How to Cite:
Rajput, A., Gupta, U. K., Rachna, R., Tzivion, G., Rajput, R., & Nahal, T. (2022). Determining new anthropometric markers for screening T2DM in Jaipur, India: A cross sectional study. *International Journal of Health Sciences*, *6*(S8), 2568–2581. https://doi.org/10.53730/ijhs.v6nS8.12617

Determining new anthropometric markers for screening T2DM in Jaipur, India: A cross sectional study

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***Abstract*---**WHO has estimated expected cases of T2DM to rise to 57.2 million by the year 2025 and 80.9 million by the year 2030. Since past two decades there has been constant marked increase in the prevalence of diabetes in urban population of India with noticeable rise in southern part of India. The Prevalence of T2DM ranges from 10-16 % from region to region. The primary objective of the study was to determine the association between Indices using height, waist, hip, thigh, arm, and wrist circumference (cm) with development of T2DM and compare it to existing markers in test subjects and assessing their feasibility as predictive indicators for the development of T2DM. In a cross-sectional study, a total of 605 subjects were involved

Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

in the study which included health centers and health camps in Jaipur, India. The study duration was of 1 years (December 2019 to November 2020). Height-to-waist ratio (HtWR), ABI (Arav Body Index), Thigh to waist ratio (TWR) and Wrist to arm ratio (WAR) was compared to common existing markers such as WHtR, WHR and BMI. The values of ratios such as WTR (.984), ABI (.983), WHtR (.982) and BMI (.939) had the higher AROC values whereas WAR (876) was slightly lower and WHR was insignificant. The cut-off values for WC, HC, BMI, WHtR, WHR was 78, 87, 28.2, 0.52, and 0.94 respectively in Men. The cut-off values for WC, HC, BMI, WHtR, and WHR was 80, 85, 26.1, 0.43, and 0.90 respectively in Women. We conclude that ABI, WHtR and WTR could be a more reliable tool for identifying individuals at risk of developing type 2 DM. Exercise and lifestyle modifications can address the modifiable risk factors can delay or prevent development of chronic diseases such hypertension and Diabetes.

***Keywords*---**anthropometric measures, receiver operating characteristics, arav body index, height-to-waist ratio.

Introduction

Obesity has been a long-standing problem and there has been a steady increase in cases of obesity and associated conditions namely Diabetes and Hypertension. There are research studies which shows an increase in trends in excessive body fat accumulation and how the human body has reached sizeable dimensions since 1980 (1). In 2010, Worldwide, >2.1 billion people were classified as overweight or obese [Body Mass Index (BMI) >25], and among them almost 0.64 billion were obese (BMI>29) (WHO, Obesity and overweight., 2015) and it is believed that obesity is closely associated with cardiovascular disease (CVD), hypertension (HTN), diabetes mellitus (DM)) and metabolic syndrome (MetS) in literature. The WHO MONICA study which was carried out between 1980 to1990 showed consistent increase in prevalence of obesity in all groups of population due to increased energy supply (2). The occurrence of obesity ranged from 0.3-3.4% in Filipinos, Japanese, Asians and Chinese (Asia pacific cohort study collaboration 2007). The occurrence in Thais (3,4) Hong Kong Chinese (5) Singaporeans was in a range of 4.7 -9.1%. The occurrence of obesity for females from Africa (6) was 12.0% - 25.0% and in males it was 6.0-9.3%. The occurrence of obesity in Netherlands was observed to be 10.0-15.5%, Spain and Sweden was 19.3-27.7% (7–9). Similar ratios were observed in Canada (10) UK (11), Italy (12) and Mexico (13). The prevalence of obesity was almost doubled in Brazil, Thailand, and China whereas it was seen not significantly increased in countries like the United States of America, India, and Mongolia. Diabetes is becoming a global public health concern and is emerging as a pandemic. There is many evidence from previous research studies which has shown that prevalence of Type 2 diabetes is increasing drastically in migrant Indians. In the past 20 years the rates of obesity have tripled in developing countries as they are more inclined towards modernization and less physical inactivity. The prevalence of diabetes in India is showing a sharp rise. WHO has estimated 19.4 million people affected by diabetes in 1995 (14) . This number is expected to rise to 57.2 million by the year

