Utility of anthropometric traits and indices in predicting the risk of coronary artery disease in the adult men of southern Andhra Pradesh

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1. Background

Cardiovascular diseases (CVDs), which include diseases of heart and blood vessels, account for 31.5% of all the deaths globally and 80% of those were observed in low- and middle-income countries.1 Higher incidence of age-standardized CVD deaths in Indians than the global average and earlier onset, higher case fatality, and higher proportion of CVD deaths among the Indians than Europeans were observed. Among CVDs, coronary artery disease (CAD) is a predominant cause of mortality in India. The risk factors for CAD include smoking, obesity, hypertension, type 2 diabetes, dyslipidemia, and physical inactivity.2 It was observed that 50% of patients with CAD have no conventional risk factors3 that are stated previously, and the search for novel risk factors that may better explain the disease is in progress.

Anthropometry has been universally used because it is a less resource-intensive and non-invasive technique to determine the size, proportions, and composition of the body. The variables such as body mass index (BMI), waist circumference, and waist-height ratio (WHtR) were found to increase the risk of CAD.4-6 Phenotype of an individual depends on acculturation, dietary habits, socioeconomic status, physical activity, and geographic location.10 In resource-poor countries, targeting high-risk people for preventive measures is likely to reduce both the economic and disease burden. High-risk groups can be identified by using anthropometric measurements, but cutoff values vary with country, population, and ethnic group.11 Finding population-specific cutoff values for anthropometric variables is therefore useful for research and clinical practice.12 Rising prevalence of obesity and improved

[Full text continues with more details on methods, results, and conclusions related to the study.]
nutritional status has also made it necessary to revise cutoffs of anthropometric indices. Very few studies were conducted to determine the cutoff values of a few anthropometric variables for assessing the risk of CAD, and the use of other anthropometric variables are yet to be assessed. In view of the foregoing examples, in a case control study, we attempt to assess the use of a set of 52 anthropometric variables in the risk prediction of CAD.

2. Materials and methods

One hundred and sixty-five CAD patients admitted to the intensive care unit of department of Cardiology, Sri Venkateswara Institute of Medical Sciences, Tirupati, Andhra Pradesh, were recruited for this study. CAD was diagnosed based on the electrocardiogram changes, increased levels of creatine kinase, and coronary angiogram. Gender-matched controls \( n = 87 \) were drawn from patient attendants and hospital staff who have no evidence of CAD. This study was carried out in accordance with the Code of Ethics of the World Medical Association. Before initiating the study, objectives were explained to the subjects, and their consent was obtained before taking measurements. All the anthropometric measurements were taken when the patients were shifted to the intermediate coronary care units. Anthropometric measurements were performed following the protocol mentioned by Singh and Bhasin. Anthropometric measurements were made with the help of anthropometer, measuring machine, tape, and Lange skinfold caliper. BMI, waist-hip ratio (WHR), waist-arm ratio (WAR), waist-thigh ratio (WTR) and arm-thigh ratio (ATR) were calculated. Sum of three (TSF3) and six skinfold thickness (SF6), total extremity ratio (TE), relative fat pattern index (RFPI), sum of four skinfold thickness (sft), subscapular/triceps ratio, sum of subscapular/suprailiac sft (mm), sum of biceps/triceps sft (mm), percent of body fat (%BF), total abdominal fat (TAF), intraabdominal adipose tissue (IAAT), subcutaneous abdominal adipose tissue (SCAT), body fat index (BFI), abdominal volume index (AVI), concinity index (CI), lean body mass (LBM), lean body mass index (LBMI), fat mass (FM), and fat mass index were calculated following earlier studies.12–20 Data on age, family history of CAD, smoking, and alcohol intake were inquired from both the cases and controls. Individuals with blood pressure > 140/90 mmHg or a previously documented history of hypertension, type 2 diabetes mellitus, smoking, alcoholism, high waist circumference, central obesity, IAAT (\( p < 0.000 \)), high TAF (\( p = 0.01 \)), and high %BF (\( p = 0.04 \)) were observed in CAD patients than those in controls (Table 1). Significantly higher mean values of age; circumferences of shoulder, chest, and waist; WHR; abdominal circumference; WAR; wrist, midaxillary and suprapatellar sft; CI; WHTR; AVI; IAAT; RFPI; %BF (all \( p \) values < 0.01); thigh circumference (\( p = 0.01 \)); minimal neck circumference (\( p = 0.02 \)); ATR; forearm circumference (\( p = 0.03 \)); and TAF (\( p = 0.04 \)) were observed in CAD than those in healthy controls. In case of controls, significantly higher mean values of thigh sft, BFI, foot circumference (\( p = 0.00 \)), and calf sft (\( p = 0.03 \)) were observed than those in CAD patients (Table 2).

