by definition × 100.

females [16 (19.3%)]. In males, however, the AHA/NHLBI definition identified the most [19 (19.4%)] (Tables 3–5).

Resistin

The normal mean specific for the population used was 18.39 ± 3.4 ng/mL [17]. Hyperresistinemia was defined as >22 ng/mL. AHA/NHLBI definition had the highest

Table 5. Frequency of females identified to have metabolic syndrome by various definitions with associated metabolic abnormality (% cases)

N = 145	IDF	AHA/NHLBI	WHO
[a] Metabolic syndrome (MS)	83 (57.2)	80 (55.2)	71 (49.0)
Hyperleptinemia	50 (60.2)	47 (56.6)	40 (56.3)
Hypoadiponectinemia	16 (19.3)	14 (17.1)	13 (18.3)
Hyperresistenemia	9 (10.8)	8 (9.6)	6 (8.5)
Elevated CRP	50 (60.2)	48 (57.8)	40 (56.3)

[a]For MS: the percentage was calculated as the number of cases having MS relative to the total number of participants. For each metabolic abnormality (from 1 to 4): the percentage was calculated as the number of cases with this abnormality/the number of MS cases by definition × 100.

frequency and percentage [15 (8.5%)] in all the cases, and among the males [8 (8.2%)]; IDF stands out in the females [9 (10.8%)]. (Tables 3–5)

C-reactive protein

The cut-off used was ≥3 μg/mL [18]. Overall, the definition of IDF yielded the highest percentage [79 (41.6%)]. Gender differences, however, reveal that males with an elevated CRP were found most often when the WHO definition was applied [30 (28.3%)]. In contrast, applying the IDF definition detected the highest percentages of females with elevated CRP levels [50 (60.2%)] (Tables 3–5).

TNF-α

The normal range is 0–20 pg/mL [17]. From the set of 305 participants, only one subject had a level beyond the range (20.68 pg/mL; not shown in the tables). Since the remaining subjects had normal levels of TNF-α

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Table 6. Odds-ratio (*confidence interval* 95%) of selected adipocytokines, CRP and cardiovascular risk score to various definitions of metabolic syndrome

Parameter	Males	Females
Hyperleptinemia (>7 ng/mL in males; >20 ng/mL in females)		
IDF	0.78 (0.15–4.13)	**2.09 (0.14–30.71)**
AHA/NHLBI	**2.03 (1.05–3.93)**	0.62 (0.30–1.27)
WHO	1.73 (0.49–6.11)	0.24 (0.04–1.28)
Hypoadiponectinemia (<6 μg/mL)		
IDF	0.76 (0.07–8.70)	**6.00 (0.47–76.17)**
AHA/NHLBI	**1.31 (0.55–3.1)**	0.52 (0.23–1.20)
WHO	0.52 (0.10–2.66)	1.08 (0.20–5.74)
Hyperresistinemia (>22 ng/mL)		
IDF	0.79 (0.22–2.83)	**0.47 (0.18–1.23)**
AHA/NHLBI	**1.63 (0.42–6.4)**	0.36 (0.14–0.97)
WHO	1.28 (0.32–5.04)	0.34 (0.12–0.95)
C-Reactive protein (>3 μg/mL)		
IDF	0.46 (0.06–3.46)	**3.07 (0.21–45.10)**
AHA/NHLBI	1.40 (0.28–7.15)	1.05 (0.52–2.11)
WHO	**2.04 (0.46–9.04)**	0.24 (0.44–1.28)

• Highlighted odds-ratio figures indicate highest risk compared to other definitions of metabolic syndrome.

with no significant difference between males and females (Table 1), this parameter was not evaluated further.