2025 and 80.9 million by the year 2030 (15). In 1970 research study has shown prevalence of diabetes in urban India was 2.1% which has skyrocketed to 12-16%. Looking at the prevalence of diabetes in different regions in India southern part of India (Chennai- 13.5%, Bangalore- 12.4%, and Hyderabad-16.6%) is more prone for diabetes as compared to eastern (Kolkata- 11.7%) northern India (New Delhi- 11.6%) and western India (Mumbai-9.3%). It is very clear that in the last two decades there has been constant marked increase in the prevalence of diabetes in urban population of India with noticeable rise in southern part of India (16). Some of the possible reasons behind this drastic rise could be environmental and lifestyle changes, central obesity and increase in visceral fat due to lack of physical activity and consumption of high calorie diets. Few research studies have shown that Indians have greater chance of insulin resistance and have stronger genetic predisposition to diabetes mellitus. Many modifiable factors like increase in physical activity, preventing obesity and healthy traditional diets rich in fiber can help curb diabetes. One of the crucial factors contributing to rise in T2DM in Asian Indians is the fact that they have a greater degree of insulin resistance compared to Caucasians (17).

Research Studies by Yajnik *et al* has demonstrated that low birth weight is also a contributor to insulin resistance among Indians. It was also shown that Indian neonates have higher insulin levels and greater adiposity even at birth compared to Caucasians. The hypothesis was put forth which stated that small Indian babies have smaller abdominal viscera and low muscle mass, but preserve body fat during their intrauterine development, which may predispose to an insulin-resistant state in later part of life (18,19). It is a known fact that insulin resistance joins with other components of the metabolic syndrome which includes hypertension, glucose intolerance, abdominal obesity, dyslipidemia etc. and hence this syndrome is also named as insulin resistance syndrome (IRS). Studies have shown high prevalence of IRS in urban population as compared to rural ex Chennai- 11.2%. Prevalence of IRS has shown comparable difference in social economic status with 6.5%in low-income group and 18.7% in middle income group (20).

In a research study to determine the prevalence of Type 2 diabetes in descendants of two diabetic parents, diabetes was observed in 50% of descendants, whereas 12% had impaired glucose tolerance (IGT). Thus, sixty two percent of all South Indian descendants of two diabetic parents had abnormal glucose tolerance which is considerably higher compared to figures around 25% among Europeans. This strongly represent an ethnic variation of the genetic factors influencing Indian patients predisposing to Type 2 diabetes (21). India has around 75% of the Type 2 diabetics who have first degree family history of diabetes which indicates a very strong familial aggregation (22). Asians Indians have shown characteristic feature of insulin resistance and require much higher levels of plasma insulin to maintain normal glycemic levels. Gestational diabetes has become very common in urban population because of lifestyle modification. Children born to gestational diabetes mother have shown more chances of diabetes mellitus (23)

Materials and Methods

The primary objective of the study was to evaluate ability of ABI (Arav body index), WTR (Waist to thigh ratio) and WAR (Wrist to arm ratio) in determining association with T2DM. The other objectives were to compare the above anthropometric indices with existing one like BMI, WHtR and WHR and as well as to determine cut off values in the study population.

Study is Cross-sectional population-based study involving subjects utilizing all health centers and health fairs in Jaipur, India. Ethnicity and Sex was self-reported. A written Consent was taken from the participant for participation in research study. The study duration was of 1 year (December 2019 to November 2020). The minimum sample size required was 150 subjects in each group. The sample size was calculated based on prevalence of the diabetes in 11% of the population of Jaipur using n= z^2pq/e^2 wherein n=sample size, p=estimated prevalence of T2DM, q=1-p, z=1.96 for a confidence level (α) of 95% and e2 is margin of error (24). $N=1.96^2 \times 0.11 \times 0.89 / (0.05)^2= 150$. Participants were divided into two groups. Non-diabetic and subjects with T2DM. The study was reviewed and approved by Ethics Review board under NIMS University, Jaipur, India.