The relative prevalence of conventional CAD risk factors in the cases and controls is given in Table 1, and mean values for different anthropometric measurements are presented in Table 2 (only for those who show significant mean difference); the remaining ones are presented in Supplementary Table S1. Significantly higher prevalence of hypertension, type 2 diabetes mellitus, smoking, alcoholism, high waist circumference, central obesity, IAAT (\( p = 0.000 \)), high TAF (\( p = 0.01 \)), and high %BF (\( p = 0.04 \)) were observed in CAD patients than those in controls (Table 1). Significantly higher mean values of age; circumferences of shoulder, chest, and waist; WHR; abdominal circumference; WAR; wrist, midaxillary and suprapatellar sft; CI; WHTR; AVI; IAAT; RFPI; %BF (all \( p \) values < 0.01); thigh circumference (\( p = 0.01 \)); minimal neck circumference (\( p = 0.02 \)); ATR; forearm circumference (\( p = 0.03 \)); and TAF (\( p = 0.04 \)) were observed in CAD than those in healthy controls. In case of controls, significantly higher mean values of thigh sft, BFI, foot circumference (\( p = 0.00 \)), and calf sft (\( p = 0.03 \)) were observed than those in CAD patients (Table 2).

The cutoff values of anthropometric parameters determined in terms of AUC are shown in Table 4 (cutoff values of 18 variables are given in Table 2 and the remaining in Table S2), and the corresponding receiver operating characteristic (ROC) curves are shown in Fig. 1 (ROC of only 18 variables that showed AUC > 0.6 are given.

### Table 1

Prevalence of coronary risk factors in male CAD patients and male controls.

| Variable                  | CAD patients \( n = 165 \) | Controls \( n = 87 \) | value |
|--------------------------|-----------------------------|------------------------|-------|
| Hypertension 42 (25.45)  | 67 (40.60)                  | 1 (1.14)               | 0.0   |
| Type 2 diabetes 42 (25.45) | 42 (25.45)                  | 1 (1.14)               | 0.0   |
| Smoking 55 (32.12)       | 53 (32.12)                  | 1 (1.14)               | 0.0   |
| Alcoholism 29 (17.57)    | 29 (17.57)                  | 1 (1.14)               | 0.0   |
| Family history of CAD 14 (8.48) | 14 (8.48)                  | 1 (1.14)               | 0.0   |
| Obesity (BMI > 25 kg/m²) | 65 (39.39)                  | 1 (1.14)               | 0.0   |
| Waist circumference (cm2) | 72 (43.63)                  | 1 (1.14)               | 0.0   |
| Central obesity (WHR > 0.9 men; >0.8 women) | 94 (56.96)                  | 1 (1.14)               | 0.0   |
| % Body fat (% >25.5 men; >38 women) | 71 (43.63)                  | 1 (1.14)               | 0.0   |
| Total abdominal fat (cm2) | 89 (53.93)                  | 1 (1.14)               | 0.0   |
| Intraabdominal adipose (cm2) | 51 (30.90)                  | 1 (1.14)               | 0.0   |
| Subcutaneous abdominal adipose tissue (cm2) | 108 (65.45)                  | 1 (1.14)               | 0.0   |

CAD, coronary artery disease; kg, kilogram; m, meter; WHR, waist-hip ratio; cm, centimeter.
Cutoff values of anthropometric variables for CAD (AUC value ≥ 0.60).

