INTRODUCTION

Obesity is progressively becoming a global health problem because of its association with many diseases, thus presenting a target for research designed to improve the assessment or treatment of abdominal obesity.1 Obesity has been recognized not only in adults, but also during childhood leading to an increased incidence of hypertension (HTN) and Cardiovascular Disease (CVD) at a young age.2 Epidemiological studies find a progressive increase in the prevalence of HTN and CVD with increasing adipose tissue accumulation and complex interactions among hormonal, homodynamic and nutritional factor.3

The accumulation of fat in visceral and posterior subcutaneous adipose tissue compartments is highly correlated with metabolic abnormalities.4 Adipose tissue secretes many important adipocytokines especially adiponectin, which has anti-diabetic, anti-atherogenic, anti-inflammatory, anti-oncogenic properties and its plasma level decreases with visceral fat accumulation.5 Moreover, visceral fat is metabolized into Low-Density Lipoprotein (LDL) cholesterol that causes atherosclerosis; further, it stimulates Sympathetic Nervous System (SNS) also and its accumulation is strongly associated with HTN.6

Several studies have assessed the role of anthropometric indices in prediction of CVD.7 BMI being an easy and inexpensive method has been considered a reliable indicator and an alternative for direct measurement of body fat; however, it can give erroneous readings in athletes having a large bone and muscle mass.8 In a conjoint WHO/IASO/IOTF meeting, a different set of criteria with lower BMI and WC measures were proposed for Asian population as it was recognized that nearly twice as many deaths from CVD occur in the developing countries as compared to developed affluent societies. A lower BMI value was recommended for
Asians (≥ 23: overweight) due to their smaller body frames, placing them at a greater risk than Caucasians at equivalent BMI.\(^9\)

WC and WHpR are two simple and convenient ways to measure stored body fat. Many studies revealed WC as a best measure of excess visceral fat, which can independently predict health risk when BMI is not markedly elevated.\(^10\) Whereas, other studies suggest WHpR as a sensitive predictor of disease, as it assesses the risk of HTN in a population when majority is considered thin as traditionally measured by BMI.\(^11\)

The relationship of basal metabolic rate and obesity is determined by optimal intake and expenditure of energy.\(^12\) Thus, appetite regulation and weight maintenance achievement is aimed for prevention of chronic diseases associated with obesity. Many studies have demonstrated a direct relationship between coronary artery disease, total cholesterol and LDL-C and an inverse relationship with HDL-C.\(^13\)

Rapid urbanization, alterations in lifestyle patterns and eating habits have led to increased risk of obesity and CVD in our population. In this study, the objective was to examine the utility of different indicators of the body composition and compare their predictive value in association with different stages of HTN, serum lipid profiles and blood glucose level.

**METHODOLOGY**

It was a case-control study conducted at National Institute of Cardiovascular Disease and General Practitioner’s Clinics, Karachi, from 2005 to 2007. The subjects were classified into four categories according to the cut-off values of Blood Pressure (BP) specified in 7\(^{th}\) JNC report i.e. control (BP <120 <80), pre-hypertension group (systolic BP >120 and <140, diastolic BP >80 and <90), hypertension stage-1 (systolic BP >140 and <160, diastolic >90 and <100) and stage-II (>160 systolic BP >100 diastolic BP) – all values in mmHg.\(^14\)

The subjects representing urban population were selected amongst patients attending hypertension clinic of National Institute of Cardiovascular Disease and general practitioner’s clinics. The controls were selected from general population, having normal BP levels without any medication. Patients suffering from any other disease (cardiac, renal, hepatic etc.) other than HTN were excluded from the study. Majority of the subjects were educated and belonged to middle and lower middle socio-economic class. Their written consents were taken and project was approved by the Board of Advanced Studies and Research and Ethical Committee of University of Karachi.

Purpose designed questionnaires were administered to ascertain biographical data, lifestyles behaviours including dietary habits, quantity of oil/ghee and salt used in food, habits of cigarette smoking and alcohol consumption, patterns of daily physical activity and medical and family history of CVD.

A digital scale was used to measure Body Weight (BW) with an accuracy of ±100 g. Subjects were weighed without shoes, in their normal clothing. Standing Body Height (BH) was measured without shoes to the nearest 0.5 cm with the use of a commercial stadiometer with the shoulders in the relaxed position and arms hanging freely. BMI was calculated as BW in kilograms (Kg) divided by square of the BH in meters (m\(^2\)).

Waist Circumference (WC) was measured in the middle between 12\(^{th}\) rib and iliac crest and the Hip circumference (HC) at the fullest point around the buttocks. WC (cm) was divided by HC (cm) and BH (m) in order to calculate the waist to hip ratio, and waist to height ratio respectively.

