ORIGINAL ARTICLE

# OPTIMAL CENTRAL OBESITY MEASUREMENT SITE FOR ASSESSING CARDIOMETABOLIC AND TYPE 2 DIABETES RISK IN ADULTS

Fareeda Tabassum[1], Ifat Ara Begum[2], Sadia Tasnim Munmun[3], Manashe Chanda[4], Hasina Begum[5], Manindra Nath Roy[6]

[1]*Department of Biochemistry, Sir Salimullah Medical College, Dhaka*

[2]*Department of Biochemistry, Sir Salimullah Medical College, Dhaka*

[3]*Department of Biochemistry, Sir Salimullah Medical College, Dhaka*

[4]*Department of Biochemistry, Sheikh Hasina Medical College, Tangail*

[5]*Department of Laboratory Medicine, BRB Hospital, Dhaka*

[6]*Department of Biochemistry, United Medical College, Dhaka*

## ABSTRACT

Numerous anthropometric indices can be used to evaluate obesity, which have been linked to type 2 diabetes mellitus (T2DM) and cardiometabolic risk. While the National Institutes of Health (NIH) advocated measuring waist circumference (WC) at the superior border of the iliac crest as the preferable method for central obesity assessment, the World Health Organization (WHO) and International Diabetes Federation (IDF) both recommended WC midway. Consequently, the purpose of this study was to assess the predictive power of WC rib measurements for adult T2DM and cardiometabolic risk. A cross-sectional analytical study was conducted during the period of March 2019 to February 2020 at the Department of Biochemistry, Sir Salimullah Medical College, Dhaka, Bangladesh. On fulfilment of the inclusion and exclusion criteria, 125 subjects were enrolled through purposive sampling, and their anthropometric measurements were obtained. After blood collection at fasting condition, high-density lipoprotein cholesterol, serum insulin, triglycerides, and plasma glucose levels were measured. The findings demonstrated that male study participants had greater mean values for weight, height, WC rib, systolic and diastolic blood pressure than female participants. The study showed that compared to female participants, the male subjects showed an aberrant lipid profile and male subjects had a considerably higher prevalence of T2DM and three or more cardiometabolic risks. Additionally, we also observed significant and positive correlation for TG, SBP, DBP, FPG and HOMA-IR with BMI, WC midway, WC rib, hip circumference and pelvic width in both genders. Odds ratio of having 3 or more cardiometabolic risks showed the odds was highest for WC rib and rib derived indices in both genders. In addition, according to ROC analysis, WC rib (AUC=0.716) and rib-derived indices demonstrated considerably greater AUC to identify three or more cardiometabolic risks in male patients. However, WC rib did not provide a greater AUC than WC midway in the case of females. For T2DM, WC rib demonstrated a considerably greater AUC in both genders (AUC=0.68 in male and 0.71 in female).

**Key words:** T2DM, Cardiometabolic risk, WC, TG, FPG

Bangladesh J Med Biochem 2020; 13(2): 31-39

## Introduction

Premature death may result from obesity and its related comorbidities which include dyslipidemia, hypertension, insulin resistance, the onset of metabolic syndrome (Mets) and type 2 diabetes[1]. Body mass index (BMI) is the most often used metric for evaluating obesity. The World Health Organization (WHO) classified Asian populations with BMI between 23 and 27 kg/m$^2$ as overweight and those with BMI exceeding 27.5 kg/m$^2$ as obese[2]. The benefit of BMI is that measuring a subject's height and weight is simple and affordable. However, because BMI is a weight-for-height measurement, it cannot differentiate between fat and lean mass[3]. Research indicates that central obesity is a significant cardiometabolic risk factor. Waist circumference (WC) measurement is the preferred approach for assessing central obesity[4,5]. The WC measurement has been adopted by the International Diabetes Federation (IDF) as a key element in the diagnosis of MetS. According to Millar et al[6], the IDF criteria for weight control vary by nation, with the cut-off value for overweight >90 cm for males and >80 cm for females in Asia. NCEP-ATP III recommended a threshold value of 102 cm for males and 88 cm for women when diagnosing MetS.

