The Metabolic Syndrome and Associated Risk Factors in an Urban Industrial Male Population in South India

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Abstract
Background: The metabolic syndrome is characterized by clustering of risk factors, which predisposes subjects to increased risk of diabetes and cardiovascular disease. Objectives of this study were to estimate prevalence of the metabolic syndrome and determine the association of risk factors with the metabolic syndrome in an urban industrial male population in Chennai, India.

Methods: We conducted a cross-sectional survey for male employees working in an industrial unit. The survey included questionnaire for risk factors, anthropometric and blood pressure measurements. Blood samples were collected for the fasting plasma glucose, serum cholesterol, high-density lipoprotein cholesterol and triglycerides. The metabolic syndrome was defined using International Diabetes Federation (IDF) and American Heart Association (AHA)/National Heart Lung and Blood Institute (NHLBI) criteria.

Results: The total numbers of male subjects included in the study were 1077. The prevalence of the metabolic syndrome was 41.3% and 51.4% using IDF and AHA/NHLBI criteria respectively. Risk factors were age above 35 years, family history of diabetes and body mass index (BMI) above 23.9 kg/m². The consumption of more than three servings of fruits and vegetables was protective.

Conclusion: The prevalence of the metabolic syndrome was very high in select industrial population in south India. Higher BMI and low intake of fruits and vegetables are modifiable by life style modification. Work site screening for the metabolic syndrome would facilitate the early detection and treatment.

Introduction
The metabolic syndrome is characterized by clustering of risk factors, which predisposes subjects to increased risk of diabetes and cardiovascular disease (CVD).¹There are various definitions proposed for the metabolic syndrome.²,³ National Cholesterol Education Program – Adult Treatment Panel III (NCEP-ATP III) and the American Heart Association (AHA)/National Heart Lung and Blood Institute (NHLBI) defined the metabolic syndrome as presence of any three out of the five components namely central obesity, raised triglycerides, low HDL, raised plasma glucose and raised blood pressure.⁴ On the other hand, the International Diabetes Federation (IDF) definition includes central obesity as an essential component of the metabolic syndrome in addition to any two of the four above-mentioned components.⁵ In India, studies have reported prevalence varying from 24.9% in northern India to 41% in southern India using different definitions.⁶,⁷ But there are limited data on comparison of the metabolic syndrome criteria in the same study population to assess the strengths and limitations of the proposed criteria in the context of South Asian ethnicity.

We conducted a cross-sectional survey to estimate the prevalence of CVD risk factors among adult males in two industrial units and it has been reported elsewhere.⁸ We estimated the prevalence of the metabolic syndrome among adult males in one industrial unit using IDF and AHA/NHLBI criteria and compared the characteristics of subjects classified as the metabolic syndrome based on these criteria. In addition, we determined the association of demographic and behavioral risk factors for cardiovascular disease with the metabolic syndrome.

Materials and Methods
Design, setting and participants
We conducted a cross-sectional survey in an industrial unit in Chennai between Oct 2005 and Dec 2005. Chennai, Tamil Nadu is the fourth largest metropolitan city in India with a population of 4.3 million.⁹ The population was purposely selected to facilitate the longitudinal follow-up with limited resources. The unit had an in-house medical center that kept medical records. All male permanent employees working in the industrial unit were considered eligible to participate and those who consented were included in the study.

Institutional ethics committee of the National Institute of Epidemiology, Chennai approved the study. We obtained free and informed consent for the questionnaire based interview, physical measurements and laboratory tests. We referred patients with newly detected hypertension, diabetes and dyslipidemias to the in house physician for further management.

Methods of assessment
The World health organization (WHO) non-communicable risk factor survey approach was used.¹⁰ The three components of the study were (1) questionnaire based survey for behavioral risk factors, (2) anthropometric and blood pressure measurements (3) biochemical measurements.

