Gender-wise variations in the Correlation between Anthropometric Indices and Cardiovascular Disease Risk Factors

Edavan Pulikkanath Praveen[a*], Jayaprakash Sahoo[b], Sunil Chouhan[c], Vinod V. Wali[a], Prakash Ghogale[d] , Arun Kumar[e] , Bindu Kulshreshtha[f]

[a]Department of Biochemistry, P.E.S. Institute of Medical Sciences and Research, Kuppam, Andhra Pradesh, India.

[b]Department of Endocrinology, Jawaharlal Institute of Postgraduate Medical Education & Research (JIPMER), Puducherry, India.

[c]Department of Physiology, All India Institute of Medical Sciences (AIIMS), Bhopal, India .

[d]Department of Medicine, Sindhudurg Shikshan Prasarak Mandal Medical College, Sindhudurg, India.

[e]Department of Biochemistry, Sindhudurg Shikshan Prasarak Mandal Medical College, Sindhudurg, India .

[f]Department of Endocrinology, Atal Bihari Vajpayee Institute of Medical Sciences (ABVIMS), New Delhi, India

Abstract

Background: Improved understanding of the gender-wise correlation of simple anthropometric indices with various cardiovascular risk factors will help in designing better disease prevention strategies.

Objectives: The study aimed to analyze the gender-wise correlation of body mass index (BMI), hip circumference (HC) waist circumference (WC), and waist-to-hip ratio (WHR) with insulin resistance, serum lipids, etc., in an adult Indian population.

Patients and methods: Adults with age 18 years and above (496 subjects) were studied. Anthropometric measurements were done in all. A standard (75g) oral glucose tolerance test was performed in all. Serum/plasma samples were assayed for lipid profile, glucose (fasting, 2-hour), and insulin.

Results: There were 192 (39%) females and 304 (61%) males. The mean age of males was 28.8 years, and that of females was 30.0 years. Gender-wise Multivariate Regression analyses were performed. BMI was the most significant predictor for HOMA-IR in both genders. In males, WHR and BMI were the most significant predictor of lipid parameters. In females, BMI was the significant predictor for triglyceride and WC was the most significant predictor for HDL-cholesterol. HC in females was better correlated with CVD risk factors compared to WHR.

Conclusion: Similarities and differences were observed in the gender-wise correlation of anthropometric indices with cardiovascular disease risk factors. In both sexes, BMI predicted Insulin resistance. In males, WHR was the most significant predictor for serum lipids. However, in females, no clear pattern was visible; BMI was a better predictor for triglyceride, and WC was a better predictor for HDL-cholesterol.

Keywords: Insulin resistance; Sex-specific association; Waist-to-hip ratio; Body mass index

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***Correspondence:** praveenbiomed@gmail.com

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Introduction

Despite the advances in healthcare, cardiovascular diseases (CVD) are the most common cause of death in both developed and developing countries **(McClellan et al., 2019)**. Overweight and obesity are well recognized to be associated with higher morbidity and mortality through their association with hypertension, type-2-diabetes mellitus (T2DM), and CVD **(Powell-Wiley et al., 2021)**. Body fat distribution is traditionally classified as subcutaneous adipose tissue and visceral adipose tissue. Visceral adipose tissue has received more attention due to its relationship with various medical pathologies **(Shuster et al., 2012)**. Even though overall obesity has a significant correlation with central or visceral obesity, central obesity is considered an independent predictor of poor cardiovascular outcomes (**Powell-Wiley et al., 2021).**

Central obesity often clusters with cardiovascular risk factors like insulin resistance (IR), atherogenic dyslipidemia, hyperglycemia, etc., and is diagnosed as a clinical entity referred as metabolic syndrome **(Alberti et al., 2005)**. Body mass index (BMI) is the most common anthropometric index used to identify overweight and obesity, other parameters commonly used are waist circumference (WC) and waist-to-hip ratio (WHR). BMI is a simple indicator of overall obesity but may not reflect the distribution of body fat. WC and WHR are good indicators of central obesity, which are also predictors of cardiovascular disorders **(Li et al., 2014: Darbandi et al 2020).**

The associations between anthropometric indices and CVD risk factors are differed by gender, and age as observed by many studies **(Dalton et al., 2003; Pawaskar et al., 2015; Zhang et al., 2019)**.