Numerous diagnostic methods, including WC and BMI, have been used in diabetes preventive programs because the glucose test is intrusive, somewhat costly, and difficult to employ for mass screening programs[7,8]. WC can be measured at two distinct locations: (i) between the iliac crest and the lowest rib (WC midway) and (ii) immediately below the lowest rib at the mid-axillary line (WC rib)[9,10]. Since WC rib is unaffected by body posture and belly elasticity, it is a superior measure of central obesity than WC midway[6]. For use in clinical practice, there is a growing need for low-cost, non-invasive techniques to identify obese individuals. There are no reports of such studies conducted in our country in the last several years. Thus, the purpose of this study was to evaluate better anthropometric measurement site for the assessment of T2DM and cardiometabolic risk.

## Materials and Methods

This cross-sectional analytical investigation was carried out in the Department of Biochemistry of Sir Salimullah Medical College (SSMC) in Dhaka, Bangladesh between March 2019 and February 2020. One hundred twenty five men and women between 30 to 59 years who appeared to be in good health participated in the study. Participants with diabetes mellitus, long-term liver illness, kidney disease, lung disease, cancer, pregnancy, smoking, and chronic alcoholism were excluded.

## Procedure

The outpatient departments of Mitford Hospital of Sir Salimullah Medical College, Dhaka and the departments of medicine and endocrinology of Sir Salimullah Medical College were the sources of the subjects. The Ethical Review Committee of Sir Salimullah Medical College gave ethical approval. Following appropriate counselling, each participant received a detailed explanation of the purpose of the study, risks, and methodology. Candidates were only sought out voluntarily to participate in the study. Consent was obtained in writing after being informed. Along with other pertinent data, sociodemographic information were gathered and entered into a data collection sheet using a pre-attached questionnaire. Six variables were generated using anthropometric measurements: i) height to midway ratio, ii) hip to midway ratio, iii) pelvis to midway ratio, iv) height to rib ratio, v) hip to rib ratio, vi) ratio of ribs to pelvis[11]. A manual sphygmomanometer was used to measure blood pressure. Six ml of fasting blood was drawn from each participant.

At the Biochemistry Laboratory at SSMC fasting plasma glucose, serum triglycerides, and HDL-C were measured properly. Serum insulin was measured in the Department of Biochemistry and Molecular Biology of Bangabandhu Sheikh Mujib Medical University. At least three of the following characteristics were associated with a higher risk of cardiovascular disease: 1) High TG ≥1.7 mmol/L; 2) Low HDL <1.03 mmol/L in males; <1.29 mmol/L in females; 3) Impaired fasting glucose level 5.6–6.9 mmol/L; 4) High blood pressure measured as systolic BP ≥130 mm Hg or diastolic blood pressure measured at ≥85 mm Hg; 5) Insulin resistance measured as HOMA above 2.5. Every measurement was categorized using the NCEP-ATP III standards[11,12]. The characteristics of T2DM were FPG ≥126 mg/dL (≥7.0 mmol/L) or 2 hours PG ≥200 mg/dL (≥11.1 mmol/L) during OGTT or HbA1c >6.5% (48 mmol/mol) during OGTT[13].

SPSS version 26.0 was used to verify, modify, and analyze the collected data. Continuous data were shown as a mean (±SD) and categorical features as percentages. The independent t-test was used to assess gender differences. Using the Z test, the proportions between the two groups were compared. Partial correlations were used to examine the relationships between anthropometric measurements and cardiometabolic factors and T2DM. The odds ratio was used to evaluate the anthropometric factors' capacity for risk prediction. Through the use of receiver operating characteristic curve (ROC) analysis, the capacity of particular indices to distinguish between three or more cardiometabolic risk factors and type 2 diabetes was assessed. AUC, or area under the curve, was employed to assess an obesity index's ability to detect positive results. P was defined as statistically significant if it was less than 0.05.

