# A Comparison of Anthropometric Indices for Predicting Hypertension and Type 2 Diabetes in a Male Industrial Population of Chennai, South India

Prabhdeep Kaur, DNB; Ezhil Radhakrishnan, PhD; Suresh Sankarasubbaiyan, MD; Sudha Ramachandra Rao, MSc; Srinivas Kondalsamy-Chennakesavan, MPH; Thota Venkata Rao, MSc; Mohan Digamber Gupte, MD

**Objectives:** To assess the association of four obesity-related indices—body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-stature ratio (WSR)—with hypertension and type 2 diabetes among a male industrial population in south India.

**Design, Setting, and Participants:** A cross sectional study of 2148 men aged 18–69 years in two purposely selected industrial units in Chennai, India, in 2003–2005.

**Main Outcome Measures:** The examination included blood pressure and anthropometric measurements (height, weight, hip circumference, and WC) to calculate BMI, WHR, and WSR. Fasting blood samples were taken to assess plasma glucose.

**Results:** Prevalence of overweight was 43.4%; prevalences of central obesity using WC ≥90.0 cm and WHR >0.90 were 50.0% and 70%, respectively. The prevalences of hypertension and type 2 diabetes were 26.5% and 16.3%, respectively. There was a significant increase in the prevalence of type 2 diabetes and hypertension across the quintiles for the four anthropometric indices. In logistic regression analysis, BMI and WC showed a significant graded increase in the odds ratio for hypertension after adjusting for age. In case of type 2 diabetes, only WHR showed significant increase in odds ratio across quintiles after adjusting for age and BMI.

**Conclusions:** WHR was the best predictor for type 2 diabetes in the study sample. BMI and WC were good predictors for hypertension. We recommend that WHR should be routinely used in this clinical setting in addition to BMI to detect persons at high risk in these industrial units. Prospective studies are needed to provide evidence of the predictive power of anthropometric indices for Asian Indians. (*Ethn Dis*. 2008;18:31–36)

**Key Words:** India, Risk Factors, Hypertension, Diabetes, Anthropometric Indices, Central Obesity, Asian Indian

From the National Institute of Epidemiology, Indian Council of Medical Research (PK, RE, RS, TVR, MDG), Sundaram Medical Foundation Dr. Rangarajan Memorial Hospital (SS), Chennai, India; Centre for Chronic Disease, Royal Brisbane Hospital, Herston, Queensland, Australia (SKC).

Address correspondence and reprint requests to: Prabhdeep Kaur; National Institute of Epidemiology (Indian Council of Medical Research); R-127, 3rd Ave, Ambattur Housing Board, Phase I and II; Chennai 600 077, India; 914426357469; 914426357464 (fax); kprabhdeep@gmail.com

## Introduction

Obesity, a risk factor for type 2 diabetes mellitus and for cardiovascular disease, is increasing in prevalence in both developed and developing countries.[1] In India, the prevalence of obesity among adults is 10%–50%, depending on the definitions used.[2] Obesity is defined by certain anthropometric indices, such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-stature ratio (WSR). Among these, BMI is the most widely used indicator of obesity, but it does not measure body fat distribution and, in particular, abdominal fat mass.[3,4] The pattern of body fat distribution has been noted to be a determinant of cardiovascular disease risk. Accumulation of fat in the abdominal region is particularly related to an increased risk of cardiovascular disease.[5,6] Hence, anthropometric indices that measure abdominal fat or central obesity such as WC and WHR are increasingly used in research and clinical settings.[3,7]

The ethnic origin of the population studied influences the predictive power of various anthropometric indices.[8–10] Hence, population-specific anthropometric indices are needed to identify subjects at risk for hypertension and type 2 diabetes. Asian Indians are a unique ethnic group in terms of body morphology and cardiovascular disease risk. Asian Indian immigrants have a higher rate of cardiovascular diseases than do other ethnic groups in Canada.[11] In terms of body morphology, Asian Indians have lower BMIs, and for any given BMI, Asian Indians have higher central obesity and abdominal fat than do Europeans.[12,13] In Indians, studies have reported the risk threshold levels of various anthropometric indices, but none have measured all four commonly used anthropometric indices in the same population to assess the relative importance of these indices for predicting cardiovascular risk factors.[14–17] A high prevalence of cardiovascular risk factors is reported among workers in industrial populations in India.[18] We determined the prevalence of cardiovascular risk factors in an industrial sample in south India. We measured BMI, WC, WHR, and WSR and determined which of these indices best identified patients with hypertension and type 2 diabetes mellitus.