Although advanced body fat measurement methods are available **(Kuriyan, 2018)**, simple anthropometric measurements are non-invasive and usually used in the clinical evaluation of CVD risk. It is important to understand the various aspects of the correlation of anthropometric parameters with CVD risk factors like insulin resistance, dyslipidemia, hypertension, etc., in various conditions for adopting better preventive strategies. Here we report our findings from a cross-sectional study regarding the gender differences in the correlation of anthropometric indices with cardiovascular risk factors like dyslipidemia, insulin resistance, fasting insulin, blood pressure, fasting, and postprandial glycemia in an adult Indian population.

Patients and methods

Recruitment of subjects

The data frame was "Offspring of individuals with diabetes study" (**Praveen et al., 2012)**. The institutional human ethics committee approval was taken before conducting the study. In brief, there were 358 offspring of subjects with type-2 diabetes mellitus (T2DM) and 287 apparently normal controls (individuals who did not have a family history of T2DM) recruited for the study. All the participants were of Indian origin. The age of the participants was from 5 to 56 years. Participants who were lactating, pregnant, or on medication for any chronic systemic illness were excluded. Subjects without a known family history of T2DM were recruited from the general population. Subjects with systemic illness, diagnosed diabetes, pregnant women, and lactating women were excluded. From this database, subjects aged 18 years and above (adult population) were selected for the analysis.

Data collection

Details of medical history and family history of diabetes were collected. Physical examination including anthropometry was performed. Stadiometer was used to measure height (nearest 0.1 cm) with the participant

standing straight position with head held in Frankfurt horizontal plane. Weight in kg was measured in light clothes, without shoes. BMI was noted in all subjects as per standard calculation. Hip circumference (HC), and Waist circumference (WC), and were measured with tape. WC was measured (to the nearest cm, at the end of normal expiration) midway between the superior border of the iliac crest and the lowermost margin of the ribs. HC was measured (to the nearest cm) at the greatest posterior protuberance of the buttocks, with the subject standing erect, feet together, in a relaxed posture. **(Wells and Fewtrell, 2012**). Waist-to-hip ratio was calculated from WC and HC measurements.

A 75 g oral glucose tolerance test (OGTT), was performed on all participants as per the standard procedure. Blood samples were collected in fasting(timing between 8.30 am and 9.30 am) and at 30, 60, and 120 minutes after oral glucose. The samples were collected in fluoride vials for glucose, serum collection vials for lipids, and EDTA vials (for hormones) under cold conditions. The fasting sample was used for plasma insulin, serum lipid profile, and plasma glucose estimation. Plasma glucose, and insulin, was measured at all-time points (Only fasting and 2-hour values were used for analysis in the present study). Glucose tolerance/intolerance was classified as per the American Diabetic Association (ADA) 2003 criteria **(Expert Committee on the Diagnosis and Classification of Diabetes Mellitus, 2003)**. International Diabetes Foundation (IDF) criteria were used to determine metabolic syndrome **(Alberti et al., 2005**). OMRON electronic apparatus (Omron Health Care, Kyoto, Japan) was used to measure blood pressure in a sitting position in the left arm, after about 10 minutes of rest.