| Variable                          | Cutoff value | AUC       | 95% CI, significance level | Sen    | Spe    | PPV   | NPV   |
|-----------------------------------|--------------|-----------|-----------------------------|--------|--------|-------|-------|
| Shoulder circumference (cm)       | >106         | 0.684     | 0.62–0.74, 0.0001           | 55.49  | 76.74  | 14.9  | 95.9  |
| Chest circumference (cm)          | >86          | 0.637     | 0.57–0.69, 0.0002           | 79.27  | 47.67  | 10    | 96.9  |
| Waist circumference (cm)          | >85          | 0.684     | 0.62–0.74, 0.0001           | 59.76  | 73.26  | 14.1  | 96.1  |
| Waist-height ratio                | >0.87        | 0.720     | 0.66–0.77, 0.0007           | 77.91  | 58.14  | 12.1  | 97.3  |
| Abdominal circumference (cm)      | >91          | 0.700     | 0.63–0.75, 0.0005           | 62.20  | 72.09  | 14.1  | 96.3  |
| Waist-arm ratio                   | >3.2         | 0.673     | 0.61–0.73, 0.0003           | 50     | 81.40  | 16.5  | 95.7  |
| Wrists circumference (cm)         | >19          | 0.635     | 0.57–0.69, 0.0002           | 53.70  | 63.95  | 9.9   | 94.9  |
| Foot circumference (cm)           | >58          | 0.673     | 0.61–0.73, 0.0001           | 59.26  | 74.42  | 14.6  | 96.1  |
| Midaxillary skinfold thicknesses (mm) | >15       | 0.646     | 0.58–0.70, 0.0001           | 37.80  | 89.53  | 21    | 95.1  |
| Thigh skinfold thickness (mm)     | ≤20          | 0.610     | 0.54–0.67, 0.0041           | 77.44  | 39.53  | 8.6   | 96.0  |
| Suprapatellar skinfold thickness (mm) | >9           | 0.799     | 0.74–0.84, 0.0001           | 84.76  | 62.79  | 14.4  | 98.2  |
| Relative fat pattern index        | >0.5         | 0.623     | 0.56–0.68, 0.0004           | 38.79  | 86.05  | 17    | 95.0  |
| Body fat index                    | >11.31       | 0.673     | 0.55–0.68, 0.0006           | 43.64  | 81.40  | 14.7  | 95.1  |
| Conicity index                    | >1.22        | 0.720     | 0.66–0.77, 0.0001           | 71.52  | 73.26  | 16.5  | 97.2  |
| Waist-height ratio                | >0.52        | 0.695     | 0.63–0.75, 0.0001           | 56.76  | 79.11  | 15.8  | 96.0  |
| Abdominal volume index (Liters)   | >14.59       | 0.677     | 0.61–0.73, 0.0001           | 59.39  | 73.26  | 14.1  | 96.1  |
| % Body fat                        | >26.27       | 0.626     | 0.56–0.68, 0.0004           | 48.48  | 76.74  | 13.3  | 95.3  |
| Intra abdominal adipose tissue (cm²) | >105.29     | 0.649     | 0.58–0.70, 0.0001           | 55.49  | 70.93  | 12.3  | 95.6  |

Sen, sensitivity; Spe, specificity; PPV, positive predictive value; NPV, negative predictive value; CAD, coronary artery disease; AUC, area under curve; CI, confidence interval; cm, centimeter; mm, millimeter.

4. Discussion

Earlier studies have observed significantly higher mean of weight, waist and hip circumference, WHR, WHR, BMI, %BF, and visceral fat in CAD patients than those in controls.23–26 Besides some of the aforementioned parameters, we observed significantly higher mean values for the number of new variables—such as shoulder, chest, waist, abdominal, wrist (p < 0.01), minimal neck,
Fig. 1. Receiver operator characteristic curves for circumference and skinfold thickness that showed AUC ≥ 0.6. Cir, circumference; WHR, waist-hip ratio; WAR, waist-arm ratio; RFPI, relative fat pattern index.
and thigh circumference ($p < 0.05$); WHR ($p < 0.01$); ATR ($p < 0.05$); FM; CI; WHTR; AVI; %BF; IAAT ($p < 0.01$); and TAF ($p < 0.05$)—for CAD patients, suggesting probably the role of these new variables in the manifestation of CAD. Given relatively small sample of females, we did not consider them for this study.