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## Methods

### Setting, Design, and Participants

Chennai is the fourth-largest metropolitan city in India, with a population

of 4.3 million as per Census India.[19] We conducted a cross-sectional study in two industrial units in Chennai. These units manufacture automobile components and have 1200 employees in each unit. These units have an in-house medical center that caters to primary healthcare needs and maintains medical records of employees. The sample was purposely selected to facilitate longitudinal followup, which will determine the validity of these anthropometric indices in predicting cardiovascular morbidity and mortality. The institutional ethics committee of the National Institute of Epidemiology, Chennai, approved the study. We obtained informed consent for the questionnaire-based interview, physical measurements, and laboratory tests. We referred patients with newly detected hypertension and diabetes to the in-house physician for further management.

We examined consenting participants from these industries during 2003–2005. There were 2283 employees in the factory. We excluded physically handicapped ($n=1$) subjects and women ($n=20$). A questionnaire was used to collect data on demographic variables and personal medical history. The examination included measurement of height, weight, waist circumference, hip circumference, blood pressure and the collection of fasting blood sample for plasma glucose.

**Table 1. Quintiles of anthropometric Indices with range of values, prevalence of hypertension and type 2 diabetes in each quintile in the study population in industrial units, Chennai, India, 2003–2005. ($n$=2148)**

| Anthropometric Indices | Range of Values | Prevalence of hypertension (%) | Prevalence of type 2 diabetes (%) |
|---|---|---|---|
| **Body mass index** | | | |
| Quintile 1 | 13.93–21.98 | 10.9 | 9.3 |
| Quintile 2 | 21.99–24.01 | 22.7 | 16.7 |
| Quintile 3 | 24.02–25.65 | 24.2 | 13.0 |
| Quintile 4 | 25.66–27.85 | 34.1 | 21.3 |
| Quintile 5 | 27.86–39.52 | 40.8 | 21.2 |
| **Waist circumference** | | | |
| Quintile 1 | 57.5–81.8 | 9.5 | 5.8 |
| Quintile 2 | 81.9–87.4 | 20.7 | 11.6 |
| Quintile 3 | 87.5–92.0 | 24.4 | 20.0 |
| Quintile 4 | 92.1–98.0 | 31.6 | 19.1 |
| Quintile 5 | 98.1–141.0 | 47.2 | 25.3 |
| **Waist hip ratio** | | | |
| Quintile 1 | 0.717–0.882 | 9.3 | 2.6 |
| Quintile 2 | 0.883–0.922 | 19.1 | 9.1 |
| Quintile 3 | 0.923–0.952 | 26.7 | 14.2 |
| Quintile 4 | 0.953–0.987 | 33.0 | 22.6 |
| Quintile 5 | 0.988–1.178 | 44.7 | 33.3 |
| **Waist stature ratio** | | | |
| Quintile 1 | 0.324–0.486 | 9.2 | 5.3 |
| Quintile 2 | 0.487–0.523 | 18.0 | 9.9 |
| Quintile 3 | 0.524–0.554 | 26.3 | 17.4 |
| Quintile 4 | 0.555–0.591 | 34.1 | 22.4 |
| Quintile 5 | 0.592–0.783 | 45.9 | 26.9 |

## Anthropometric and Biochemical Measurements

Weight was measured in the upright position to the nearest 0.1 kg using a calibrated balance beam scale. Height was measured without shoes to the nearest 0.1 cm using calibrated stadiometer. BMI was calculated as the observed weight in kilograms divided by height in meters squared (kg/m$^2$). WC was measured to the nearest 0.1 cm at the midpont between lower end of the rib cage and iliac crest. Hip circumference (HC) was measured to the nearest 0.1 cm at the greatest horizontal circumference below the iliac crest at the level of the greater trochanters. WHR was calculated as waist circumference divided by hip circumference. WSR was calculated as WC divided by height. The blood pressure was measured with an automated blood pressure apparatus (Omron MX3) from the right arm after the subject had been sitting for at least five minutes. The average of the two readings taken five minutes apart was recorded. The blood pressure measuring apparatus and weighing machines were periodically calibrated. All measurements were taken by trained field investigators under the guidance and supervision of a medical officer.