Analytical measurements: Plasma glucose (glucose oxidase method) and lipid profile (enzymatic methods) assays were done on a Labmate 20 chemistry Analyser (Trivitron Diagnostics, Chennai, India). Serum high-density lipoprotein (HDL)-cholesterol was measured after precipitation of chylomicrons, very-low-density lipoprotein-cholesterol (VLDL), and low-density lipoprotein (LDL) by phosphotungstic acid and magnesium chloride. After centrifugation, the supernatant is used for measuring HDL-cholesterol by the enzymatic cholesterol method. LDL-cholesterol was calculated by Friedewald's equation **(Friedewald et al., 1972).** Intra-assay CVs for total cholesterol, TG, and HDL-cholesterol were 1.90%, 1.90%, and 4.50%, respectively, whereas inter-assay CVs were 2.50%, 2.70%, and 4.90%, respectively.

Electro-chemiluminescence assay method was used for the estimation of plasma insulin (Roche Diagnostics, IN, USA). This insulin assay has very minimal (0.05%) cross-reactivity with human proinsulin and its split forms. Intra-assay CV for insulin was 5.10% and inter-assay CV was 5.70%. HOMA-IR (homeostasis model assessment-insulin resistance) was calculated from glucose and insulin values as described **(Matthews et al., 1985).**

Statistical analysis

Statistical analysis of data was done using SPSS version-15 software (Lead Technologies, Lead, United States). Mean and standard deviation (SD) were used to express continuous data. Log transformation was also applied to skewed data for serum insulin, HOMA-IR, and serum TG. Student's unpaired t-test was used to compare the two groups. The general linear model was used for comparing groups after adjusting for confounding variables. Chi-square test/Fisher's exact test was used to see the association between categorical variables. Multiple linear regression analyses were applied to find the possible

predictors with the continuous variable. Partial correlation was applied to adjust for confounding variables such as BMI and age. Tests/results were considered significant at a P-value < 0.05.

Results

Six hundred and forty-five subjects were recruited in the study and underwent OGTT. Among these participants, 496 subjects who were aged 18 years or above were selected for the analysis. There were 304 (61%) males and 192 (39%) females. In male subjects, the mean age was 28.8 years, and in females, the age was 30.0 years, which was not significantly different. Among males, 257 (84.5%) had normal glucose tolerance, 39 (12.8%) subjects had impaired fasting glucose/impaired glucose tolerance, and 8 (2%) subjects had newly diagnosed diabetes. Among females 166 (86.5%) subjects had normal glucose tolerance, 24 (12.5%) subjects had impaired fasting glucose/impaired glucose tolerance and 2 (1%) had newly diagnosed diabetes. No significant difference (P = 0.613) in glucose intolerance between males and females. There were 126 (41.4%) subjects with a family history of T2DM in males and 101 (52.6%) subjects with a family history of T2DM in females, significantly higher (P = 0.015) in females. Metabolic syndrome was diagnosed in 19.4% of subjects in males and 20.9% of subjects in females and was not significantly different (P = 0.380). Basic anthropometric and serum profiles of male and female subjects were given in (**Table.1**).