## Results

There were total 125 subjects- 64 were men and 61 were women. of the total participants, 81(64.8%) were either overweight or obese meeting the BMI categorization for the Asian population. Table I shows that weight, WC rib and systolic BP were significantly higher in male. BMI and hip circumference were significantly higher in female. There is no significant difference in age, height, WC midway, pelvic width and diastolic BP between two groups.

**Table I:** Socio-demographic and anthropometric characteristics of study subjects (n=125)

| Features | Men (n=64) mean±SD | Women (n=61) mean±SD | p values |
|---|---|---|---|
| Age (years) | 43.34 ± 7.9 | 43.02 ± 9.1 | 0.111 |
| Weight (kg) | 67.81 ± 9.77 | 64.62 ± 8.5 | <0.01 |
| Height (m) | 1.64 ± 0.08 | 1.55 ± 0.06 | 0.127 |
| BMI (kg/m²) | 25.15 ± 3.38 | 26.93 ± 2.9 | <0.01 |
| WC midway (cm) | 97.89 ± 9.1 | 97.67 ± 8.5 | 0.115 |
| WC rib (cm) | 91.56 ± 8.1 | 89.67 ± 9.0 | <0.01 |
| Hip circumference (cm) | 101.97 ± 7.4 | 103.21 ± 6.2 | <0.01 |
| Pelvic width (cm) | 32.54 ± 1.7 | 32.57 ± 1.8 | 0.08 |
| Systolic BP (mm Hg) | 120.94 ± 10.3 | 117.54 ±12.8 | <0.01 |
| Diastolic BP (mm Hg) | 81.48 ± 8.7 | 80.41 ± 10.3 | 0.056 |

*p value was calculated with Student's t-test.*

Table II reveals that HDL, FPG, fasting insulin, and HOMA-IR are significantly higher in females whereas TG is significantly greater ($p<0.01$) in males.

Table III stated that the frequency of three or more cardiometabolic risks and T2DM were significantly higher in male than in females.

Table IV demonstrates that triglycerides, FPG, HOMA-IR, systolic and diastolic blood pressure are all significantly positively correlated with BMI, WC midway, WC rib, and pelvic width. There is a significant negative correlation between HDL-C and the anthropometric measurements. In both genders, the WC rib displayed the strongest correlative strength.

**Table II:** Biochemical parameters of study subjects (n=125)

| Features | Males (n=64) mean±SD | Females (n=61) mean±SD | P values |
|---|---|---|---|
| Triglycerides (mmol/L) | 1.87±0.5 | 1.75±0.4 | <0.01 |
| HDL-C (mmol/L) | 1.09 ±0.1 | 1.23 ± 0.1 | <0.01 |
| Fasting Plasma Glucose (mmol/L) | 5.69±1.3 | 5.85±1.4 | <0.01 |
| Fasting serum insulin (µU/mL) | 11.03±3.4 | 11.21±3.6 | <0.01 |
| HOMA-IR | 2.82±1.1 | 2.96±1.2 | <0.01 |

*p value was calculated with Student's t-test.*

**Table III:** Prevalence of cardiometabolic and type 2 diabetes risks in male and female study subjects (n=125)

| Features | Men (%) (n=64) | Women (%) (n=61) | p values |
|---|---|---|---|
| Three or more cardiometabolic risk features | 21.87 (n=14) | 19.67 (n=12) | <0.01 |
| Type 2 diabetes | 18.75 (n=12) | 14.75 (n=9) | <0.01 |