Five milliliters of blood was collected from the antecubital vein in a test tube containing heparin sodium fluoride after a 10-hour overnight fasting period. Plasma glucose was measured using the oxidase - peroxidase method in an autoanalyzer. Hypertension was defined as a systolic blood pressure $\geq$140 mm Hg or diastolic blood pressure $\geq$90 mm Hg or history of previously known disease.[20] Type 2 diabetes mellitus was diagnosed either by history of previously known disease or fasting plasma glucose $\geq$126 mg/dL (7 mmol/L).[21]

## Statistical Analysis

We compared the association of various anthropometric indices with hypertension and diabetes using partial correlation, multiple logistic regression, and receiver operating characteristic (ROC) curve analyses. We classified each of the four anthropometric indices into quintiles. We calculated the prevalence of hypertension and diabetes in each quintile. We computed the odds ratios (OR) (unadjusted, age adjusted, age and WHR/BMI adjusted) for hypertension and diabetes across the

quintiles of the anthropometric indices. The statistical package SPSS for Windows (version 13.0) was used for analysis.

## RESULTS

There were 2262 eligible men; among them 2148 (95%) agreed to participate in the study. Results are expressed as mean (±standard deviation). The age was 40.5 (±11.06) years, BMI 24.98 (±3.63) kg/m$^2$, WC 89.7 (±10.11) cm, WHR .93 (±.06), and WSR .54 (±.06). The mean systolic and diastolic blood pressures were 126±16.72 mm Hg and 77±10.55 mm Hg, respectively. The mean fasting plasma glucose was 95.8±30.35 mg/dL. The prevalences of overweight using the cutoff recommended for Asians (BMI ≥23.0 kg/m$^2$)[3] and the World Health Organization (WHO) cutoff (BMI ≥25 kg/m$^2$)[1] were 67.1% and 43.4%, respectively. Prevalence of central obesity using WC ≥90.0 cm and WHR >.90 were 50.0% and 70%, respectively.[3,22] The overall prevalences of hypertension and type 2 diabetes were 26.5% and 16.3%, respectively.

All four anthropometric indices showed significant Pearson correlation coefficient and partial correlation (age adjusted) with systolic blood pressure, diastolic blood pressure, and fasting plasma glucose ($P<.0001$). The prevalence of hypertension and type 2 diabetes increased across the quintiles of all the anthropometric indices (trend Chi square $P<.001$). There was a graded increase in the prevalence of type 2 diabetes across the increasing quintiles of WHR and WSR (Table 1).

By logistic regression analyses, all four anthropometric indices showed a significant unadjusted OR for hypertension across the quintiles (Table 2). BMI and WC showed significant age-adjusted OR in all quintiles. WC showed a significant increase in age and BMI adjusted OR in the last two quintiles. In case of WHR and WSR, the significance was no longer evident after adjustment for age and BMI. Only BMI showed a graded increase in OR for hypertension with all adjustments across the quintiles.

**Table 2. Unadjusted and adjusted odds ratio (OR) with 95% confidence intervals (CI) for hypertension according to quintiles of anthropometric indices in the study sample in industrial units, Chennai, India, 2003–2005 (*n*=2148)**