Table 1.Basic anthropometric and serum profiles of male and female subjects

Parameters	Males (n = 304)		Females (n=192)		P value
	Mean ± SD	Minimum -Maximum	Mean ± SD	Minimum-Maximum	
Age (years)	28.8 ± 8.0	18 - 56	30.0 ± 9.4	18-56	0.141
BMI (kg/m^2)	23.4 ± 4.1	15.4 - 38.1	24.7 ± 5.6	14.4 - 47.6	0.001
Waist circumference (cm)	86.6 ± 11.1	61 - 131	83.2 ± 12.8	52 - 118	0.002
Hip circumference (cm)	95 ± 8.3	78 - 141	97 ± 11.9	52 - 132	0.03
Waist-to-hip ratio	0.9 ± 0.06	0.76 -1.09	0.86 ± 0.08	0.63 - 1.44	<0.001
Serum Triglycerides (mg/dL)	150 ± 79	42 - 550	120 ± 65	37 - 524	<0.001
Serum Total Cholesterol (mg/dL)	170 ± 36	77 - 340	166 ± 32	101 - 268	0.23
Serum HDL cholesterol (mg/dL)	41.8 ± 9.8	19 - 80	46.6 ± 10	25 - 79	<0.001
Serum LDL cholesterol (mg/dL)	98 ± 39	15 - 205	95 ± 29	17 - 193	0.410
Fasting glucose (mg/dL)	90.4 ± 14.4	70 - 249	87.5 ± 10	62 - 138	0.01
2-hour glucose (mg/dL)	103.2 ± 33	50 - 393	103.3 ± 24.6	54 - 264	0.98
Serum Fasting insulin (µU/mL)	10.8 ± 8.2	1.17 - 58.5	10.8 ± 5.8	0.74 - 36	0.30
HOMA-IR(µU/mL,mmol/l)	2.48 ± 2.0	0.25 - 14.3	2.38 ± 1.4	0.16 - 8.5	0.65
Systolic Blood pressure (mm	118.9 ±	90 - 166	112.0 ± 14	85 - 179	<0.001

Hg)	11.9				
Diastolic Blood pressure (mm Hg)	74.5 ± 8.5	53 - 107	72.4 ± 8.9	53 - 105	0.02

BMI: body mass index; LDL: low-density lipoprotein; HDL: high-density lipoprotein; HOMA-IR: homeostasis model assessment-insulin resistance

Waist circumference, waist-to-hip ratio, systolic and diastolic blood pressure, fasting glucose, and serum triglycerides, were significantly higher in males compared to females. BMI, Hip circumference, and HDL cholesterol were significantly higher in females. Fasting and 2-hour glucose levels, serum fasting insulin, HOMA-IR, total cholesterol, and LDL-cholesterol were not significantly different. Gender-wise comparison of anthropometric correlation with serum lipids, HOMA-IR, fasting insulin, fasting, and 2-hour glucose, systolic, and diastolic blood pressure, after adjusting for age and family history of T2 DM were given in (**Table.2**).

Table 2.Correlation of anthropometric parameters and CVD risk factors after adjusting for age and family history of diabetes

Parameters	Waist Circumference (WC)		Hip Circumference (HC)		Waist-to-hip ratio(WHR)		Body mass index (BMI)	
	Male (n=304) r value (P value)	Female (n=192) r value (P value)	Male (n=304) r value (P value)	Female (n=192) r value (P value)	Male (n=304) r value (P value)	Female (n=192) r value (P value)	Male (n=304) r value (P value)	Female (n=192) r value (P value)
Serum triglyceride (mg/dL)	0.256 (<0.001)	0.238 (0.001)	0.128 (0.026)	0.316 (<0.001)	0.292 (<0.001)	-0.028 (0.699)	0.264 (<0.001)	0.314 (<0.001)
Serum Total Cholesterol (mg/dL)	0.211 (0.001)	0.139 (0.056)	0.121 (0.038)	0.177 (0.015)	0.247 (<0.001)	-0.027 (0.712)	0.250 (<0.001)	0.166 (0.020)
Serum HDL cholesterol (mg/dL)	-0.133 (0.022)	-0.245 (0.001)	-0.062 (0.286)	-0.128 (0.081)	-0.173 (0.003)	-0.197 (0.007)	-0.136 (0.019)	-0.192 (0.008)
Serum LDL cholesterol (mg/dL)	0.178 (<0.001)	0.148 (0.043)	0.115 (0.049)	0.126 (0.085)	0.184 (0.002)	0.050 (0.498)	0.213 (<0.001)	0.131 (0.074)
Fasting plasma glucose (mg/dL)	0.024 (0.679)	0.167 (0.031)	-0.011 (0.853)	0.046 (0.527)	0.059 (0.307)	0.178 (0.014)	0.033 (0.568)	0.132 (0.069)
2-hour plasma glucose (mg/dL)	0.096 (0.095)	0.312 (<0.001)	0.043 (0.454)	0.157 (0.030)	0.121 (0.035)	0.253 (<0.001)	0.128 (0.026)	0.272 (<0.001)
Fasting plasma insulin (µU/mL)	0.526 (<0.001)	0.471 (<0.001)	0.431 (<0.001)	0.521 (<0.001)	0.393 (<0.001)	0.067 (0.356)	0.566 (<0.001)	0.598 (<0.001)
HOMA-IR(µU/mL,mmol/l)	0.499 (<0.001)	0.468 (<0.001)	0.401 (<0.001)	0.498 (<0.001)	0.352 (<0.001)	0.093 (0.202)	0.537 (<0.001)	0.581 (<0.001)
Systolic Blood Pressure (mm Hg)	0.288 (<0.001)	0.102 (0.192)	0.257 (<0.001)	0.169 (0.030)	0.194 (0.001)	-0.041 (0.604)	0.317 (<0.001)	0.196 (0.012)
Diastolic blood pressure (mm Hg)	0.283 (<0.001)	0.302 (<0.001)	0.252 (<0.001)	0.295 (<0.001)	0.187 (0.002)	0.143 (0.066)	0.315 (<0.001)	0.317 (<0.001)