*p value was calculated with Z test.*

**Table IV:** Partial correlations between anthropometric measurements and cardiometabolic variables in male and female (adjusted for age)

| | | | BMI (p) | WC Midway (p) | WC Rib (p) | Hip circumference (p) | Pelvic width (p) |
|---|---|---|---|---|---|---|---|
| Triglyceride | M | r | 0.58 (<0.01) | 0.54 (<0.01) | 0.58 (<0.01) | 0.46 (<0.01) | 0.55 (<0.01) |
| | F | r | 0.46 (<0.01) | 0.51(<0.01) | 0.55 (<0.01) | 0.41 (<0.01) | 0.22 (0.08) |
| HDL-C | M | r | -0.72(<0.01) | -0.67(<0.01) | -0.66(<0.01) | -0.63(<0.01) | -0.61(<0.01) |
| | F | r | -0.57(<0.01) | -0.56(<0.01) | -0.53(<0.01) | -0.36(<0.01) | -0.46(<0.01) |
| Systolic BP | M | r | 0.55 (<0.01) | 0.58 (<0.01) | 0.62 (<0.01) | 0.54 (<0.01) | 0.44 (<0.01) |
| | F | r | 0.55 (<0.01) | 0.54 (<0.01) | 0.54 (<0.01) | 0.45 (<0.01) | 0.33 (<0.01) |
| Diastolic BP | M | r | 0.48 (<0.01) | 0.42 (<0.01) | 0.52 (<0.01) | 0.53 (<0.01) | 0.44 (<0.01) |
| | F | r | 0.54 (<0.01) | 0.51 (<0.01) | 0.53 (<0.01) | 0.45 (<0.01) | 0.31 (<0.01) |
| FPG | M | r | 0.69 (<0.01) | 0.67 (<0.01) | 0.71 (<0.01) | 0.57 (<0.01) | 0.63 (<0.01) |
| | F | r | 0.63 (<0.01) | 0.70 (<0.01) | 0.65 (<0.01) | 0.47 (<0.01) | 0.50 (<0.01) |
| HOMA-IR | M | r | 0.69 (<0.01) | 0.70 (<0.01) | 0.76 (<0.01) | 0.67 (<0.01) | 0.6 (<0.01) |
| | F | r | 0.71 (<0.01) | 0.72 (<0.01) | 0.80 (<0.01) | 0.55 (<0.01) | 0.59 (<0.01) |

From Fig 1 it is evident that WC rib and rib derived indices shows positive association with cardiometabolic risk in the study subjects. It also shows that the association is stronger in males than females. (All models exclude subjects with T2DM). Fig. 2 shows that rib/hip ratio followed by WC rib shows stronger association with T2DM in both genders. It also shows that WC rib and rib derived indices displayed stronger association with T2DM..

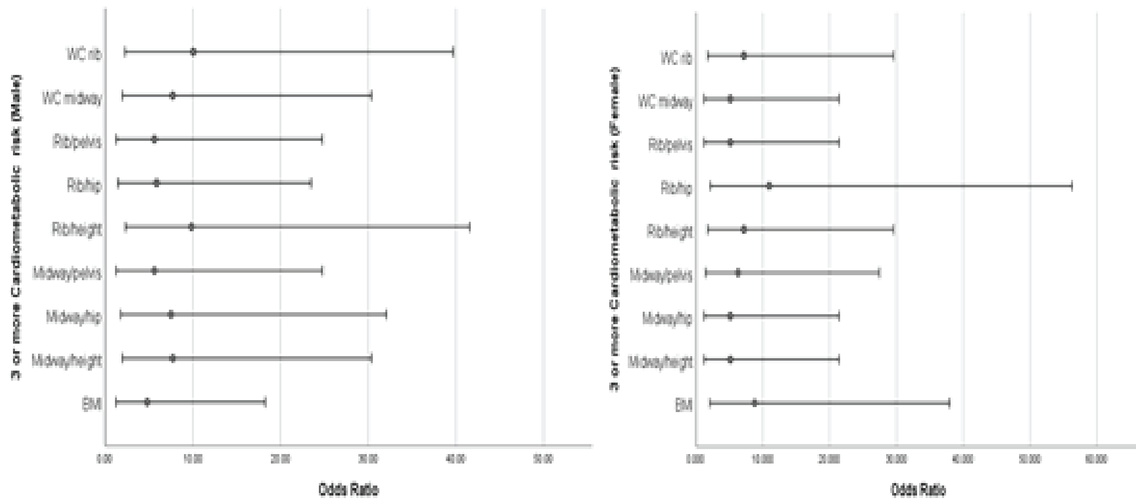


**Fig 1.** Odds ratio (95% CI) of having three or more cardiometabolic risk features for a one standard deviation increase in each obesity measure