Subjects with age between 40 to 70 years and with self-reported history of Diabetes and subjects without history of diabetes were included in the study. Subjects who are pregnant and lactating at the time of study, recorded weight was incomplete or implausible (Ex. BMI < 15 or > 45 kg/m2; weight < 30 or > 150 kg; height < 130 or > 190 cm; and the difference between systolic and diastolic blood pressure < 10 mmHg) were excluded from the study. The subjects who involved in bodybuilding and athletic events/sports sinch past 1 month were also excluded. Subjects with hypertension were excluded from this study. Diabetes was defined based on self-reported physician-diagnosed diabetes or self-reported current intake of anti-diabetic medication during the 7 days prior to the participation in the study. Covariates, such as age, sex, smoking habits and alcohol consumption were collected by direct interviews.

Anthropometric measurement

Height was measured using a Stadiometer. Weight was measured using a calibrated Digital weighing scale. Waist, hip, Thigh, Arm and Wrist Circumference was measured using Calibrated tape. BMI is defined as the weight in kilograms divided by the square of the height in meters (kg/m^2). Cut-off standards by the World Health Organization was used (25). Waist circumference (WC) was measured to the nearest centimeter using a flexible tape with the respondent standing. In women, the abdominal circumference (waist) was measured as the narrowest part of the body between chest and hips and in men it was measured at the level of the umbilicus. Measurements were taken at the end of normal expiration. The participant's hip circumference was measured at the maximum circumference around buttocks posteriorly at the level of greater trochanters and measured in cm. Thigh circumference (cm) was measured in participants at mid-thigh on the right side. Mid-thigh circumference in this study was the midpoint between the superior ridge of the patella inferiorly and the crease of the groin superiorly. The arm circumference is the circumference of the upper arm which was estimated using measuring point midway between the olecranon process of the ulna inferiorly and the acromion process of the scapula superiorly, measured with a non-stretchable calibrated tape measure on the right side of the patient. All circumferences are measured in centimeters.

Waist-hip ratio (WHR) was determined by dividing waist circumference by hip circumference (cm). Waist-height ratio (WHtR) is defined as waist circumference divided by height in centimeters. This ratio is a measure of the distribution of body fat. Higher values of WHtR indicate higher risk of obesity-related cardiovascular diseases; it is correlated with abdominal obesity. Height-waist ratio (HtWR) which is inverse of WHtR was also taken into consideration. Thigh to waist ratio (TWR) was determined by dividing Waist circumference by Thigh circumference (cm). Wrist to arm ratio (WAR) was determined by dividing wrist circumference by Arm circumference. ABI (Arav Body Index) is newer index was measured using following equation:

ABI = Waist circumference / (Thigh circumference + Height) (all units in cm) (26). Blood pressure was taken in a seated position and on the right arm by trained health workers who did follow a standardized procedure using regularly calibrated mercury sphygmomanometers or Omron digital devices, Indonesia Family Life Survey (IFLS).

Statistical analysis

The distributions of continuous anthropometric and clinical variables will be described using measures of central tendency and variation (means and standard deviations). Means was compared using independent "T" test. Receiver-operating characteristic (ROC) curve analyses was used to examine the overall discriminatory power represented by Area under receiver operating curve (AROC), sensitivity and specificity, and corresponding cutoff points of each of the anthropometric indices for diabetes using IBM SPSS v23.