LDL: low-density lipoprotein; HDL: high-density lipoprotein; HOMA-IR: homeostasis model assessment-insulin resistance

In males, after adjusting for age and family history of T2DM; WC, WHR, and BMI showed a positive correlation with serum triglyceride, total cholesterol, LDL-cholesterol, fasting insulin, HOMA-IR, and blood pressure. WC, WHR, and BMI showed a negative correlation with serum HDL cholesterol.

In females, WC, and BMI showed a significant positive correlation with TG, 2-hour glucose, insulin, HOMA-IR, diastolic blood pressure, and a negative correlation with HDL cholesterol. WHR showed correlation with HDL cholesterol (negative), a positive correlation with fasting and 2-hour glucose. The correlation of WHR with

remaining lipid profile parameters, HOMA-IR, fasting insulin, and blood pressure was insignificant or weaker in females. In females, hip circumference in general showed a better correlation with CVD risk factors compared to males, In general, anthropometric measurements showed a better correlation with 2-hour glucose than with fasting glucose in both males and females.

Univariate and multivariate linear regression analysis was performed in males (**Table.3**) and females (**Table.4**) to find the best predictors of the cardiovascular risk factors, among anthropometric measurements (BMI, WHR, WC, and HC). Age and family history of diabetes were also added as factors in the analysis.

In multivariate analysis, BMI was the most significant predictor for HOMA-IR and fasting insulin in males and females (age was also a significant predictor in females). In males, significant predictors for serum triglyceride were WHR and BMI, whereas in females; BMI and age were the significant predictors for triglycerides. In males, significant predictors of total cholesterol were WHR and BMI, in females, the significant predictors for total cholesterol were hip circumference and age. In males, WHR and family history of type-2 DM was the significant predictor for HDL-cholesterol, in females, WC and family history of T2DM was the significant negative predictor for HDL-cholesterol,

For fasting glucose, in males; age ($P < 0.001$) and family history of T2DM ($P = 0.003$) were the significant predictors and in females, age ($P < 0.001$) and WHR ($P = 0.014$) were the significant predictors.

In males, BMI ($P = 0.004$) and family history of T2DM ($P = 0.028$) were the most important predictor for 2-hour glucose. In females, WC ($P = 0.002$), HC ($P = 0.003$) and BMI ($P = 0.003$) were significant predictors for 2-hour glucose.

For systolic and diastolic blood pressure, BMI was the most significant predictor in females ($P < 0.001$). In males, BMI was the most significant predictor for systolic blood pressure ($P < 0.001$), whereas age ($P = 0.001$), WC ($P = 0.005$), and BMI ($P = 0.03$) were significant predictor for diastolic blood pressure.