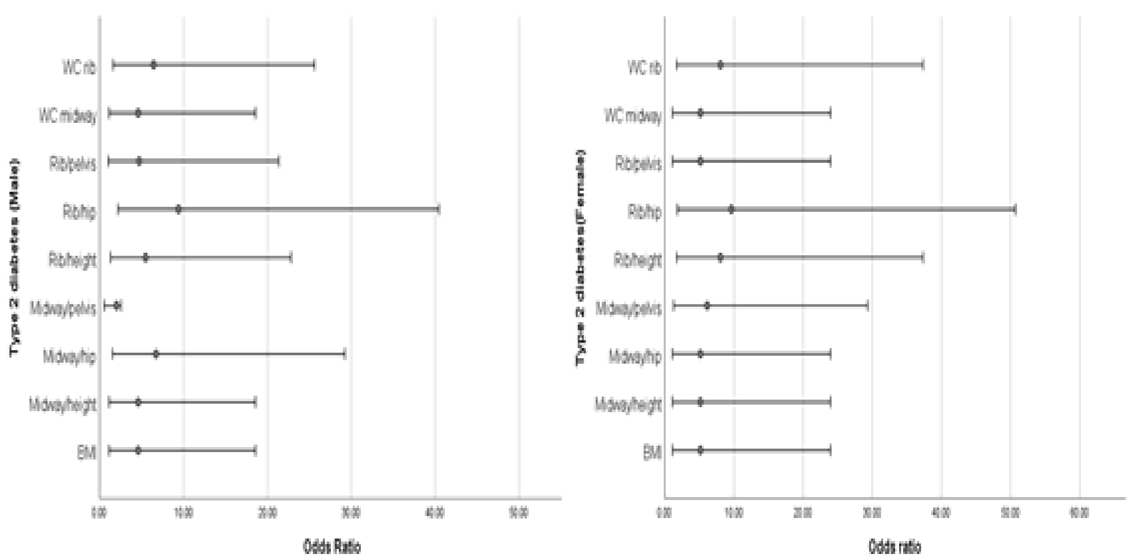


**Fig 2.** Odds ratio (95% CI) of having type 2 diabetes for a one standard deviation increase in each obesity measure.

Fig. 3 shows that, WC rib (AUC=0.716) and rib/height ratio (AUC=0.693) showed a higher AUC to detect 3 or more cardiometabolic risk features than WC midway (AUC=0.682) in male subjects. In female BMI (AUC=0.699) showed higher AUC followed by WC rib (AUC=0.689) and rib/height ratio (AUC=0.689) compared to WC midway (AUC=0.647).

In Figure 4, WC rib (AUC=0.683) and rib/hip ratio (AUC=0.702) shows much higher AUC than WC midway (AUC=0.641) to differentiate T2DM in male. In female both WC rib (AUC=0.710) and rib/height ratio (AUC=0.71) shows significantly higher AUC when compared to WC midway (AUC=0.655).

