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Mid Arm Circumference: An Alternate Anthropometric Index of Obesity in Type 2 Diabetes and Metabolic Syndrome

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Authors' contributions

This work was carried out in collaboration between all authors. Author ND designed the study, wrote the protocol and wrote the first draft of the manuscript. Author PA managed the literature searches, analyses of the study performed the spectroscopy analysis and author MN managed the experimental process. Author SR identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate alternate anthropometric index for obesity in type 2 diabetes and metabolic syndrome.
Study Design: This is a cross sectional study.
Place and Duration of the Study: Department of Medicine, Kasturba medical college-hospital, Mangalore, Manipal university, between January 2012 - July 2015.
Methodology: We recruited 207 type 2 diabetic and 101 metabolic syndrome subjects with their age and sex matched controls. Anthropometric parameters like BMI, Waist circumference and mid arm circumference (MAC) were measured. Biochemical details were collected from case record.
Results: The mean differences in anthropometric and biochemical parameters were compared between cases and controls by independent T test. MAC was correlated with clinical parameters in control subjects by Karl pearson's correlation and multiple linear regression analysis. There was significant difference in MAC between metS and their control subjects (31.35±4.21 vs 28.04±2.86,

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P<.001). There was significant positive linear correlation of MAC with BMI (*P*<.001), WC (*P*<.05), post prandial blood sugar (*P*<.05) and HbA1c (*P*<.05) in controls. Further multivariate analysis after adjusting for conventional risk factors showed a significant association of MAC with BMI (β=0.611, *P*<.001).

Conclusion: These findings show that MAC can be useful as an alternate index for obesity in South Indians.

Keywords: Mid arm circumference; type 2 diabetes; metabolic syndrome; anthropometry; body mass index; waist circumference.

ABBREVIATIONS

BMI	:	*Body Mass Index*
DBP	:	*Diastolic Blood Pressure*
FBS	:	*Fasting Blood Sugar*
HbA1c	:	*Glycemic Index*
HDL	:	*High Density Lipoprotein*
LDL	:	*Low Density Lipoprotein*
MAC	:	*Mid Arm Circumference*
metS	:	*Metabolic Syndrome*
PPBS	:	*Post Prandial Blood Sugar*
RBS	:	*Random Blood Sugar*
SBP	:	*Systolic Blood Pressure*
SPSS	:	*Statistical Package Version of Social Sciences*
TC	:	*Total Cholesterol*
T2D	:	*Type 2 Diabetes*
TG	:	*Triglycerides*
WC	:	*Waist Circumference*

1. INTRODUCTION

The highly prevalent diabetes is increasing at an alarming rate. Type 2 diabetes (T2D) and prediabetic condition like metabolic syndrome (metS) are commonly associated with obesity and body fat [1]. The relationship of adiposity indices to incidence of T2D have been extensively documented and frequently commented upon enough in developed nations of the world [2]. Common screening tools include waist circumference (WC), biceps skin fold thickness, body mass index (BMI) and the rohrer index (wt(kg)/ ht (m^3)). Techniques such as underwater weighing [3], Dual-energy X-ray absorptiometry scans [4], total body water [5], total body electrical conductivity [6] and computed tomography [7], used for estimating total body fat are often expensive, complicated and unsuitable for routine clinical use. The malnutrition universal screening tool states that mid arm circumference (MAC) can be used as a general indicator of BMI, when height, weight or BMI cannot be measured (www.bapen.org.uk).

MAC is the circumference of the left upper arm, measured at the mid-point between the tip of the shoulder and the tip of the elbow ie acromium and olecranon process. MAC offers the reliable clinical advantages for being quick, portable and inexpensive, uncomplicated and noninvasive and can be measured without difficulty [8] and can be performed on most debilitated individuals. Though, BMI is the most routinely used measure of obesity, it has disadvantages for reflecting body frame size, relative leg length, and fat free mass. Also it depends on two separate measurements – height and weight. MAC is less affected than BMI by the localised accumulation of excess fluid and height [9], relies on single measure and suitable for clinical practice. Powell-tuck and Hennessy [10] showed MAC to correlate directly with BMI in undernourished patients and showed for clinical purposes BMI can be approximated from “MAC - 5” – when patients cannot be easily weighed or their height measured. There are quite a lot studies on use of MAC to screen obesity in children [8,11-16], yet literature on use of MAC as a screening tool for adult obesity is sparse [16-17].

The aim of our study is to test whether MAC can be used as an alternative index for measuring obesity instead of BMI and WC and to find the correlation of MAC with blood sugar, glycemic control, lipid profile and other anthropometric parameters such as WC and BMI.

2. METHODOLOGY

2.1 Ethics Statement

The study protocol was reviewed and approved by Manipal University Ethics Committee and written consent was obtained from each of the study participants after explaining the nature of study.