Discussion

Simple anthropometric indices such as body mass index, waist circumference, waist-to-hip ratio, etc., are very commonly used in clinical setups, to assess the risk for cardiovascular and metabolic diseases **(Després, 2012)**. However, the population is very wide including males and females, and also with different age groups such as children, adolescents, and adults. The cardiovascular risk factors could have different associations with anthropometric measurements under different circumstances. There are ethnic differences such as higher body fat content for lower BMI in South Asian Populations than that of Caucasians **(Deurenberg-Yap et al., 2002)**. The associations of triglycerides, BMI, and glycated hemoglobin with cardiovascular disease were stronger in South Asians compared to the White population **(Ho et al., 2022**). Large-scale studies have suggested gender and age factors affect the association between cardiovascular risk factors and obesity-related anthropometric measurements **(Sakurai et al., 2006; Zhang et al., 2019)**. A wider knowledge of these aspects will help clinicians and public health personnel to better utilize the anthropometric tools when dealing with a spectrum of populations.

Table 3. Univariate and multivariate analysis in males (n=304)

Predicting Variables	Triglycerides				Total cholesterol				HDL Cholesterol				HOMA-IR			
	Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate	
	β* (P Value)	SE	β (95% CI)	SE	β* (P Value)	SE	β (95% CI)	SE	β* (P Value)	SE	β (95% CI)	SE	β* (P Value)	SE	β (95% CI)	SE
Age (Years)	2.29 (<0.001)	0.26	-	-	1.145 (<0.001)	0.25			-0.043 (0.55)	0.07			0.039 (0.007)	0.01		
FH of T2DM (Yes=1, No=0)	-21.3 (0.021)	9.2	-	-	0.214 (0.96)	0.003			3.3 (0.004)	1.14	*2.9 (0.7-5.1)*	*1.1*	-0.89 (<0.001)	0.23		
WC (cm)	2.2 (<0.001)	0.34	-	-	0.937 (<0.001)	0.18			-0.147 (0.004)	0.05			0.095 (<0.001)	0.009		
HC (cm)	1.7 (0.001)	0.54	-	-	0.79 (0.002)	0.18			-0.126 (0.06)	0.07			0.114 (<0.001)	0.01		
Waist to Hip ratio (x100)	4.7 (<0.001)	0.68	*3.58 (1.9-5.2)*	*0.84*	1.872 (<0.001)	0.32	*1.31 (0.53-2.1)*	*0.4*	-0.284 (0.002)	0.09	*-0.25 (-0.43--0.08)*	*0.09*	0.125 (<0.001)	0.02		
Body mass index (kg/m^2)	6.1 (<0.001)	1.06	*2.9 (0.36-5.4)*	*1.28*	2.631 (<0.001)	0.49	*1.45 (0.26-2.6)*	*0.6*	-0.431 (0.002)	0.18			0.27 (<0.001)	0.02	0.276 (0.23-0.32)	0.02

* β is the regression coefficient. CI Confidence interval, FH of T2DM: family history of type-2 diabetes mellitus, WC: waist circumference, HC: hip circumference

Table 4. Univariate and multivariate analysis in females (n=192)