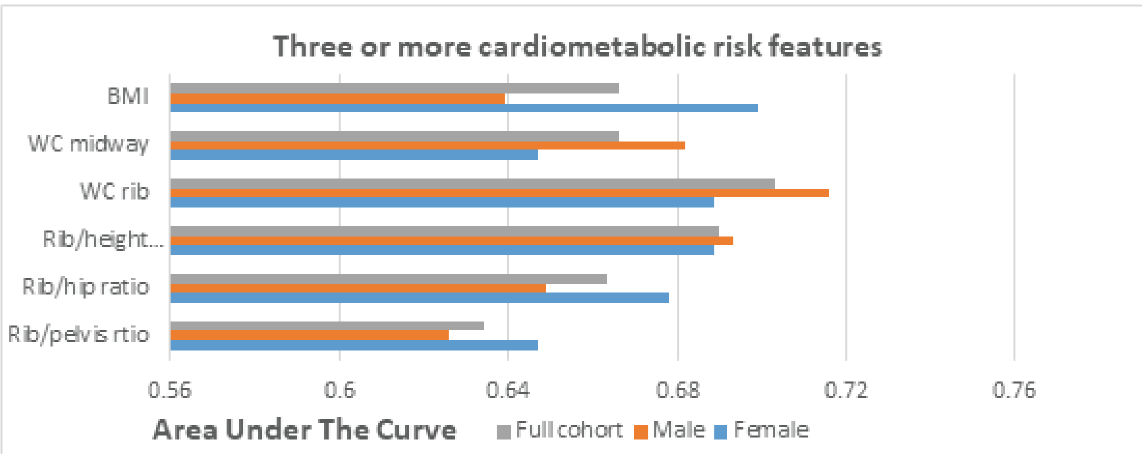


**Fig 3.** Adjusted area under the receiver operating characteristic (ROC) curve values for obesity measures to discriminate subjects with three or more cardiometabolic risk features

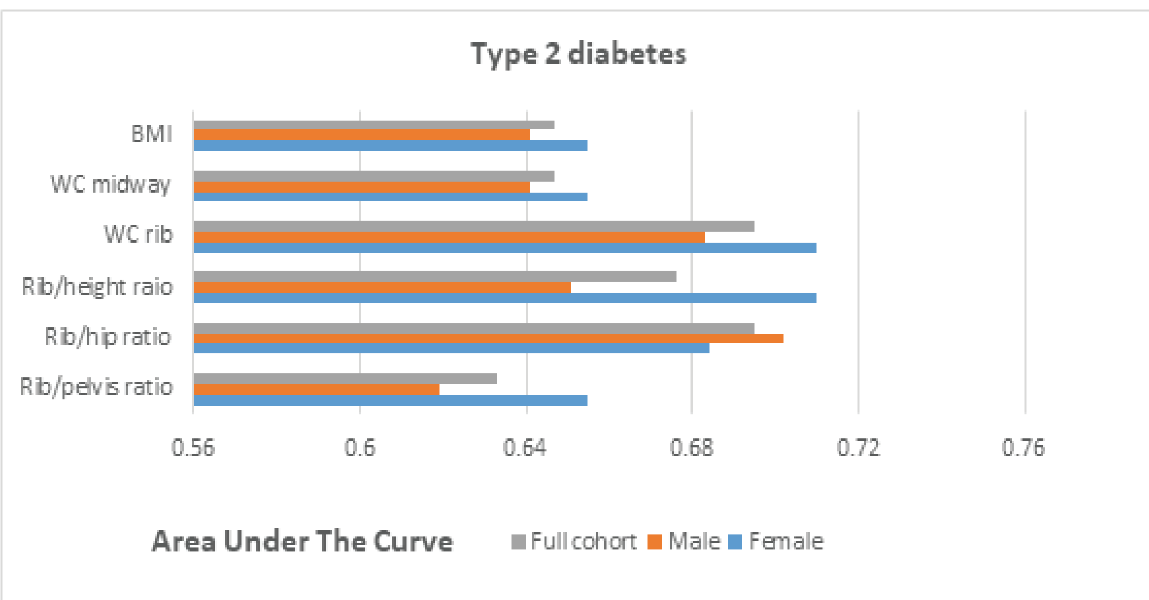


**Fig 4:** Adjusted area under the receiver operating characteristic (ROC) curve values for obesity measures to discriminate subjects with T2DM.