Table 6 shows leptin, adiponectin, resistin and CRP in relation to the different definitions of MS. Analysing the odds ratio (95% confidence interval), it is demonstrated that in males, three out of the four parameters were predicted to be strongest using the AHA/NHLBI-defined MS; hyperleptinemia [2.03 (1.05–3.93)]; hypoadiponectinemia [1.31 (0.55–3.1)] and hyperresistinemia [1.63 (0.42–6.4)]. The risk of elevated CRP, however, was highest using the WHO definition [2.04 (0.46–9.04)]; nevertheless, the AHA/NHLBI definition can still detect the elevated CRP in males [1.4 (0.28–7.15)]. Moving on to females, the IDF-defined MS has the most frequent association in all four parameters analysed in this study compared to the other criteria: hyperleptinemia [2.09 (0.14–30.71)]; hypoadiponectinemia [6.00 (0.47–76.17)]; elevated CRP [3.07 (0.21–45.10)] and hyperresistinemia [0.47 (0.18–1.23)].

Figures 1 and 2 show the high prevalence of obesity in the study population using BMI and WHR as parameters.

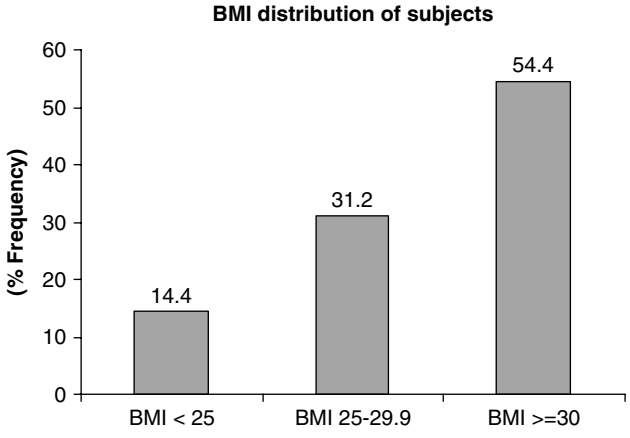

Figure 1. Cut-off reference taken from Relimpio *et al.* [19]

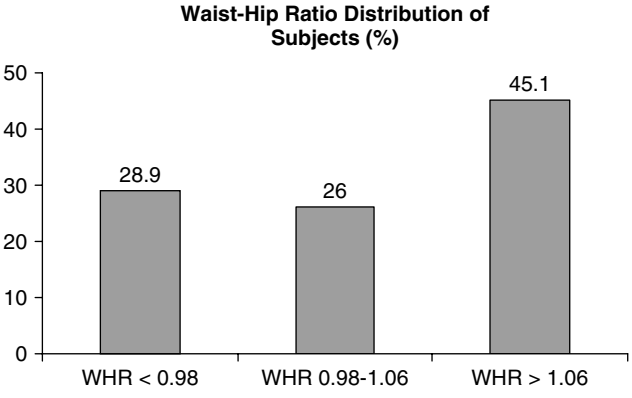

Figure 2. Cut-off reference taken from Relimpio *et al.* [19]

Discussion

MS, *per se*, is an array of cardiovascular risk factors, which have been linked to insulin resistance and obesity as their common breeding ground. Further investigations then provided additional evidence involving adipocytokines, though most mechanisms are still hardly established. Initially, most of the studies focused on the prevalence of different metabolic and clinical variables and their correlations to the individual components of the MS. With further advancement later on, the trend shifts to associations of the same metabolic and clinical variables with various recent definitions of MS by well-respected international authorities [9,20–22]. This cross-sectional study is the first of its kind among Arabs, to identify which among the most commonly used criteria (IDF, AHA/NHLBI and WHO) can best predict the incidence of hyperleptinemia, hypoadiponectinemia, hyperresistinemia and elevated CRP levels in a cohort of male and female type 2 diabetic Saudis.

Most of the studies undertaken on the various MS criteria – including the results obtained from our study – confirm that the IDF definition is quantitatively more powerful than its counterparts in terms of prevalence [22–25]. The rationale behind this was obviously the inclusion of lower cut-offs in glucose levels and BP compared to the WHO definition, as well as specific differences in terms of abdominal obesity. The main difference between the IDF and AHA/NHLBI definitions of MS is not limited to the difference between waist-circumference measurements, but it also involves the diagnosis, since abdominal obesity is a necessary element in IDF while it is optional in AHA/NHLBI. On the predictive powers of harder outcomes such as coronary heart disease, however, existing definitions such as those of AHA/NHLBI provide more clinical relevance [26,27]. Regardless of the dependent variable used, with different definitions for the MS as independent variables, there is an on-going trend of exploring the prevalence and association of these definitions among different races

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with a view to discovering which definition best suits each one's ethnicity.