Screening of asymptomatic individuals of CAD in appropriate age groups enables early detection, risk estimation, to initiate management strategies, and to arrest disease progression. At the same time, there is search for novel risk factors that can better explain the disease and can be easily measured, inexpensive, non-invasive and affordable in resource-poor settings. Anthro-

pometry has been in use for identifying high-risk group based on its optimal cutoff values, which are population specific and influenced by lifestyle changes involving diet, physical activity, geography, social and cultural factors.

We initiated this study in view of the limitations associated with presently used anthropometric parameters such as BMI, waist circumference (WC), WHR, CI, and the absence of population-specific cutoff values of these parameters for predicting the risk of CAD among the Indians. We used ROC curve to assess the ability of anthropometric variables in predicting the risk of CAD and found 18 anthropometric variables, viz., thigh sft, BFI, RFPI, %BF, wrist circumference, chest circumference, midaxillary sft, IAAT, foot circumference, WAR, AVI, waist and shoulder circumference, WHTR, abdominal circumference, WHR, CI, and suprapatellar sft to show AUC in the range of 0.61–0.72, suggesting their predictive value. To the best of our knowledge, this is the first study to show the cutoff values for predicting the risk of CAD in any Indian population for the known anthropometric parameters such as BMI, WC, WHR, and WHTR and for the many other earlier unused anthropometric parameters. Cutoff value is defined based on the risk association with the disease. BMI showed low ability in predicting the risk of CAD in the present study as shown by AUC of 0.515. The cutoff value was estimated to be $>26.35$ kg/m$^2$ in our study. An optimal cutoff value was observed to be 22.7 kg/m$^2$ and 26.95 kg/m$^2$ in Korean and Iranian men, respectively. The optimal cutoff value of WC for CAD risk in Korean and Iranian men were 83.2 cm and 94.5 cm, respectively. WC is included as one of the components for defining metabolic syndrome (MS). Cutoff values given for defining MS as per European group for study of insulin resistance, National Cholesterol Education Programme adult panel III, and International Diabetes Federation (IDF) for men were $>94$, $>102$, and $>94$, respectively, and $>90$ cm for Asians. In the present study, we have measured WC at the most lateral contour of the body between the ribs and intestine. The AUC of 0.684 obtained is a fair discriminator for the risk of CAD, and the obtained cutoff value is $>85$ cm and similar to that reported in the study by Snehalatha et al. AUC of 0.75–0.82 was reported for WHR for predicting the risk of CAD in all ethnic groups. The World Health Organization included WHR as a component for the defining MS using the cutoff value of 0.9 in men. In the Iranian men, the cutoff value for predicting the risk of CAD was reported as 0.95.
A cutoff value of WHR > 0.5 was shown to increase the risk of CAD in 78 studies. A cutoff value of 0.5 in Korean men and 0.55 in Iranian men was observed for predicting the risk of CAD. In our study, a cutoff value of >0.52 for WHR with AUC of 0.695 was observed. This cutoff value is similar to the earlier studies. A cutoff value of 16.48 L in Indian railway men employees was observed for AVI. In our study, the cutoff value was found to be >14.59 L with a corresponding AUC of 0.677. A cutoff value of 25.5 for %BF was proposed for prediction of coronary risk factors in Asian men. In the present study, we found a cutoff value of >26.27 for %BF with AUC of 0.626. A cutoff value of 15.1 kg was reported for FM in Asian men. We observed a cutoff value of 245.6 cm², 210.23 cm², 78.4 cm², and 105.29 cm² for TAF, IAAT, and SCAT in Asian men. In the present study, the cutoff values of >274.58 cm² (AUC: 0.577 cm²), >105.29 cm² (AUC: 0.649 cm²), and >191.5 cm² (AUC: 0.53 cm²) for TAF, IAAT, and SCAT in predicting the risk of CAD were observed.