BMR was calculated by the formula: \( \text{BMR /hour} = \text{Body surface area} \times \text{BMR factor.} \)

Body surface area is determined by using a normogram, and multiplied by BMR factor given in normogram according to age and gender of person.

For BP measurement, subjects were seated in a chair with their back supported and their arms rested at heart level. Measurement was performed with the subject not having ingested coffee or smoked for 30 minutes and after at least five minutes of rest. The appropriate cuff size was used to ensure an accurate measurement. The first and fifth Korotkoff sounds were recorded by the height of mercury column on sphygmomanometer.

Fasting venous blood samples were drawn (after 9-12 hours fasting), centrifuged and analyzed (by commercially available kits) for estimation of Total cholesterol (TC), triglycerides (TG), High-Density Lipoproteins (HDL), Low-Density Lipoprotein (LDL), and Fasting Blood Glucose (FBG) level.

Based on WHO recommendations for Asian population a person was said to be underweight with BMI <18.5, normal weight between 18.5-22.9, overweight between 23-24.9, obese type-1: between 25-29.9, and type II obese >30.\(^15\)

The WC, WHpR and WHtR measurements were used to determine the extent of central adiposity.\(^16\) For WC in Asian-Indian population values of > 90 cm in man and > 80 cm in woman were identified as risk factor by ATP III and these values were used in this study. WHR value of > 0.50 in either gender were adopted as cut-offs.\(^14\) Normal values of BMR in males was taken at 40 calories/square meter body surface area/hour and in females as 37 calories/square meter body surface area/hour.

According to Adult Treatment Panel III (revised 2006), dyslipidemia was defined as TC > 180 mg/dL, TG > 150 mg/dL, HDL < 40 mg/dL, LDL > 100 mg/dL.\(^17\) Impaired
fasting glucose was defined as a fasting glucose level that is higher than the upper limit of normal, but not high enough to be classified as Diabetes mellitus (FBG > 110-125 mg/dL).18

Data was analyzed by using SPSS version 10. All variables were presented by mean ± SD. Analysis of variance was performed to compare four study groups and Least Significance Difference (LSD) test was applied to compare pair-wise groups. Test of linear correlation was applied to assess relationship of anthropometric measurements with systolic and diastolic BP, serum lipids and glucose levels. Statistical significance was taken at p < 0.05.

RESULTS
Among 276 subjects aged 25-65 years, 137 (49.6%) were males and 139 (50.4%) females, with female predominance in control group (60% vs. 40%) and pre-HTN group (63.6% vs. 36.4%). Male predominance was observed in HTN stage I group (64.3% vs. 35.7%) and HTN stage II group (55.3% vs. 44.7%). The data of subject profile is presented in Table I.

The mean age of control group was 37.5 ± 8.54, which was significantly less than the mean age of HTN stage I and II groups (p<0.001) but insignificant with the mean age of pre-HTN group (p=0.346). Among 75 healthy controls, 52 (69.3%) were found to be overweight (BMI >23) with significantly higher proportions (p=0.023) of overweight individuals in pre-HTN (80%), HTN stage I (90%) and stage II (76.3%).

The mean values of all anthropometric indices and their pair-wise comparisons are presented in Table I. The mean BMI of control group was 24.9 ± 3.77 kg/m², which was significantly less than the mean BMI of HTN stage I and II groups (p<0.001) but insignificant with the mean BMI of pre-HTN group (p=0.346). Among 75 healthy controls, 52 (69.3%) were found to be overweight (BMI >23) with significantly higher proportions (p=0.023) of overweight individuals in pre-HTN (80%), HTN stage I (90%) and stage II (76.3%).

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The mean WHtR of control group was 0.905±0.068 which was significantly less than the mean values of other groups. The pair-wise comparison showed that the mean WHtR ratio was highest in HTN stage-I group. It had significant linear correlation with BMI, WC and WHtR in all the four groups. It was significantly correlated to SBP, DBP and FBS in control and pre-HTN groups, to SBP in HTN stage I and to SBP and DBP in HTN stage II (Table III).

The average WHtR was highest in HTN stage-I group (59.7±7.24). The same pattern of statistical significance as WHtR was observed regarding WHtR in all study groups (Table I). The coefficient correlation analysis showed that WHtR was significantly correlated to other anthropometric measures in all four groups; to FBS in pre-HTN group, to SBP and TG in HTN stage I (Table II).

The mean BMR of control group was 57.8±7.40 which was significantly less than the means of pre-HTN, HTN stage I and II groups. BMR showed significant correlation, in addition to other obesity measures in all groups, and with SBP, DBP in control group and to TG in HTN stage II.