In our study, the dependent variables used were novel markers such as leptin, adiponectin, resistin, and CRP. These are factors recently considered to provide a link not only between diabetes and insulin resistance but also to coronary heart disease [28–30]. This study revealed that in males, the AHA/NHLBI definition provides the highest predictive power in terms of detecting hyperleptinemia hypoadiponectinemia, and hyperresistinemia, while the WHO criteria best predict elevated CRP. Still, the IDF definition outperforms the remaining definitions among females in assessing the risk of hyperleptinemia, hypoadiponectinemia, hyperresistinemia and elevated CRP levels. The reason for this is largely a consequence of the manner in which MS is diagnosed, a manner which, for IDF is focused in abdominal obesity. Obesity is more prevalent in women than men, due to hormonal fluctuations which easily predispose them to gain weight [31]. Furthermore, women generally have a higher percentage of body fat, and there are indications that basal fat oxidation is lower in females than in males, thereby contributing to a higher fat storage in women [32]. These factors predispose women with MS to be more easily detected using the IDF criteria.

These data provide first-hand, yet additional information, as to the capacity of each definition, using diabetic Arabs as subjects. Unfortunately, there have been few studies on the predictive powers of various definitions of MS in relation to adipocytokines and inflammatory markers. The information from this study, therefore, provides gross data as to which among the roster of MS definitions can best detect a patient with concomitant adipocytokine abnormalities, aside from the conventional risk factors for its diagnosis. In current clinical settings, where a primary care physician or a consultant is seeing more and more patients with diabetes and MS than other diseases, there is a need to identify the most applicable definition, which can provide physicians with a solid basis for valid and evidence-based management.

According to Reisin and his colleague, MS is reserved for pre-diabetic patients who share the risk of becoming diabetic or developing cardiovascular and chronic kidney disease [33]. While this premise holds true in some aspects, the image of MS *per se*, has developed far beyond its previous reputation of merely being a precursor to a more serious illness. In the present study, our results reveal that not all diabetic subjects had metabolic syndrome, although many did. The risks of selected adipocytokine profile abnormality in the presence of both diabetes and MS will give insights into not only which definition is most appropriate, given the set of variables, but more importantly, can provide relevant information for more accurate health-care strategies, such as using these variables as therapeutic targets aimed at lowering diabetic complications and associated cardiovascular risk.

This study acknowledges some limitations and other points to note. First, the high prevalence of obese subjects as shown in the figures, does not necessarily reflect the overall prevalence of obese subjects in the Kingdom, since all the subjects were type 2 diabetics. The results in this study hold true only among diabetics; thus, further research assessing MS definitions among non-diabetics should be undertaken as well. Second, additional research should seek to establish the cut-off for abdominal obesity among the Arab population. Owing to a lack of available data, no cut-off has been established so far, and thus, the recommendations of IDF were used in the absence of better information. Third, the overall sample size was small and may not be representative of the whole type 2 diabetic Saudi population. However, this study also has strengths that may contribute to the understanding of MS prevalence among diabetic Saudis. Our findings emphasize the possible ethnicity-related suitability of one MS definition versus another, as well as the gender difference in relation to the best MS definition to apply. Future studies may include physical activity questionnaires and questions about lifestyle and habits, including eating habits and dietary components. This may help to investigate the effect of these parameters on the prevalence of MS among the Saudi diabetic population, as defined by various MS criteria.

In summary, our results showed that there is no uniformity of findings and that gender differences exist in assessing the risk of various metabolic abnormalities in relation to different MS criteria. This study supports the use of the IDF definition among females and the use of the AHA/NHLBI definition in males in studies involving MS and obesity, since these definitions hold the strongest predicting powers in detecting pathological levels of key adipocytokines.

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