| Anthropometric quintiles | Unadjusted OR (95% CI) | Age-adjusted OR (95% CI) | Age- and WHR/BMI-adjusted OR* (95% CI) |
|---|---|---|---|
| **Body Mass Index (BMI)** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 2.40 (1.64–3.50) | 1.91 (1.29–2.84) | 1.75 (1.17–2.63) |
| 3 | 2.60 (1.79–3.78) | 2.10 (1.42–3.11) | 1.88 (1.25–2.82) |
| 4 | 4.22 (2.94–6.07) | 3.27 (2.24–4.78) | 2.80 (1.86–4.22) |
| 5 | 5.61 (3.92–8.04) | 4.17 (2.86–6.06) | 3.44 (2.26–5.24) |
| **Waist Circumference** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 2.48 (1.66–3.69) | 1.71 (1.13–2.58) | 1.41 (.91–2.17) |
| 3 | 3.06 (2.07–4.51) | 1.86 (1.24–2.79) | 1.35 (.85–2.14) |
| 4 | 4.39 (3.00–6.41) | 2.66 (1.79–3.95) | 1.70 (1.03–2.79) |
| 5 | 8.48 (5.83–12.35) | 4.38 (2.95–6.51) | 2.19 (1.19–4.04) |
| **Waist-to-Hip Ratio (WHR)** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 2.30 (1.53–3.44) | 1.46 (.96–2.23) | 1.08 (.70–1.67) |
| 3 | 3.55 (2.40–5.24) | 1.82 (1.20–2.76) | 1.18 (.76–1.82) |
| 4 | 4.81 (3.28–7.05) | 2.15 (1.42–3.24) | 1.25 (.80–1.95) |
| 5 | 7.89 (5.41–11.51) | 3.11 (2.06–4.70) | 1.53 (.96–2.44) |
| **Waist-to-Stature Ratio** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 2.17 (1.44–3.26) | 1.48 (.97–2.26) | 1.09 (.70–1.72) |
| 3 | 3.52 (2.38–5.20) | 2.12 (1.41–3.19) | 1.34 (.83–2.14) |
| 4 | 5.11 (3.49–7.48) | 2.70 (1.81–4.04) | 1.40 (.83–2.37) |
| 5 | 8.38 (5.74–12.23) | 3.90 (2.61–5.84) | 1.46 (.77–2.79) |

* OR adjusted for age and additionally for WHR/BMI.

WHR showed a graded and higher OR for type 2 diabetes across the quintiles after adjusting for age and BMI (Table 3). When adjusted for age and BMI, WC and WSR had significant ORs from the third quintile onward. For BMI, the significance completely disappeared after all adjustments. Though WHR, WC, and WSR were better predictors than BMI, WHR showed the highest OR even after adjustments.

The areas under the ROC curve for hypertension for BMI, WC, WHR, and WSR were .651, .683, .679, and .690, respectively, with overlapping confidence intervals. For type 2 diabetes, the areas under the ROC curve for these anthropometric measurements were .590, .645, .719, and .666, respectively. WHR had the highest area under the ROC with non-overlapping confidence intervals for type 2 diabetes.

Figure 1 shows the adjusted (age, BMI, waist) OR with confidence intervals for hypertension and type 2 diabetes across the quintiles of hip circumference. There was significant decrease in OR for type 2 diabetes with increasing quintiles, but for hypertension the decrease in OR was not significant.

## DISCUSSION

Our study has shown, that among commonly used anthropometric indices, WHR was the best predictor for type 2 diabetes in a sample of industrial

**Table 3. Unadjusted and adjusted odds ratio (OR) with 95% confidence intervals (CI) for type 2 diabetes according to quintiles of anthropometric indices in the study sample in industrial units, Chennai, India, 2003–2005 (*n*=2148)**