Results of lipid profile showed that the mean total cholesterol level was 168.7±33.9 mg/dL in control group, 171.7±32.3 mg/dL in pre-HTN, 191.4±48.4 mg/dL in stage I and 179.1±32.1 mg/dL in stage II HTN. Cholesterol was >180 mg/dL in 36% controls, 38% pre-HTN, 56% stage I and 46% stage II HTN patients. The triglycerides level was 134.6±60.3 mg/dL in control, 136.1±62.2 mg/dL in pre-HTN, 161.8±79.9 mg/dL in stage-I, and 166.6±66.7 mg/dL in stage-II HTN. TG was >150 mg/dL in 54% controls, 30% pre-HTN, 50% in stage I and 60% in stage II HTN cases.

The level of high density lipoproteins was 44.6±9.04 mg/dL in controls, 43.8±10.2 mg/dL in pre-HTN, 37.8±12.9 mg/dL in stage I, and 49.4±19.6 mg/dL in stage II HTN patients. The HDL-C level was <40 mg/dL in 24% in controls, 36% pre-HTN, 70% stage I and 46% in stage II HTN cases.

The level of LDL was >100 mg/dL in 55% controls, 58% pre-HTN, 70% stage I and 47% stage II HTN patients. The LDL-C level was <40 mg/dL in 24% controls, 36% pre-HTN, 70% stage I and 46% in stage II HTN cases.

The mean TC/HDL-C ratio was 3.89±1.05 in controls, 4.04±1.29 in pre-HTN, 5.38±1.72 in stage I and 4.09±1.51 in stage II HTN patients. The mean LDL-C level was 106.5±30.7 mg/dL in controls, 105.6±32.7 mg/dL in pre-HTN, 116.4±32.9 mg/dL in stage I and 103.7±29.2 mg/dL in stage II HTN groups. The level of LDL was >100 mg/dL in 55% controls, 58% pre-HTN, 70% stage I and 46% stage II HTN patients. The mean LDL-C level was 168.7±33.9 mg/dL in control group, 171.7±32.3 mg/dL in pre-HTN, 191.4±48.4 mg/dL in stage I and 179.1±32.1 mg/dL in stage II HTN. Cholesterol was >180 mg/dL in 36% controls, 38% pre-HTN, 56% stage I and 46% stage II HTN patients. The triglycerides level was 134.6±60.3 mg/dL in control, 136.1±62.2 mg/dL in pre-HTN, 161.8±79.9 mg/dL in stage-I, and 166.6±66.7 mg/dL in stage-II HTN. TG was >150 mg/dL in 54% controls, 30% pre-HTN, 50% in stage I and 60% in stage II HTN cases.

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Mean fasting blood glucose level was 96.6±38.4 mg/dL in control, 108.4±38.2 mg/dL in pre-HTN, 103.7±32.7 mg/dL in stage I, and 101±34.6 mg/dL in stage II HTN patients. Fasting blood glucose level was found to be in the impaired range (110-125 mg/dL) in 2.6% controls, 14% pre-HTN, 13% stage I and 5% stage II HTN patients; whereas it was > 125 mg/dL in 9% controls, 22% pre-HTN, 16% stage I and 14% stage II HTN cases.
### Table I: Subject profile.

<table>
<thead>
<tr>
<th>Control (n=75)</th>
<th>Pre-HTN (n=55)</th>
<th>HTN stage-I (n=70)</th>
<th>HTN stage-II (n=76)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n =</td>
<td>Male Female</td>
<td>Male Female</td>
<td>Male Female</td>
</tr>
<tr>
<td>Age</td>
<td>30.5±9.96</td>
<td>37.4±7.7</td>
<td>41.4±5</td>
</tr>
<tr>
<td>&lt; 40</td>
<td>16 28</td>
<td>11 13</td>
<td>10</td>
</tr>
<tr>
<td>≥ 40</td>
<td>14 17</td>
<td>09 22</td>
<td>35</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 23</td>
<td>6 15</td>
<td>8 02</td>
<td>03</td>
</tr>
<tr>
<td>≥ 23</td>
<td>4 14</td>
<td>2 8</td>
<td>03</td>
</tr>
<tr>
<td>≥ 25</td>
<td>20 16</td>
<td>10 25</td>
<td>39</td>
</tr>
<tr>
<td>Smoking (%)</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family History (%)</td>
<td>6 2</td>
<td>18 11</td>
<td>45 24</td>
</tr>
<tr>
<td>Stress (%)</td>
<td>14 7</td>
<td>30 24</td>
<td>39 20</td>
</tr>
<tr>
<td>Exercise (%)</td>
<td>-</td>
<td>9</td>
<td>29</td>
</tr>
</tbody>
</table>

Pre-HTN = Prehypertension group; HTN-stage-1 = Hypertension stage 1; HTN-stage-II = Hypertension stage II; BMI = Body mass index.