Results

In our study, out of 605 participants, 300 belonged to Normal group (non-diabetic) and 305 were diabetics. Males were predominant proportion in Diabetic group (77%). Around 37% diabetics had poorly controlled glucose with RBS over 200 ml/dl among which 5% had RBS over 310 mg/dl. None of the participants in normal group were obese as per WHO guidelines whereas in diabetics the percentage of obese group was as high as 69% (Fig 1)

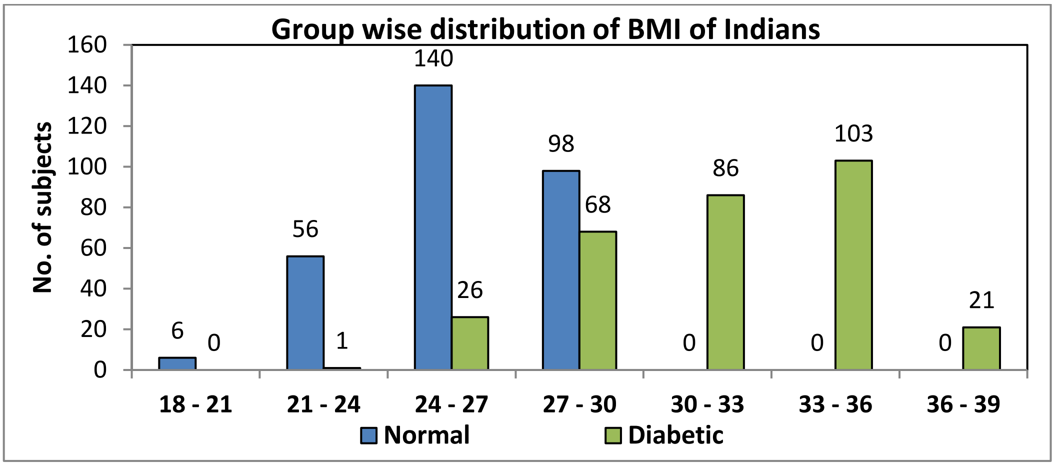

Figure 1: Group wise distribution of BMI of Indians

2.3% of normal group, whereas 43.3% of diabetic group had waist circumference more than 90 cm which is cut-off value set by WHO (27). It is quite evident in the Indian group too that diabetic group had higher proportion of the waist circumference above 90 cm and hence waist circumference is also a very important marker for determining persons at risk of developing T2DM in India (Fig 2) (28) .

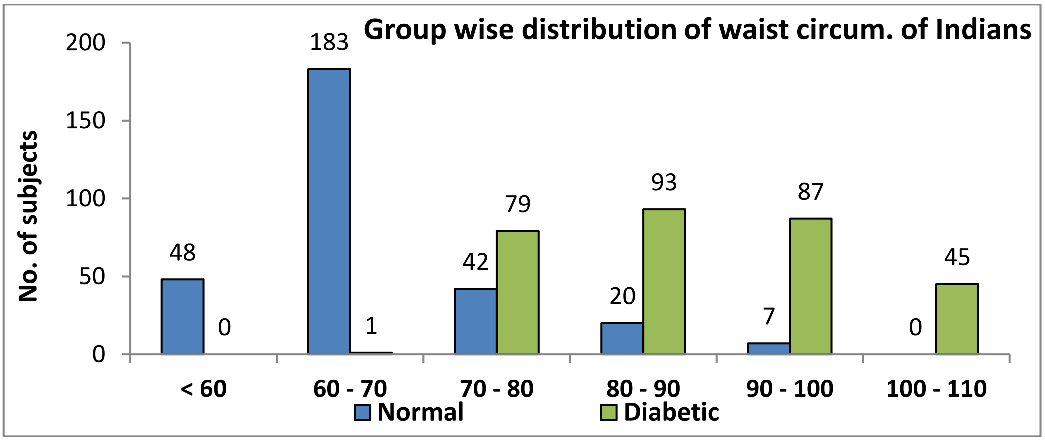

Figure 2: Group wise distribution of waist circum. of Indians

BMI, Waist, wrist and Hip circumference was significantly higher in diabetics ($p<0.001$). Thigh circumference was significantly higher in Normal group which resonates with previous studies showing higher thigh circumference as favorable factor and reduces the risk of T2DM. WHR and TWR was significantly higher in normal group ($p<0.001$). WHtR, ABI and WAR was significantly higher in diabetic group ($p<0.001$). Inverse ABI was significantly higher in normal group ($p<0.001$) and lowest in diabetic group.