Predicting Variables	Triglycerides				Total cholesterol				HDL Cholesterol				HOMA-IR			
	Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate	
	β* (P Value)	SE	β (95% CI)	SE	β* (P Value)	SE	β (95% CI)	SE	β* (P Value)	SE	β (95% CI)	SE	β* (P Value)	SE	β (95% CI)	SE
Age (Years)	2.62 (<0.001)	0.47	1.9 (1.0-2.8)	0.46	1.34 (<0.001)	0.23	1.15 (0.69-1.6)	0.23	-0.065 (0.08)	0.42			0.003 (0.775)	0.01	-0.03 (-0.05--0.01)	0.01
FH of T2DM (Yes=1, No=0)	-24.7 (0.009)	9.4	-	-	-3.7 (0.424)	4.7			5.57 (<0.001)	1.46	*4.3 (1.4-7.2)*	*1.4*	-0.62 (0.003)	0.20		
WC (cm)	1.86 (<0.001)	0.35	-	-	0.73 (<0.001)	0.18			-0.250 (<0.001)	0.06	*-0.21 (-0.3 - -0.09)*	*0.06*	0.05 (<0.001)	0.007		
HC (cm)	2.1 (<0.001)	0.54	-	-	0.78 (<0.001)	0.28	0.52 (0.16-0.9)	0.19	-0.19 (0.06)	0.002			0.06 (<0.001)	0.008		
Waist to Hip ratio (x100)	0.62 (0.273)	0.56			0.305 (0.272)	0.28			-0.239 (0.007)	0.09			0.022 (<0.07)	0.01		
Body mass index (kg/m^2)	4.8 (<0.001)	0.78	*3.8 (2.3-5.4)*	*0.79*	1.69 (<0.001)	0.41			-0.53 (<0.001)	0.12			0.14 (<0.001)	0.015	0.161 (0.13-0.19)	0.01

* β is the regression coefficient. CI Confidence interval, FH of T2DM: family history of type-2 diabetes mellitus, WC: waist circumference, HC: hip circumference

In the current study, we have used standard methods to measure BMI, WC, HC, and WHR. BMI is considered as a generalized measurement of obesity while, WC and WHR more accurately describe the distribution of body fat with higher values indicating higher cardiovascular disease risk **(Huxley et al., 2010)**. The cardiovascular risk factors studied are insulin resistance (as measured by HOMA-IR), serum lipid parameters, fasting, 2-hour glucose levels, and blood pressure. All correlations were done after adjusting for age and family history of diabetes for minimizing the confounding effects of those parameters, on the correlation of anthropometric parameters with CVD risk factors. Subjects above 18 years (up to 56 years) were selected for analysis to confine to the adult population where the effect on age with anthropometric parameters will be lower compared to that of children.

Both in males and females, BMI significantly correlated with serum lipid parameters, blood pressure, and insulin resistance (as measured by HOMA-IR). In multivariate linear regression analysis, which includes all anthropometric parameters measured, age, and family history of T2DM, in both genders, BMI was the most significant predictor for insulin resistance and fasting insulin levels. This indicates a similar kind of relationship between insulin resistance to overall obesity (more than body fat distribution) in both sexes. Hyperinsulinemia as measured by fasting plasma insulin was suggested as an important independent etiological factor, not only in the development of cardio-metabolic disorders but also in cancer and premature aging **(Janssen, 2021).**

WC as a measure of abdominal obesity has shown a similar kind of correlation with cardiovascular risk factors in both genders; except for no correlation with total cholesterol and systolic blood pressure in females and no correlation with glucose levels in males. In multivariate analysis, in males, WC was not a better predictor for serum lipids and insulin resistance compared to BMI, and WHR. WC (along with family history of T2DM) was the best negative predictor for HDL-cholesterol in females. In a study conducted in Tanzanian older age population, WC significantly correlated with the lipid risk factors and fasting glucose in males. In females, WC was only associated with blood pressure **(Njelekela et al., 2009)**. As per a study conducted in Indian population by Pawaskar et al., WC was the most sensitive anthropometric parameter in predicting altered lipid profiles in females **(Pawaskar et al., 2015**). Our study agrees partially with the above-mentioned study, in the case of WC as a better predictor for serum low HDL-cholesterol. WC cut-offs ≥ 90 cm for males and ≥ 80 cm for females were mentioned for the diagnosis of metabolic syndrome as per IDF criteria **(Zhu et al., 2020).**