### Table II: Pair-wise comparison of different anthropometric measurement among study groups.

<table>
<thead>
<tr>
<th>Control (n=75)</th>
<th>Pre-HTN (n=55)</th>
<th>HTN stage-I (n=70)</th>
<th>HTN stage-II (n=76)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>24.9 ± 3.77</td>
<td>26.4 ± 4.47</td>
<td>v/s C = 0.019*</td>
</tr>
<tr>
<td>WC</td>
<td>82.2 ± 13.4</td>
<td>86.9 ± 17.2</td>
<td>v/s C = 0.001*</td>
</tr>
<tr>
<td>WHpR</td>
<td>0.91 ± 0.07</td>
<td>0.95 ± 0.08</td>
<td>v/s C = 0.001*</td>
</tr>
<tr>
<td>WHtR</td>
<td>50.1 ± 7.84</td>
<td>54.3 ± 11.3</td>
<td>v/s A &lt; 0.001*</td>
</tr>
</tbody>
</table>

Values are given as mean ± SD; *The mean difference is significant at the 0.05 level.

### Table III: Coefficient correlation of anthropometric indices with cardiovascular risk factors ("r" value).

<table>
<thead>
<tr>
<th>Obesity index</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>FBG (mg/dL)</th>
<th>TC (mg/dL)</th>
<th>TG (mg/dL)</th>
<th>HDL-C (mg/dL)</th>
<th>TC/HDL</th>
<th>LDL-C (mg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>0.158</td>
<td>0.195</td>
<td>0.297**</td>
<td>0.261*</td>
<td>-0.51</td>
<td>-0.177</td>
<td>0.310**</td>
<td>0.172</td>
</tr>
<tr>
<td>WC</td>
<td>0.228*</td>
<td>0.124</td>
<td>0.236*</td>
<td>0.338**</td>
<td>0.008</td>
<td>-0.208</td>
<td>0.254*</td>
<td>0.289*</td>
</tr>
<tr>
<td>WHpR</td>
<td>0.266**</td>
<td>0.379**</td>
<td>-0.042</td>
<td>0.223</td>
<td>0.025</td>
<td>0.092</td>
<td>-0.030</td>
<td></td>
</tr>
<tr>
<td>WHtR</td>
<td>0.378**</td>
<td>0.400**</td>
<td>-0.088</td>
<td>0.115</td>
<td>0.203</td>
<td>0.080</td>
<td>0.173</td>
<td>0.035</td>
</tr>
<tr>
<td>BMR</td>
<td>0.201</td>
<td>0.400</td>
<td>-0.088</td>
<td>0.129</td>
<td>0.102</td>
<td>-0.175</td>
<td>0.192</td>
<td>0.191</td>
</tr>
</tbody>
</table>

* P < 0.05; ** P < 0.01;

FBG = Fasting blood glucose; BMI = Body mass index; TC = Total cholesterol; WC = Waist circumference; TG = Triglyceride; WHpR = Waist hip ratio; LDL = Low-density lipoprotein; WHtR = Waist height ratio; SBP = Systolic blood pressure.
DISCUSSION

Obesity and HTN are two interrelated CVD risk factors and decrease in adiposity is one of the most effective preventive measures in decreasing not only the BP but also the overall cardiovascular risk.

Age is a recognized risk factor for developing high BP. The range used in this study was 25-65 years; as most men develop high BP between ages of 35-55 years and women mostly develop HTN after menopause. Moreover, incidence and prevalence of HTN is increasing in young adults also because of increasing obesity in this age group. The analysis of mean age in this study among different groups revealed that the frequency of HTN increased with age, as mean age in control group is significantly less than age in HTN stage I and II. Age and gender specific prevalence of HTN showed progressive rise of systolic and diastolic BP in women when compared to men, as age increased.

The prevalence of overweight (25%) and obesity (10%) in general Pakistani population is consistent with previous findings that a quarter of Pakistani population should be classified as overweight or obese. In this study, a relatively high proportion of subjects were overweight and obese (70% controls, 80% pre-HTN, 90% HTN stage I and 76% stage II). Since, all the obesity indices showed above normal values in both males and females, further categorization on the basis of gender was not done.