| Anthropometric quintiles | Unadjusted OR (95% CI) | Age-adjusted OR (95% CI) | Age- and WHR/BMI-adjusted OR * (95% CI) |
|---|---|---|---|
| **Body Mass Index (BMI)** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 1.96 (1.30–2.95) | 1.51 (.98–2.32) | 1.09 (.70–1.69) |
| 3 | 1.46 (.95–2.24) | 1.12 (.72–1.75) | 0.71 (.45–1.13) |
| 4 | 2.63 (1.77–3.93) | 1.94 (1.28–2.94) | 1.04 (.66–1.63) |
| 5 | 2.63 (1.76–3.91) | 1.80 (1.19–2.73) | 0.83 (.52–1.34) |
| **Waist Circumference** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 2.13 (1.29–3.51) | 1.41 (.84–2.36) | 1.33 (.78–2.27) |
| 3 | 4.04 (2.53–6.44) | 2.42 (1.49–3.93) | 2.20 (1.28–3.79) |
| 4 | 3.81 (2.39–6.09) | 2.21 (1.36–3.59) | 1.93 (1.06–3.51) |
| 5 | 5.48 (3.46–8.70) | 2.62 (1.62–4.25) | 2.13 (1.03–4.40) |
| **Waist-to-Hip Ratio (WHR)** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 3.80 (1.92–7.52) | 2.52 (1.26–5.04) | 2.58 (1.28–5.21) |
| 3 | 6.28 (3.26–12.11) | 3.42 (1.74–6.72) | 3.54 (1.77–7.08) |
| 4 | 11.09 (5.85–21.03) | 5.39 (2.78–10.45) | 5.62 (2.82–11.23) |
| 5 | 18.97 (10.09–35.68) | 8.25 (4.27–15.96) | 8.73 (4.30–17.75) |
| **Waist-to-Stature Ratio** | | | |
| 1 | 1.00 | 1.00 | 1.00 |
| 2 | 1.97 (1.17–3.33) | 1.30 (0.75–2.23) | 1.36 (0.77–2.41) |
| 3 | 3.78 (2.32–6.16) | 2.21 (1.33–3.66) | 2.38 (1.34–4.24) |
| 4 | 5.15 (3.20–8.30) | 2.61 (1.58–4.29) | 2.91 (1.54–5.48) |
| 5 | 6.59 (4.11–10.57) | 2.89 (1.75–4.75) | 3.40 (1.57–7.34) |

* OR adjusted for age and additionally for WHR/BMI.

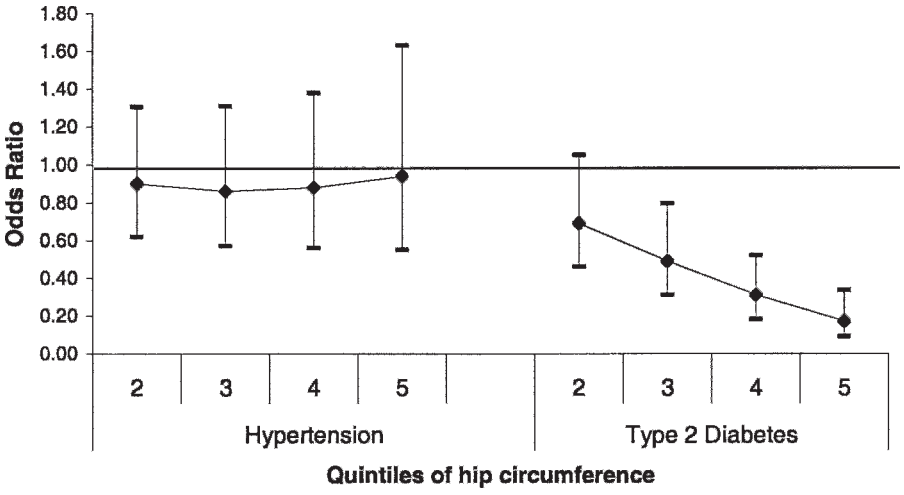


**Fig 1. Adjusted odds ratio (adjusted for age, body mass index and waist circumference) for hypertension and type 2 diabetes mellitus with quintiles of hip circumference in the study population in industrial units, Chennai, India, 2003–2005. (*n*=2148)**

*Our study has shown, that among commonly used anthropometric indices, WHR was the best predictor for type 2 diabetes in a sample of industrial workers in South India.*

workers in South India. Both BMI and WC were good predictors for hypertension. Our results were consistent across various statistical methods, such as the age adjusted partial correlations, logistic regression, and ROC analyses.