The WHR, in males, significantly correlated with serum lipids, 2-hour glucose, and HOMA-IR. In females, apart from a negative correlation with HDL-cholesterol and a positive correlation with glucose levels; WHR showed no correlation with lipid parameters, insulin resistance, and blood pressure. In males, WHR was a significant predictor for serum triglycerides, total cholesterol, and HDL-cholesterol, however, WHR was not a significant predictor for any of the above-mentioned parameters in females. In males, the results are in agreement with the study conducted by Pawaskar et al., which also describes WHR as a sensitive parameter predicting altered lipids **(Pawaskar et al., 2015)**. A study conducted on Australian adults by Dalton et al.,, has described WHR as having a strong association with dyslipidemia in females **(Dalton et al., 2003)**. In the present

study, multivariate analysis did not show WHR as a significant predictor for lipid parameters in females. World health organization's (WHO) definition of metabolic syndrome has given WHR > 0.9 in males and > 0.85 as a cut-off measure of central obesity **(Huang, 2009).**

In males, hip circumference (HC) showed only a weak correlation with lipid parameters, in multivariate regression analysis, hip circumference was not a significant predictor compared to WHR, WC, or BMI in males. However, in females, HC showed a significant correlation with lipids, and HC (along with age) was a significant predictor for serum total cholesterol levels in multivariate analysis. We could not find studies, which mention HC as a significant parameter in predicting cardiovascular events.

The most significant anthropometric parameter associated with 2-hour glucose was BMI in males and WC in females. The positive association of BMI and WC with fasting glucose and 2 hours was also reported in a large-scale study in the Chinese population even though the gender-wise association was not available in the published data **(Li et al., 2014).** In our study, the anthropometric parameters' correlation with fasting glucose was weaker/non-significant compared to 2-hour glucose in both males and females. Post-prandial sugar is suggested as an important cardiovascular risk factor that can induce oxidative stress, inflammatory reactions, and endothelial dysfunction in blood vessels **(Node and Inoue, 2009).**

A study by Sakurai et al. suggests WC in men and BMI in women should be given more importance in the screening for hypertension in the Japanese-Asian population **(Sakurai et al., 2006).** Our study also showed a similar pattern of significant association of BMI with blood pressure in females. However, in males, WC was a significant factor in diastolic blood pressure, and BMI was the significant predictor for systolic blood pressure.

The limitations of the study are; we did not study the socioeconomic status and nutritional background of the participants which could affect the cardiovascular factors. However, we assume that it will affect both genders equally. The percentage of male participants was higher compared to females. The percentage of family history of diabetes where higher in females; for minimizing the confounding effect, the analysis was adjusted for family history of diabetes. Being a cross-sectional study, the current study cannot deduce any cause-effect relationship for gender differences observed in the association of anthropometric measurements and cardiovascular risk factors. The gender differences in cardiovascular risk factors could be attributed to some common factors and women-specific factors **(ZujieGao et al., 2019**). Common factors are hypertension, diabetes, smoking, serum LDL levels, HDL levels, body fat distribution, etc., which may differentially modify cardiovascular risk factors in men and women. Women-specific factors which affect cardiovascular risk factors could be polycystic ovarian syndrome, other reproductive endocrine disorders, menopause, pregnancy-related complications etc **(Karastergiou et al., 2012; ZujieGao et al., 2019**).

Conclusion

Similarities, as well as differences, were observed in the gender-wise correlation of anthropometric indices with different cardiovascular risk factors, in the adult Indian population studied. Body mass index was the most significant predictor for insulin resistance and fasting insulin in both males and females. In both genders, anthropometric indices were better correlated with 2-hour glucose than with fasting glucose. The waist-to-hip ratio has

shown only a weak or negative correlation with cardiovascular risk factors in females. In males, the most significant predictor for serum lipid parameters was the waist-to-hip ratio. However, in females, no clear pattern of correlation was visible, with BMI as a better predictor for serum triglyceride, hip circumference being a better predictor for total cholesterol, and waist circumference as a better predictor for serum HDL-cholesterol.

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