## Discussion

The study clearly shows that male study participants had greater mean values for weight, height, WC rib, systolic and diastolic blood pressure than female study subjects had. These findings aligned with research by Matsushita et al[14]. The increased BMI and hip circumference of female subjects may have resulted from the large number of overweight female study participants. Men had a considerably higher serum TG level and a lower HDL-C level than females-perhaps due to men's greater susceptibility to aberrant lipid profiles. In a study by Kim et al[15] similar results were noted.

Female study participants had greater levels of FPG, fasting serum insulin, and HOMA-IR than male participants. Insulin resistance and metabolic problems are more likely to occur in overweight females with a high visceral adipose tissue (VAT) composition[16]. These findings aligned with a study carried out by Guh et al[1].

Males had a greater prevalence of T2DM and three or more cardiometabolic risks than females. This difference may be attributed to males' increased vulnerability to cardiometabolic disorders despite Asian populations' generally low BMIs[2]. In a different investigation, Okorodudu et al[3] found similar observations.

Anthropometric indices showed a statistically significant positive correlation with TG, SBP, DBP, FPG, and HOMA-IR in both genders. There was a negative correlation found with HDL-C. Millar et al[11] and Bosy-Westphal et al[10] found comparable associations.

The likelihood of having three or more cardiometabolic risks were found highest in males with WC ribs and females with rib/hip ratios. Nevertheless, Millar et al[11] found that in both males and females, the WC rib had the highest correlation with cardiometabolic risk. The subjects with T2DM had the highest probabilities for both genders' rib/hip ratio, with WC rib coming in second. Bossy-Westphal et al[10] found that women were more strongly associated with WC rib with T2DM than men were. It might be caused by the WC rib's superiority as an index for estimating visceral adipose tissue in obese people.

It was clear from ROC curve research that male patients' AUC for WC rib was substantially higher (AUC=0.716). Both Ashwell et al[17] and Lin et al[18] found that WC and WC-derived indices were strong predictors of cardiovascular risk variables, as did a study involving 55,563 participants in Taiwan. In relation to T2DM, males' WC rib (AUC=0.68) demonstrated a considerably higher AUC, but females' WC rib (AUC=0.71) and rib/height ratio (AUC=0.71) demonstrated a significantly higher AUC. Additionally, according to a number of studies[17,19], the AUC for WC rib and rib derived ratios was much greater than that of other anthropometric parameters to predict T2DM. It was clear from the study that WC rib and rib derived indices have much higher diagnostic ability. WC and WC derived measures are more sensitive to diet and physical exercise than the BMI because an increase or decrease in muscle mass may have little effect on BMI but clear change is observed in WC and WC derived indices[19]. Wang et al[20] and Bossy-Westphal et al[10] likewise came to the conclusion that WC rib has a significantly stronger discriminating capacity.

According to our research, WC rib is a more accurate indicator of cardiometabolic risk and type 2 diabetes than WC midway or BMI. This link could have its origin in the fact that the measurement of rib level is less affected by the elasticity of the abdominal wall[11]. The findings of this study indicate that rib-level WC measurement, as opposed to WC midway measurement, is a more reliable indicator of cardiometabolic risk and type 2 diabetes.

## Limitations

The study was conducted in only one center and the sampling technique was purposive so there may be chance of bias. Sample size was small which could influence the level of statistical significance. Multiple confounding factors other than age was not adjusted in this study.

## Conclusion

WC rib and rib derived indices were more strongly related to cardiometabolic risk factors and T2DM. WC rib measures showed stronger association with cardiometabolic risk in male subjects but not in female but WC rib measures have much higher diagnostic accuracy to detect cardiometabolic risk and T2DM than WC midway in both sexes.

## References

1. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis. BMC Public Health 2009; 9(1): 88.

2. Nishida C, Barba C, Cavalli-Sforza T, Cutter J, Deurenberg P, Darnton-Hill I et al. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004; 363(9403): 157-163.

3. Okorodudu DO, Jumean MF, Montori VM, Romero-Corral A, Somers VK, Erwin PJ et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis. Int J Obes (Lond) 2010; 34(5): 791-799.