Questionnaire for demographic and behavioral risk factors
We used a questionnaire to collect data on demographic and
behavioral risk factors including tobacco, alcohol use and fruit and vegetable intake. We used a physical activity questionnaire, validated for urban middle class Indians.11

**Anthropometric measurements**

Weight was measured in the upright position to the nearest 0.1 kg using a calibrated weighing scale. Height was measured without shoes to the nearest 0.1 cm using a calibrated stadiometer. Body mass index (BMI) was calculated as the observed weight in kilograms by height in metres squared (kg/m²). Waist circumference (WC) was measured to the nearest 0.1 cm at the narrowest point between lower end of the rib cage and iliac crest. Blood pressure was measured from the right arm after the subject had been sitting for at least five minutes using digital automatic blood pressure apparatus (Omron MX3). The average of two readings taken five minutes apart was recorded.

**Biochemical measurements**

Five ml of blood was collected from the ante-cubital vein in two test tubes after a 10-hour overnight fasting period. Blood sample for plasma glucose was collected in the test tube containing heparin sodium fluoride. Plasma glucose, serum total cholesterol, high-density lipoprotein cholesterol (HDL-C) and triglycerides (TGL) were measured using an autoanalyser. The glucose oxidase-peroxidase method and the cholesterol oxidase-peroxidase method were used for measuring plasma glucose and serum cholesterol respectively.

**Definitions for behavioral risk factors**

Smoking: Current smoker was defined as a person who had smoked at least 100 cigarettes over their lifetime, and continued to smoke every day or some days. Ex-smoker or former smoker was defined as a person who had smoked more than 100 cigarettes over their lifetime and who did not smoke every day or some days.12

Alcohol use: Regular consumer was defined as person who consumed alcohol at least once a week. Occasional consumer was defined as person who consumed alcohol less than once a week.

Physical activity level (PAL): It was calculated as: 24 hour energy expenditure / basal metabolic rate. Cut-offs for physical activity levels describe grades of physical activity. These cut-offs are <1.4 = sedentary, 1.55-1.60 = moderately active and > 1.75=heavily active.13

**Definition of the metabolic syndrome using IDF criteria**

Central obesity (defined as waist circumference > 90 cm for South Asian men) plus any two of the following four factors:

1. Elevated TGL: > 150 mg/dl (1.7 mmol/l), or specific treatment for this lipid abnormality
2. Reduced HDL-C: < 40 mg/dl (1.03 mmol/l) in males and < 50 mg/dl (1.29 mmol/l) in females, or specific treatment for this lipid abnormality
3. Elevated blood pressure: systolic BP > 130 or diastolic BP > 85 mm Hg, or
4. treatment of previously diagnosed hypertension
5. Elevated fasting plasma glucose (FPG) > 100 mg/dl (5.6 mmol/l), or previously diagnosed type 2 diabetes

**Definition of the metabolic syndrome using AHA/NHLBI criteria**

Presence of any three of the five components given below:

1. Waist circumference > 90 cm for Asian American men.
2. Elevated TGL: > 150 mg/dl (1.7 mmol/l), or drug treatment for this lipid abnormality.
3. Reduced HDL-C: < 40 mg/dl (1.03 mmol/l) in males and < 50 mg/dl (1.29 mmol/l) in females, or drug treatment for this lipid abnormality.
4. Elevated blood pressure: systolic BP > 130 or diastolic BP > 85 mm Hg, or antihypertensive drug treatment for patient with history of hypertension.
5. Elevated fasting plasma glucose (FPG) > 100 mg/dl (5.6 mmol/l), or on drug treatment for elevated glucose.

**Statistical Methods**

The prevalence of the metabolic syndrome was calculated using IDF and AHA/NHLBI criteria. The prevalence of the individual components was expressed in percentages. Continuous variables were expressed as mean ± SD. Trend chi-square was used to test for linear trend among the individual components of the metabolic syndrome across the tertiles of BMI categories. We compared the characteristics of subjects in three non-overlapping groups namely sub-group with no metabolic syndrome, sub group with the metabolic syndrome identified using both criteria (IDF and AHA/NHLBI) and subgroup with the metabolic syndrome identified using the AHA/NHLBI criteria excluding central obesity using Students ‘t’ test. Multiple logistic regression analyses were performed to examine risk factors for the metabolic syndrome separately using two criteria.15 All analyses were two-tailed and P-value < 0.05 was considered statistically significant.