2.2 Participants

A total of 616 South Indians (313 males and 303 females) were enrolled in the current study from South Canara region of India. Patients fulfilling the diagnostic criteria as recommended by the American Diabetes Association for diabetes and International Diabetes Federation for metabolic syndrome, were recruited from the inpatient department of Kasturba Medical College hospital, Manipal University to the cross sectional study. Exclusion criteria for cases were individuals with type 1 diabetes, malignancy, acute infections, inflammation, endocrine disorders like hypothyroidism, patients on insulin therapy and chemotherapeutic agents, patients with confirmed neoplastic changes, old, sick and pregnant patients. Inclusion Criteria for controls were: fasting blood sugar (FBS) <126 mg/dl, post prandial (PPBS) and random blood sugar (RBS) <200 mg/dl, glycemic index (HbA1c) < 6.5% without family history of diabetes. Controls with atleast one feature of metS were excluded for metS controls.

2.3 Anthropometric and Biochemical Analysis

2.3.1 Anthropometry

Anthropometric parameters such as mid arm circumference (MAC), waist circumference (WC) and body mass index (BMI) were measured. The height was measured barefoot with head in horizontal plane to the nearest 0.1 cm using a graduated tape attached to the wall. The weight was measured in light clothes using a calibrated electronic weighing machine. Waist circumference is measured at the midpoint between the lowest rib and the highest point of the iliac crest, during normal expiration with a non-stretchable measuring tape. BMI is measured as the ratio of weight (kg) and square of height (meters) [17]. MAC was measured by a flexible non- stretchable tape on the front of the left upper arm by measuring the half way distance between inferior aspect of the acromion and the olecranon.

2.3.2 Biochemical analysis

Biochemical details such as FBS, total cholesterol (TC), high density & low density lipoprotein (HDL, LDL), triglycerides (TG) and HbA1c were collected from case records. Determination of the following biochemical markers: glucose, total cholesterol, HDL, LDL and TG were carried out using Hitachi 917 autoanalyser. Glucose was estimated by GOD-PAP method [18], total cholesterol was estimated by CHOL-PAP method, HDL was estimated by HDL plus method, triglycerides was estimated by the GPO-PAP method and LDL was calculated using freidwald's equation [19].

Systolic and diastolic blood pressures (SBP, DBP) were measured.

2.4 Statistical Analysis

All statistical analysis was performed using SPSS version 20 for windows (SPSS, Chicago, Illinois, USA). Comparison of clinical variables between cases and their controls were performed using independent t- test and are represented as mean ± Standard deviation. Karl Pearson's correlation was used to find correlation of MAC with BMI, WC, SBP, DBP, FBS, PPBS, HbA1c, TC, HDL, LDL and TG in control subjects. Since cases were on treatment, only controls were used for correlation and regression analysis. P value less than .05 was considered statistically significant**.** Further Multivariate analysis was done after adjusting for conventional risk factors to find out whether there is a significant association between MAC and biochemical and other anthropometric parameters.

3. RESULTS

The mean values of anthropometric and biochemical parameters of the T2D, metS cases and their controls are shown in Tables 1 and 2.

By Karl Pearson's correlation analysis, MAC shows significant positive correlation with BMI (r=0.821, P<.001), WC (r=0.742, P<.001), FBS (r=0.313, P<.05), PPBS (r=0.367, P<.05) and HbA1c (r=0.360, P<.05) in T2D controls (Table 3). MAC shows significant positive correlation with BMI (r=0.805, P<.001), WC (r=0.716, P<.001), FBS (r=0.350, P<.05) and PPBS (r=0.402, P<.05) in metS controls. There was no significant correlation of MAC with lipid parameters.

From the multivariate regression analysis, MAC showed significant positive linear correlation with BMI (β =0.611, P<.001) in T2D controls. MAC showed positive linear correlation with BMI (β =0.483, P=.006) and moderate positive linear correlation with PPBS (β=0.291, P=.026) in metS controls (Table 4).

Table 1. Anthropometric and biochemical parameters of the study population with and withoutT2D; n, mean ± SD