Table 1: Anthropometric markers measurements from Normal and Diabetic group were subjected to Independent sample "T" Test. [Inverse ABI (Aarav body index) = (height + thigh Circumference)/ Waist Circumference, HtWR (height to waist

ratio), TWR (Thigh to waist ratio) and WAR (Wrist to arm ratio) to that of BMI (Body mass index), WHtR (Waist to height ratio) and WHR (Waist to hip ratio)]

Group Statistics					
	DM	N	Mean	Std. Deviation	Std. Error Mean
BMI*	Normal	300	25.68	2.07	.11
	Diabetic	305	31.83	3.34	.19
Waist C (cm)*	Normal	300	66.50	8.03	.46
	Diabetic	305	88.41	9.72	.55
Hip C (cm)*	Normal	300	70.92	8.92	.51
	Diabetic	305	96.74	11.51	.65
Thigh C (cm)*	Normal	300	52.40	4.16	.24
	Diabetic	305	50.04	2.90	.16
Arm C (cm)	Normal	300	31.75	2.80	.16
	Diabetic	305	31.22	2.62	.15
Wrist C (cm)*	Normal	300	15.91	1.99	.11
	Diabetic	305	16.54	1.19	.06
WHR*	Normal	300	.93817	.011925	.000688
	Diabetic	305	.91517	.023716	.001358
TWR*	Normal	300	.79440	.071247	.004113
	Diabetic	305	.56955	.034516	.001976
WAR*	Normal	300	.49979	.025996	.001501
	Diabetic	305	.53080	.021798	.001248
WHtR*	Normal	300	.39897	.037325	.002155
	Diabetic	305	.53531	.033496	.001918
ABI*	Normal	300	.30363	.029404	.001698
	Diabetic	305	.41056	.025316	.001450

Table 1: Anthropometric markers measurements from Normal and Diabetic group
*p-value < 0.001

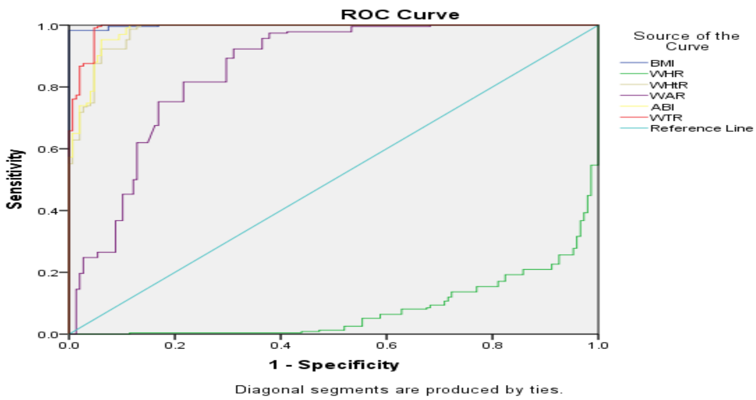

Figure 3: India: Receiver-operating characteristic curve (AROC) Curve in diabetic men: ABI (Arav body index=Waist Circumference / (height + thigh Circumference), WHtR (Waist to height ratio), BMI, WTR (Waist to thigh Ratio), WAR (Wrist to arm ratio) and WHR (Waist to hip ratio).