Assessing the risk for the presence of major CVD risk factors is of particular importance, for it would promptly allow us to identify persons at high risk for development of clinical CVD later in life. The results of multivariate analysis showed that all four indices were variably related to CVD risk factors in this study. The performance of different anthropometric indices in predicting obesity-related outcomes has been addressed in several reports. BMI has been conventionally used to define and classify overweight and obesity; however, it does not take into account the pattern of body fat as waist size, WHpR and skin fold measurement do in predicting intra-abdominal fat accumulation. It can also overestimate the prevalence of obesity among women of lower socio-economic status. In this study, results disclosed that BMI had significant linear correlation with serum lipid levels – total cholesterol in control group and both cholesterol and triglycerides in HTN stage I.

Several studies concluded that WC, whereas many other suggested that WHpR might be a superior index in predicting the presence of central adiposity and dyslipidemia and has the highest specificity and accuracy in predicting CV risk factors. Although, all anthropometric indicators may have a significant association to CV risk factors, in this study WHpR had the highest coefficient correlation with systolic BP in HTN stage I and II and with diastolic BP in all the three stages of HTN, as compared to other anthropometric indices. It was also significantly correlated to FBG level in control and pre-HTN groups, which is possibly the factor responsible for progression of pre-HTN stage into HTN stage I.

The Inter HEART study reported that current practice with BMI being used as a tool to measure obesity underestimates the hazards of overweight and obesity and recommends WHpR as preferred measure, as this ratio is three times stronger predictor of risk of heart attack as compared to BMI. A WHpR cut-off value of 0.83 for women and 0.9 for men would result in three fold increase in population attributable risk for HTN and MI especially in Asian population who face no significant problem with obesity measured by BMI. Another study documented that the WHpR was the best predictor for HTN, diabetes, dyslipidemia in Australian aboriginal people, as it reflects both abdominal subcutaneous and visceral adipose tissue accumulation.

A study in Pakistan on normotensive subjects showed that WC and WHtR were strongly associated with increase in systolic and diastolic BP with increasing age. In this study, WC was correlated significantly with DBP in pre-HTN group and stage II HTN; WHtR on the other hand was significantly correlated with SBP in pre-HTN and HTN stage I, and with DBP in pre-HTN group and HTN stage II. However, both had no correlation with serum lipid or glucose levels. Measurement of obesity by WC is unsuitable for excessively overweight individuals as it is difficult to identify the narrow location between ribs and iliac crest. Recording at umbilicus gives a large value, thus this variability in measurement limits the validity of WC and WHtR, affecting standard deviation values. This study thus revealed WHpR to have much stronger predictive power and greater statistical significant correlation with CVD risk factors as compared to other indices. The study further revealed that obese hypertensive subjects have smaller but significant increase in BMR compared with age and BMI matched obese normotensive control subjects.

Dyslipidemia contributes to endothelial dysfunction, vascular inflammation and atherosclerosis, thus not only causing HTN but also leading to progression of pre-HTN stage into clinical HTN. The prevalence of mean level of cholesterol, triglycerides and LDL-C increased consistently with stages of HTN, and were highest in HTN stage I. The mean level of HDL-C was lowest in this stage showing the strong association of lipids with HTN. It was worth noting that higher lipid levels were observed with normal or even less BMI values, whereas WC and WHpR were above normal in these subjects in all the groups. High TC/HDL ratio is also independently associated with increased risk of HTN in apparently
healthy men as well as this ratio and non HDL-C are good indicators of future cardiovascular events.\textsuperscript{27} In this study, this ratio was linearly correlated to SBP, pulse and mean arterial pressure in stage II HTN. Lifestyle factors such as high fat diet, cigarette smoking, less physical activity and stress factors have been found to be associated with high prevalence of HTN and CVD.

Impaired and elevated blood glucose levels were also an important finding in apparently normoglycemic subjects and patients. High percentage of impaired (14%) and higher blood glucose levels (22%) in pre-HTN group documented the relationship of insulin resistance with obesity and subsequent HTN. Blood glucose level was found to have positive correlation with cholesterol and pulse pressure in control group and with LDL-C in pre-HTN group.

CONCLUSION

A substantial proportion of subjects were overweight and obese, reflecting the general obesity trend in our society and who had higher levels of BP, serum lipids and blood glucose levels. WHpR was found to be a superior index for the prediction of the presence of central adiposity, HTN and diabetes; while BMI was a strong indicator of dyslipidemia. Moreover, the combination of WHpR and BMI can increase the explanatory power of each index alone. Elevated blood glucose level, dyslipidemia along with the visceral obesity may be the responsible factors for progression of pre-HTN stage into HTN stage-1.

REFERENCES


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