Phenotype	With T2D (n=207)			Without T2D (n=207)		
	Total	Females	Males	Total	Females	Males
BMI (Kg/mt^2)	25.6±4.08*	25.71±4.19*	25.48±4*	24. 13 ± 3.36	23.68±3.51	24.38±3.26
Waist (cms)	92.07 ± 13.42*	90.68±10.37	93.53±15.96*	88.56 ± 9.93	87.54±10.7	89.18±9.43
MAC (cms)	28.57±3.01	28.66±3.36	28.46±2.59	28.28±3.07	27.79±3.28	28.56±2.93
SBP (mmHg)	135.52±17.37**	135.74±17.1**	135.22±17.84*	124.76±16.77	124.6±12.12	124.9±19.9
DBP (mmHg)	81.25 ± 10.67	81.88±11.46*	80.41±9.49	78.95±9.11	77.64±6.3	80±10.8
FBS (mg/dl)	160.51±56.89**	160.57±55.45**	160.45±58.7**	98.41 ± 10.99	98.23±12.08	98.52±10.35
PPBS (mg/dl)	217.73±82.41**	215.33±80.59**	219.64±84.69**	103.77±26.4	104.28±28.78	103.5±25.39
TC (mg/dl)	196.37±58.23	216.05±55.57	181.62±56.26	200.11 ± 45.8	205.48±44.63	197.42±46.81
HDL (mg/dl)	43.99±12.3**	45.05±13.06**	43.21±11.79*	52.62 ± 15.06	60.06±14.76	49.02±13.94
LDL (mg/dl)	121.88 ± 46.15	136.5±49.62	111.19±40.67*	132.82±40.88	137.9±39.67	130.52±41.51
TG (mg/dl)	159.31±98.66**	166.13±80.45**	154.1±111.1*	113.63±49.58	97.82±32.2	121.66±54.89
HbA1c (%)	8.81 ± 2.47**	8.73±1.62**	8.86±293**	5.67±0.54	5.48±0.68	5.78±0.42

***P<.001, *P<.05 for differences in the total study population and within gender between the T2D and without T2D groups. BMI, body mass index; WC, waist circumference; MAC, mid arm circumference; FBS, fasting blood sugar; PPBS, postprandial blood sugar; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; TG, triglyceride; HbA1c, glycemic index*

Table 2. Anthropometric and biochemical parameters of the study population with and without metS; n, mean ± SD

Phenotype	With metS (n=101)			Without metS (n=101)		
	Total	Females	Males	Total	Females	Males
BMI (Kg/mt^2)	29.62±5.87**	29.82±6.44**	29.10±4.02**	23.81±3.30	23.76±3.95	23.85±2.82
Waist (cms)	96.83±13.51**	96.88±15.16*	96.69±7.75**	87.34 ± 10.20	87.12±12.69	87.48±8.31
MAC (cms)	31.35 ± 4.21**	31.37±4.65**	31.30±2.83**	28.04±2.86	27.79±3.25	28.20±2.62
SBP (mmHg)	140.42±18.53**	139.80±19.69*	143.5±11.22	125.42±19.50	122.95±13.58	127.89±24.17
DBP (mmHg)	85.85 ± 14.67*	85.32±15.72*	88.5±7.47	78.97±9.01	76.89±6.06	81.05±11.00
FBS (mg/dl)	105.42 ± 11.39**	106.77±11.7*	102.13±10.11	97.41±10.10	97.6±11.34	97.31±9.51
PPBS (mg/dl)	112.38 ±30.78	119.74±30.62	103.07±29.33	104.56 ±25.43	102.92±20.18	105.38±28.03
TC (mg/dl)	201.56 ± 46.61*	199.51±50.13	205.75±39.10*	182.74±33.64	184.88±35.99	181.72±32.95
HDL (mg/dl)	40.55 ± 8.35**	42.45±8.74**	36.75±6.03**	50.85 ± 13.48	58.6±13.79	47.18±11.83
LDL (mg/dl)	134.16 ± 37.93*	134.26±39.38	133.95±35.6	119.42±34.01	120.72±42	118.89±30.75
TG (mg/dl)	173.99±80.01**	152.69±63.75**	213.92±92.73**	104.29±43.88	84.94±25.28	113.69±48.05
HbA1c (%)	5.81±0.58	5.95±0.60*	5.61±0.506	5.59 ± 0.5	5.4±0.56	5.68±0.46

***P<.001, *P<.05 for differences in the total study population and within gender between the metS and without metS groups. BMI, body mass index; WC, waist circumference; MAC, mid arm circumference; FBS, fasting blood sugar; PPBS, postprandial blood sugar; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; TG, triglyceride; HbA1c, glycemic index*

Table 3. Correlation of MAC with the BMI, WC, blood sugar, blood pressure, glycemic control and lipid profile in the control subjects

	T2D controls		metS controls	
	r	*P* value	r	*P* value
BMI (Kg/mt^2)	0.821	<.001**	0.805	<.001*
WC (cms)	0.742	<.001**	0.716	<.001*
SBP (mmHg)	-0.026	>.05	0.006	>.05
DBP (mmHg)	0.011	>.05	0.060	>.05
FBS (mg/dl)	0.313	<.05*	0.350	<.05*
PPBS (mg/dl)	0.367	<.05*	0.402	<.05*
HbA1c (%)	0.360	<.05*	0.286	>.05
TC (mg/dl)	0.046	>.05	-0.172	>.05
HDL (mg/dl)	-0.151	>.05	-0.126	>.05
LDL (mg/dl)	0.053	>.05	-0.126	>.05
TG (mg/dl)	0.194	>.05	0.013	>.05