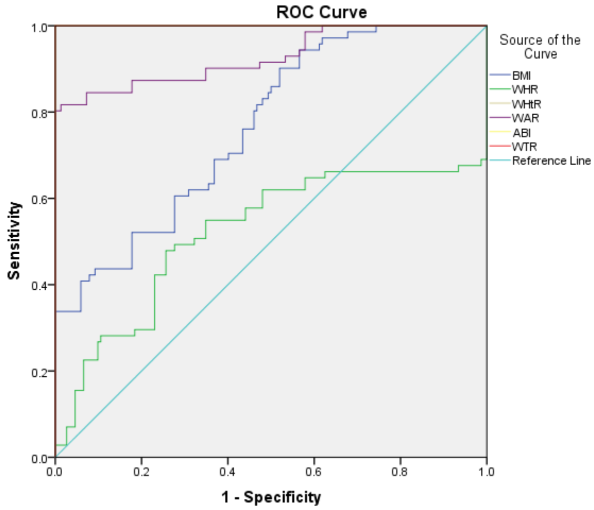

Figure 4: India: Receiver-operating characteristic curve (AROC) Curve in diabetic women: ABI (Arav body index=Waist Circumference / (height + thigh Circumference), WHtR (Waist to height ratio), BMI, WTR (Waist to thigh Ratio), WAR (Wrist to arm ratio) and WHR (Waist to hip ratio).

Table 2: Diabetes: AROC characteristics of the newer and existing Anthropometric indices in India. This table compares the AROC of ABI (Aarav body index), TWR (Thigh to waist ratio) and WAR (Wrist to arm ratio) to that of BMI (Body Mass index) and WHtR (Waist to height ratio). AROC values were subjected to Mann–Whitney U test considering Null hypothesis: true area = 0.5.*Significant correlation with diabetes (p-value <0.001)

Receiver-operating characteristic curve (AROC) (95% Confidence Interval) for predicting risk of diabetes in Indian population and comparing with other studies.				
Parameters	Study	Overall	Men	Women
BMI	Present study- India	.939 (.920, .958)	.998 (.996, 1.00)	.765 (.701, .829)
	Łopatyński 2003 (29)	0.731 (0.698, 0.765)		
	Mansour AA 2007 (30)		0.630 (0.620, 0.650)	0.590 (.570, .600)
	Khader Y 2009 (31)		.630 (.59, .61)	.700 (.67, .69)
	Zafari N et al 2018 (32)		.680 (.65, .71)	.720 (.70, .74)
ABI	Present study- India	.983 (.974,	0.987 (.976,	1.0 (1.0, 1.0)

		.992)	.998)	
WTR	Present study- India	.984 (.976, .991)	.991 (.984, .998)	1.00 (1.00, 1.00)
WAR	Present study- India	.876 (.849, .903)	.856 (.813, .898)	.928 (.886, .970)
WHtR	Present study- India	.982 (.974, .991)		
	Łopatyński 2003 (29)	.731 (.698, .763)		
	Mansour AA 2007 (30)		.700 (.68, .71)	.68 (.66, .69)
	Khader Y 2009 (31)		.73 (.70, .71)	.810 (.77, .78)
	Zafari N et al 2018 (32)		.690 (.67, .72)	.750 (.73, .78)

Table 2: Diabetes: AROC characteristics of the newer and existing Anthropometric indices in India

In Indian Diabetic group, BMI, WTR, ABI, WTR and WHtR showed superior values of AROC in Indian Diabetic group. WHR AROC values were not significant in both sexes. (See Figure 3-4; Table 2) Table 3: Cutoff values of the new and existing Anthropometric markers in diabetic men and women, and comparison with other studies. WC (wait circumference), HC (hip circumference), BMI (Body mass index), WHtR (Waist to height ratio), WHR (Waist to hip ratio), ABI (Aarav body index), TWR (Thigh to waist ratio) and WAR (Wrist to arm ratio).