**Results**

There were total of 1113 eligible subjects, among them 1077 (96.7%) consented to participate in the study. The number of subjects below 35 years was 394 (36.6%), 35 to 54 years 634 (58.9%) and 49 (4.5%) were 55 years or above. Level of education was up to secondary school (12 years of school education) for 679 (63.1%) subjects. Prevalence of behavioral risk factors was: current smoking 225 (20.9%), regular alcohol use 68 (6.3%) and sedentary physical activity level 90 (8.4%).

**Prevalence of the metabolic syndrome and its components**

The prevalence of the metabolic syndrome was 41.3% and 51.4% using the IDF and the AHA/NHLBI criteria respectively. Among the individual components for the metabolic syndrome, prevalence was lowest for high blood pressure and highest for low HDL (Table 1). We analyzed the prevalence of five components of the metabolic syndrome across the tertiles of BMI and all showed an increasing prevalence across the tertiles although to varying degrees. Among the components, central obesity was least prevalent (6%) in the first tertile of BMI. There was sharp increase in the prevalence of central obesity in second (56%) and third (96.4%) tertiles. In contrast, low HDL was the most prevalent (66%) component in first tertile but the rise across the tertiles was very gradual reaching a maximum of 96.4% in the third tertile. The prevalence of raised blood pressure, triglycerides and plasma glucose in the first tertile was 26.7%, 32.9% and 34.3% respectively but the prevalence of all the three factors increased sharply across the tertiles doubling by the third tertile as compared to the first tertile (Figure 1). For all the components of MS, the linear trend was statistically significant (P<0.01) across the BMI tertiles.

**Characteristics of subjects with the metabolic syndrome**

We compared the characteristics of subjects in three non-overlapping groups namely sub-group with no metabolic...
syndrome, subgroup with the metabolic syndrome identified using both criteria (IDF and AHA/NHLBI) and sub group with the metabolic syndrome identified using the AHA/NHLBI criteria excluding central obesity (Table 2). The reason for excluding central obesity in the third group was to observe the characteristics of subjects who are not identified as the metabolic syndrome using the IDF criteria. When subjects with the metabolic syndrome excluding central obesity (AHA/NHLBI) were compared with subjects with the metabolic syndrome using both criteria, former had significantly higher mean triglycerides and lower mean HDL (p<0.05). There was no significant difference in the other metabolic syndrome components namely mean fasting plasma glucose and blood pressure (both systolic and diastolic). In addition, other characteristics such as age, body mass index, vegetable and fruit intake and total cholesterol levels also had similar mean values.

**Risk factors associated with the metabolic syndrome**

We conducted multiple logistic regression analysis for the risk factors for the metabolic syndrome (using AHA/NHLBI definition) namely age above 35 years, per capita income above the median, family history of hypertension and type 2 diabetes, current smoking, current alcohol use (occasional and regular) and BMI>23.9 kg/m². In addition, protective factors namely college level education, moderate and heavy physical activity level and intake of more than three servings of fruits and vegetables were included in the analysis. Both unadjusted and adjusted odds ratios were significantly increased for age above 35 years, family history of diabetes and BMI above 23.93 kg/m². Similarly, unadjusted and adjusted odds ratio were significantly decreased for consumption of more than three servings of fruits

### Table 1: Prevalence of the metabolic syndrome and individual components in an industrial population in South India, 2005

<table>
<thead>
<tr>
<th>Metabolic Syndrome &amp; its components</th>
<th>Total (n =1077)</th>
<th>No.</th>
<th>Proportion (95% C.I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic syndrome (IDF)</td>
<td>445</td>
<td>41.3</td>
<td>(38.4 - 44.3)</td>
</tr>
<tr>
<td>Metabolic syndrome (AHA/NHLBI)</td>
<td>554</td>
<td>51.4</td>
<td>(48.5 - 54.4)</td>
</tr>
<tr>
<td>Raised triglyceride level &gt; 150 mg/dl</td>
<td>487</td>
<td>45.2</td>
<td>(42.2 - 48.2)</td>
</tr>
<tr>
<td>Reduced HDL cholesterol &lt; 40 mg/dl</td>
<td>757</td>
<td>70.3</td>
<td>(67.6 - 73.0)</td>
</tr>
<tr>
<td>Raised blood pressure</td>
<td>427</td>
<td>39.6</td>
<td>(36.7 - 42.6)</td>
</tr>
<tr>
<td>Raised fasting plasma glucose †</td>
<td>494</td>
<td>45.9</td>
<td>(42.9 - 48.8)</td>
</tr>
<tr>
<td>Waist circumference ≥ 90 cm</td>
<td>569</td>
<td>52.8</td>
<td>(49.9 – 55.8)</td>
</tr>
</tbody>
</table>