4. Arsenault B, Després J, Boekholdt M. Hypertriglyceridemic waist: missing piece of the global cardiovascular risk assessment puzzle? Clin Lipidol 2011; 6(6): 639-651.

5. Klein S, Allison DB, Heymsfield SB, Kelley DE, Leibel RL, Nonas C et al. Waist circumference and cardiometabolic risk: a consensus statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. Am J Clin Nutr 2007; 85(5): 1197-1202.

6. Millar SR, Perry IJ, Phillips CM. Surrogate Measures of Adiposity and Cardiometabolic Risk-Why the Uncertainty? A Review of Recent Meta-Analytic Studies 2013; 25-29.

7. Rolka DB, Venkat Narayan KM, Thompson TJ, Goldman D, Llndenmayer J, Alich K et al. Performance of recommended screening tests for undiagnosed diabetes and dysglycemia. Diabetes Care 2001; 24(11): 1899-1903.

8. Schulze MB, Hoffmann K, Boeing H, Linseisen J, Rohrmann S, Möhlig M et al. An Accurate Risk Score Based on Anthropometric, Dietary, and Lifestyle Factors to Predict the Development of Type 2 Diabetes. Diabetes Care 2007; 30(3): 510-515.

9. Huxley R, Mendis S, Zheleznyakov E, Reddy S, Chan J. Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk-a review of the literature. Eur J Clin Nutr 2010; 64(1): 16-22.

10. Bosy-Westphal A, Booke CA, Blöcker T, Kossel E, Goele K, Later W et al. Measurement Site for Waist Circumference Affects Its Accuracy As an Index of Visceral and Abdominal Subcutaneous Fat in a Caucasian Population. J Nutr 2010; 140(5): 954–961.

11. Millar SR, Perry IJ, Broeck J, Van den, Phillips CM. Optimal Central Obesity Measurement Site for Assessing Cardiometabolic and Type 2 Diabetes Risk in Middle-Aged Adults. PLoS One 2015; 10(6): e0129088.

12. Salgado ALFDA, De Carvalho L, Oliveira AC, Dos Santos VN, Vieira JG, Parise ER. Insulin resistance index (HOMA-IR) in the differentiation of patients with non-alcoholic fatty liver disease and healthy individuals. Arq Gastroenterol 2010; 47(2): 165-169.

13. Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes-2019. Diabetes Care 2019; 42(Supplement_1): S13-28.

14. Matsushita Y, Tomita K, Yokoyama T, Mizoue T. Relations Between Waist Circumference at Four Sites and Metabolic Risk Factors. Obesity 2010; 18(12): 2374-2378.

15. Kim H Il, Kim JT, Yu SH, Kwak SH, Jang HC, Park KS et al. Gender differences in diagnostic values of visceral fat area and waist circumference for predicting metabolic syndrome in Koreans. J Korean Med Sci 2011; 26(7): 906-913.

16. Kabir M, Catalano KJ, Ananthnarayan S, Kim SP, Van Citters GW, Dea MK et al. Molecular evidence supporting the portal theory: a causative link between visceral adiposity and hepatic insulin resistance. Am J Physiol Endocrinol Metab 2005; 288(2): E454-461.

17. Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. Obesity Reviews 2012; 13(3): 275-86.

18. Lin CC, Yu SC, Wu BJ, Chang DJ. Measurement of waist circumference at different sites affects the detection of abdominal obesity and metabolic syndrome among psychiatric patients. Psychiatry Res 2012; 197(3): 322-326.

19. Qiao Q, Nyamdorj R. Is the association of type II diabetes with waist circumference or waist-to-hip ratio stronger than that with body mass index? Eur J Clin Nutr 2010; 64(1): 30-34.

20. Wang J, Thornton JC, Bari S, Williamson B, Gallagher D, Heymsfield SB et al. Comparisons of waist circumferences measured at 4 sites. Am J Clin Nutr 2003; 77(2): 379-384.