Information on the cutoff values of CI is not available for adults. In the present study, the cutoff value for CI is >1.22 with AUC of 0.720. WC, WHR, WHtR, CI, %BF, TAF, IAAT, SCAT, neck circumference, and AVI are parameters used to assess the central obesity. In the present study, WHR and CI showed AUC of 0.72. Followed by WHtR (0.685), WC (0.684), AVI (0.677), IAAT (0.649), %BF (0.626), minimal neck circumference (0.587), TAF (0.577), and SCAT (0.530). Comparison of AUC of central obesity parameters suggests that WHR, CI, WHtR, WC, AVI, %BF, and IAAT are better predictors of central obesity than SCAT, TAF, and neck circumference.

Comparison of the AUC of the six central obesity measures—WHR, CI, WHtR, WC, AVI, and IAAT—suggests statistically significant difference between WHR and IAAT (p = 0.01), between CI and IAAT (p = 0.05), and between WC and AVI (p = 0.02). IAAT and SCAT were found to be associated with adverse cardiometabolic risk factors. In view of higher mass of SCAT, it was shown to affect metabolic factors. In our study, IAAT was found to have higher ability of predicting the risk of CAD (AUC = 0.649) than SCAT (AUC = 0.530). The foregoing discussion demonstrates that cutoff values vary with population for predicting the risk of CAD and also suggest the need of establishing population-specific cutoff values.

Owing to the collinearity associated with anthropometric variables, we performed discriminant analysis and found that nine out of the 52 variables discriminate cases and controls, correctly classifying 87.4% of the subjects into the respective groups. Examination of AUC of these variables showed that only six variables such as shoulder, abdominal, and foot circumferences; WHR; and thigh and supratellar sft showed >0.6, and the remaining three variables BMI, calf sft, and sum of subscapular/suprailiac sft ratio showed AUC ranging between 0.5 and 0.6. Based on our observations, we propose that six anthropometric variables such as shoulder, abdominal, and foot circumferences; WHR; and thigh and supratellar sft are significant predictors of CAD with fair predictive ability as shown by AUC value of 0.610–0.799.

4.1. Limitations

There are number of limitations however. The present study is based only on male samples, and hence, the results cannot be extrapolated to the female gender. Even though cutoff values vary with age and coronary risk factors, we have not evaluated age and coronary risk factor—specific cutoff values due to small sample size. For calculating body fat, sum of sfts is used, and it has limitations because of interindividual differences in subcutaneous body fat pattern and variations in intraabdominal fat. Percentage of body fat, TAF, IAAT, and SCAT were calculated using predictive equations and not by imaging tools. Direct methods for assessing FM are better, but they are cost-intensive, available in only few centers, carry the risk of radiation, and not useful in field settings. Anthropometry is still a widely used method for epidemiological studies, albeit interpretation of cutoff values obtained should be done with caution. It is also necessary that the cutoffs are established based on large-scale cross-sectional as well as longitudinal studies.

5. Conclusions

Eighteen anthropometric variables such as thigh sft, BFI, RFPI, %BF, wrist circumference, chest circumference, midaxillary sft, IAAT, foot circumference, WAR, AVI, waist and shoulder circumference, WHR, abdominal circumference, WHR, CI, and supratellar sft showed AUC ranging from 0.61 to 0.72, suggesting use of these variables in predicting the risk of CAD. However, both stepwise LR analysis and discriminant analyses suggest that a relatively much smaller set of these variable can be more efficiently used in predicting the disease.

Optimal cutoff values determined in the study can be used to screen young and middle-aged asymptomatic men who can be benefitted due to preventive strategies against the lifestyle diseases. The optimal cutoff values should not be used as test in predicting the disease in clinics and for stratifying individual into risk categories. Establishment of optimal cutoff values depends on the study design, geographic area, study population, age of the participant, and expected outcome. Anthropometric variables are surrogate measures of body fat and have limited use in guiding treatment modalities in individual patients. Framingham score, which is used to predict the future risk of CAD, does not contain any anthropometric variable as its component. Nevertheless, the AUC of most of the anthropometric variables used for prediction of the risk of coronary risk factors ranged from 0.60 to 0.70, which is similar to the range of AUC of 18 variables obtained in the present study (0.61–0.72).

Conflicts of interest

All authors have none to declare.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ijhj.2018.07.016.

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