†Raised blood pressure: systolic BP > 130 or diastolic BP > 85 mm Hg, or treatment of previously diagnosed hypertension

### Table 2: Characteristic of the Study Population (mean ± SD)

<table>
<thead>
<tr>
<th>Description</th>
<th>No Metabolic syndrome (n = 523)</th>
<th>IDF Metabolic syndrome (n = 445)</th>
<th>AHA/ NHLBI Metabolic syndrome (non waist) (n = 109)</th>
<th>Total population (n = 1077)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>36.0 ± 8.50</td>
<td>41.3 ± 8.33</td>
<td>40.7 ± 8.58</td>
<td>38.7 ± 8.83</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.7 ± 3.31</td>
<td>28.0 ± 2.83</td>
<td>23.7 ± 1.93</td>
<td>25.5 ± 3.66</td>
</tr>
<tr>
<td>Vegetables &amp; fruits (servings)</td>
<td>3.3 ± 1.23</td>
<td>3.1 ± 1.23</td>
<td>3.1 ± 1.28</td>
<td>3.2 ± 1.24</td>
</tr>
<tr>
<td>Total cholesterol (mg/dl)</td>
<td>175.9 ± 33.19</td>
<td>192.4 ± 40.46</td>
<td>194.9 ± 43.43</td>
<td>184.7 ± 38.37</td>
</tr>
<tr>
<td>Metabolic syndrome components</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triglyceride (mg/dl)</td>
<td>123.8 ± 72.28</td>
<td>212.5 ± 155.61</td>
<td>268.3 ± 223.90</td>
<td>175.1 ± 142.46</td>
</tr>
<tr>
<td>High density lipo protein (mg/dl)</td>
<td>38.4 ± 8.65</td>
<td>33.9 ± 6.92</td>
<td>32.3 ± 5.15</td>
<td>36.0 ± 8.05</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>118.2 ± 12.30</td>
<td>130.1 ± 14.86</td>
<td>129.2 ± 11.66</td>
<td>124.2 ± 14.58</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>72.0 ± 9.10</td>
<td>80.2 ± 10.11</td>
<td>80.2 ± 9.30</td>
<td>76.2 ± 10.38</td>
</tr>
<tr>
<td>Fasting blood sugar (mg/dl)</td>
<td>92.8 ±17.09</td>
<td>118.8 ± 42.31</td>
<td>123.4 ± 45.01</td>
<td>106.6 ± 35.60</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>85.2 ± 9.14</td>
<td>97.9 ± 6.40</td>
<td>85.3 ± 3.72</td>
<td>90.5 ± 9.90</td>
</tr>
</tbody>
</table>

†IDF- International Diabetes Federation

†AHA/ NHLBI- American Heart Association / National Heart Lung and Blood Institute

### Fig. 1: Prevalence of individual components of the metabolic syndrome in tertiles of body mass index in an industrial population in South India, 2005.
and vegetables daily. Unadjusted odds ratio was significant for college level education but adjusted odds ratio was not significant (Table 3). The analysis of all the above-mentioned risk factors for subjects identified by the IDF definition yielded similar results. Dose response relationship was observed for increasing age and BMI across the categories irrespective of the criteria used.