To our knowledge, this is the first study that has compared four anthropometric indices to predict hypertension and diabetes in an industrial population of Asian Indians. Our focus was to compare various indices in terms of their ability to predict hypertension or diabetes. Previous studies from India have focused on identifying appropriate risk threshold levels for diabetes or hypertension, using either ROC curve analysis or arbitrary cutoffs of anthropometric indices.[14,16,17] We used a standardized method of comparison rather than the conventionally used arbitrary cutoff points for obesity[8] because the age-adjusted partial correlations for all the anthropometric indices with systolic blood pressure, diastolic blood pressure, and fasting plasma glucose were highly significant. As it was difficult to identify true differences between various indices in their ability to identify individuals at cardiovascular risk, we used a quintile classification of anthropometric indices.

BMI and WC were significantly associated with hypertension in our study. This was consistent with a recent study in the Indian rural population, in which both BMI and WC had a strong correlation with systolic and diastolic

blood pressure.[14] However, among British adults, the prevalence of elevated BP was associated with quintiles of all four anthropometric indices.[23] WHR, an index of central obesity consistently emerged as the best predictor for type 2 diabetes. Our results were consistent with the fact that high prevalence of type 2 diabetes and insulin resistance in South Asians are associated with central obesity.[24,25] Previous studies among Indians have shown an association of diabetes with indices of central obesity,[16,25] but none have compared all four anthropometric indices in same population; therefore, comparison of the results to the results of our study is not possible. However, our findings are consistent with studies done in other ethnic groups.[8,10] In Australian adults, WHR has been recommended as the most useful measure of obesity to identify individuals with cardiovascular disease risk factors in clinical settings.[8] In addition, WHR has also been found to be good predictor of coronary heart disease. In the Interheart study, a case-control study involving participants from 52 countries representing nine different ethnic groups, WHR showed a graded and highly significant association with myocardial infarction risk.[7]

The best anthropometric index for predicting type 2 diabetes may vary in ethnic groups.[5] Contrary to our study, among Australian aborigines, WC was the best predictor of diabetes.[9] These variable results may be due to different body morphology and body composition in different ethnic groups. An increased WHR may result from increased visceral fat or reduced leg muscle.[26] Hence, the association between high WHR and diabetes may not be only due to large waist but also narrow hip circumferences.[27] A previous study showed that Indian men had less leg muscle mass as compared to Swedish men, and it was associated with increased fasting glucose levels.[28] In addition, there is evidence that large hips might be associated with lower glucose levels and lower prevalence of diabetes in several ethnic groups, including Indians from Mauritius.[29,30,31] In our population, we observed an inverse relation between hip circumference and diabetes, which suggested a probable protective effect of large hips that needs to be explored further.

Our findings, though potentially not representative of the general population, are still relevant as there are no nationally representative data available for India. However, the results need to be interpreted with caution, as cross-sectional study design has inherent biases. Another limitation was a study sample that consisted of urban males from middle- and higher-income groups working in an industrial setting and hence is not representative of the demographic of the general urban population.

We conclude that WHR is the best predictor of type 2 diabetes in this population and therefore should be routinely used in a clinical setting in addition to BMI for detecting high-risk groups. BMI continues to be a useful index for predicting hypertension. Prospective studies with long-term followup need to be conducted to provide stronger evidence for relationships between measures of obesity, body fat distribution, and the risk of hypertension and diabetes among Asian Indians.

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## AUTHOR CONTRIBUTIONS

*Design concept of study:* Kaur, Sankarasubbaiyan Kondalsamy-Chennakesavan, Venkata Rao, Digamber Gupte

*Acquisition of data:* Kaur, Venkata Rao

*Data analysis and interpretation:* Kaur, Radhakrishnan, Ramachandra Rao

*Manuscript draft:* Kaur, Radhakrishnan, Sankarasubbaiyan, Ramachandra Rao, Kondalsamy-Chennakesavan, Digamber Gupte

*Statistical expertise:* Radhakrishnan, Ramachandra Rao, Kondalsamy-Chennakesavan

*Acquisition of funding:* Kaur, Sankarasubbaiyan, Digamber Gupte

*Administrative, technical, or material assistance:* Kaur, Sankarasubbaiyan, Venkata Rao, Digamber Gupte

*Supervision:* Kaur, Radhakrishnan, Venkata Rao