***p<0.001, *p<0.05 for significant correlation of MAC with clinical parameters. BMI, body mass index; WC, waist circumference; MAC, mid arm circumference; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; FBS, fasting blood sugar; PPBS, postprandial blood sugar; TC, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; TG, triglyceride; HbA1c, glycemic index*

Table 4. Multiple linear regression analysis of MAC and other known risk factors of obesity, T2D and metS

	T2D controls		metS controls	
	MAC		MAC	
	β	*P* value	β	*P* value
Age (years)	-0.067	.405	-0.079	.485
BMI (Kg/mt^2)	0.611	<.001**	0.483	.006*
WC (cms)	0.210	.092	0.414	.070
SBP (mmHg)	0.239	.239	0.438	.241
DBP (mmHg)	0.111	.624	0.213	.60
FBS (mg/dl)	0.1	.199	0.046	.726
PPBS (mg/dl)	0.142	.059	0.291	.026*
HbA1c (mg/dl)	0.061	.475	0.063	.607
TC (mg/dl)	-0.067	.405	-0.122	.859
HDL (mg/dl)	0.125	.440	-0.147	.666
LDL (mg/dl)	1.017	.054	0.332	.594
TG (mg/dl)	0.049	.586	-0.214	.260

BMI, Body Mass Index; WC, waist circumference; MAC, mid arm circumference; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; FBS, fasting blood sugar; PPBS, postprandial blood sugar; TC, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; TG, triglyceride; HbA1c, glycemic index

4. DISCUSSION

By this study we confirmed the usefulness of MAC as an aternate index of obesity. MAC significantly correlated positively with BMI and positively correlated with PPBS also. MAC appears to be reliable marker for obesity in South Indian population.

Studies have shown significant correlation of MAC with BMI in adults [20-25]. Farah et al. [26] observed an increased MAC in diabetic women compared to nondiabetics. The number of women with a MAC >33.0 cm was 23% in the diabetic clinic compared with 12% in the standard clinic (p<0.001). In the BMI 30.0-34.9 kg/m^2 category, 29.4% had a MAC>33.0 cm while in the BMI >35.0 kg/m^2 category, 92% had a MAC >33.0 cm.

In another study by Haboubi et al. [27] BMI showed significant correlation (p<0.05) with MAC in control, obese nondiabetics and obese diabetic subjects. Dube et al. [28] showed that the BMI and MAC can predict degree of blood glucose levels and lipidemia in bulawayo district Zimbabwe. Sagun et al. [29] showed that the MAC is associated with metabolic syndrome and visceral fat. A study by Satvin et al. [30] on residents of klang valley, malaysia showed the increased prevalence of obesity (p<0.001) in mets patients characterized by higher BMI, total body fat, visceral fat adiposity and MAC. In a study by Nagah et al. FBS, total blood cholesterol, HDL-cholesterol and LDL-cholesterol showed significant correlation with mid arm circumference [31]. Salil et al. showed that the ratio of Height/Waist circumference (H/WC) and Height/ mid arm circumference is better indicator for the prediction of coronary heart disease and dyslipidemia [32].

Although computed tomography and magnetic resonance imaging techniques are used to assess visceral fat, assessment of abdominal obesity in large scale studies are not viable [33]. In our study we found positive correlation of MAC with post prandial blood glucose levels, hence this anthropometric index can be used to predict blood glucose levels. Additionally, since MAC is significantly correlated with BMI and WC, it can be used as an alternate index for obesity.

Measurement of MAC requires fewer instruments and calculations as compared to weight and height measurements for calculation of BMI or other anthropometric measurements, such as skinfold thicknesses [34]. Measuring MAC is very simple to perform, and equipment is much cheaper than for weighing and measuring a subject's height making MAC an alternative index to measure obesity instead of waist circumference and BMI. Quantifying body fat in obese patients can often be difficult as they do not like being weighed, or find other anthropometric measures such as waist circumference and skinfold thickness equally unpleasant. MAC is less intrusive than other anthropometric measures and is advantageous over BMI and skinfold measures in that it is just a single measure requiring inexpensive equipment (a tape measure) – not needing calibration or maintenance.

5. CONCLUSION

In conclusion, MAC can be used as an alternate index to measure obesity as the MAC correlates very well with BMI. MAC is significantly higher in metS patients compared to T2D patients hence MAC can predict the onset of T2D. MAC correlates with PPBS in metS controls. Hence anthropometry is useful in predicting the blood sugar level.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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