**Discussion**

We observed a high prevalence of the metabolic syndrome in an industrial population using both IDF and AHA/NHLBI criteria. But the prevalence by AHA/NHLBI criteria that includes subjects with metabolic syndrome without central obesity showed higher prevalence of the metabolic syndrome as compared to the prevalence using IDF criteria. The metabolic syndrome by both criteria was associated with increasing age, BMI and family history of diabetes; the consumption of more than three serving of fruits and vegetables was protective.

The prevalence of the metabolic syndrome in the study population was higher than the reported prevalence in general population in India probably due to better socio-economic status, the male preponderance and urbanisation of the study population.6,7,14,15 In a recent population based study from Chennai a large metropolitan city in India, the metabolic syndrome prevalence was 23.2% by WHO criteria, 18.3% by ATPIII criteria and 25.8% by IDF criteria.14 In another population-based study from Chennai, the prevalence of the metabolic syndrome by modified ATPIII criteria (waist circumference ≥90 cm for men and ≥85 cm for women) was 41.1%.7 In Northern India, the prevalence (ATPIII with waist circumference=94cm) was 35% in an industrial population and 24.9% in a community-based study.6,15 It is likely that the differences in population characteristics and the criteria used have resulted in wide variation in prevalence of the metabolic syndrome.

It would be important to identify a more “suitable definition” for Asian Indians which would enable cardiovascular risk prediction maximally. In our population, the AHA/NHLBI criteria identified large sub-group of subjects without central obesity in addition to the subjects identified using both criteria. Lipid abnormalities were more pronounced in this group indicating increased cardiovascular risk even in the absence of central obesity. These findings suggest it may be important to identify subjects with the metabolic syndrome even in the absence of central obesity to initiate appropriate interventions. Whether central obesity should be an essential or optional component of the metabolic syndrome has been recently questioned.16 Lee et al in a prospective study in Singapore observed the increased risk of Ischemic Heart disease (IHD) in subjects (including Asian Indians) with the metabolic syndrome with or without central obesity.16

Risk factors associated with increased prevalence of the metabolic syndrome were similar even when different criteria were used. Age was an important risk factor. There was sharp rise in the prevalence of the metabolic syndrome in the 35–44 yr age group as compared to less than 35 years age group. The high prevalence of the metabolic syndrome in younger age group is of concern because early onset will expose these subjects to the risk factors for prolonged duration and increase the risk of diabetes and cardiovascular disease. It is consistent with the study from Singapore where higher prevalence of the metabolic syndrome was observed at younger age in Asian Indians and Malays.17

We identified two modifiable risk factors overweight and intake of less than three servings of fruits and vegetables. Our findings were consistent with studies from western countries where behavioral risk factors associated with increased risk of the metabolic syndrome include higher intake of dietary carbohydrates, lower intake of crude fiber, overweight and obesity and the protective factor is moderate physical activity.18,19 We did not use food frequency questionnaire, hence proportion of various macronutrients and various food groups could not be quantified. Prevalence of leisure time physical activity (LTPA) was very low in the study population, hence we could not include it in the analysis though it is an established protective factor.

Lifestyle modification in the form of weight reduction, low calorie diet and moderate physical activity 150 minutes a week has been shown to be an effective intervention in randomized controlled trials.20 Therefore, we recommended work site interventions to the management in the form of modification in canteen meal menu, health education to encourage increased fruit and vegetable intake and counseling for regular physical activity and weight loss in the in-house medical center.

Limitations of our study is that population consisted of urban males from the middle and higher income group working in an industrial setting and are not representative of general urban population. However, this subset of the population may be first ones entering the epidemiological transition and lessons learnt about the unique aspects of CVD risk factors in this population may be valuable in planning cardiovascular disease prevention programs.

In summary, there is need for cross-sectional studies with larger representative samples to get more reliable estimates of prevalence of the metabolic syndrome among Asian Indians. Based on the findings we recommend periodic worksite screening for cardiovascular risk factors at 35 years and above to facilitate early detection of subjects with the metabolic syndrome. The subjects with the metabolic syndrome should be advised regarding lifestyle modification and weight reduction. Prospective studies among Asian Indians will help identify the appropriate criteria that will predict cardiovascular disease risk in this population.

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**Conflict of Interest**

All the authors declare that there is no conflict of interest.

**References**