Anthropo-metric markers	Sex	Present study India	Łopatyński J, 2003	Mansour AA, 2007	Khader Y, 2019	Zafari N, 2018	Mirzaei M, 2018	Qiao 2010
WC	Male	78	99	90	100	89	91	97-99
	Female	80	97	91	92	87	96	85
HC	Male	87	-	-	104	96	-	-
	Female	85	-	-	104	103	-	-
BMI	Male	28.2	27.9	25.4	27	25.56	26.2	-
	Female	26.1	29.2	26.1	30	27.12	25.9	-
WHtR	Male	0.52	0.57	0.52	0.57	0.52	0.56	-
	Female	0.43	0.62	0.56	0.60	0.56	0.60	-
WHR	Male	0.94	0.97	0.92	0.93	0.93	0.95	-
	Female	0.90	0.91	0.91	0.85	0.89	0.85	-
ABI	Male	0.38	-	-	-	-	-	-
	Female	0.34	-	-	-	-	-	-
WTR	Male	1.6	-	-	-	-	-	-
	Female	1.4	-	-	-	-	-	-

WAR	Male	0.50	-	-	-	-	-	-
	Female	0.42	-	-	-	-	-	-

Table 3: Cutoff values of the new and existing Anthropometric markers in diabetic men and women, and comparison with other studies.

Discussion

The study was carried out at NIMS hospital and several locations in Jaipur, India. Our sample size was sufficient based on the prevalence rate of diabetes in India. The values of ratios such as WTR (.984), ABI (.983), WHtR (.982) and BMI (.939) had the higher AROC values whereas WAR (876) was slightly lower and WHR was insignificant. The cut-off values for WC, HC, BMI, WHtR, WHR was 78, 87, 28.2, 0.52, and 0.94 respectively in Men. The cut-off values for WC, HC, BMI, WHtR, and WHR was 80, 85, 26.1, 0.43, and 0.90 respectively in Women. Cut-off values of these Anthropometric measurements and indices were comparable to that of various studies (29–34) but Waist and Hip circumference were lower in the Indian group (See Table 3). Cut-off values of Waist circumference in studies by Mohan et al and Diaz et al were higher than that of present study (35,36). The higher Waist circumference has been closely related with T2DM and Obesity. It is clear in our study in both India and Saint Kitts. Indian study showed better correlation (AROC- 0.953) as compared to Saint Kitts study (AUROC- 0.684) in general (Both males and females combined). These findings are in coherence with other studies compared in table 3. This highlights importance of waist circumference as well as basis of its inclusion in important Anthropometric marker worldwide such as Waist-to-Height ratio and in ABI in this study. Increased Mid arm circumference has been associated and has shown positive results in insulin resistance individuals with normal BMI (37). Our study aimed to assess if the Mid Upper Arm Circumference can be used as a marker of central obesity and Insulin Resistance in type 2 diabetes patients. Researchers have shown that MUAC can predict overweight and excess fatness in individuals with reasonable accuracy. Our study did not find value of significance in inclusion of Arm circumference in Wrist-to-arm ratio as reliable marker in predicting T2DM or HTN in India. Every 1cm increase in circumference of thigh was associated with a 3% reduction in the risk of all-cause mortality but was not related with any change in the risk of cerebrovascular mortality. The decrease in thigh circumference has been associated with insulin resistance, atherosclerosis, and risk of T2 DM (38). Small thigh circumference was significantly related with greater risk of diabetes among men and women. Studies have shown among women, diabetes risk increased with smaller thigh circumference. Smaller thigh circumference was associated with diabetes, and this association was stronger among participants with a BMI of less than 25 kg/m2. Thigh circumference might be a significantly vital diabetes marker in lean populations (39). That was the basis of adding thigh circumference to denominator of the ABI. One of the limitations of the study was the results are just representative of a smaller proportion of the Indian population as more studies are needed in different geographical location within India to get a better picture. We recommend having a long-term follow-up study with enrolled participants to see how lifestyle changes influence the Anthropometric markers and the quality of life over timeline.

Conclusion

Obesity has been uprising global health problem and is closely linked with various cardiovascular conditions like hypertension and T2DM in all ethnic groups. Anthropometric markers have been used in various studies to measure both general as well as central adiposity. Due to increasing incidences of obesity, steps to prevent obesity have favorable Anthropometric measurements hence can prevent development of diabetes. BMI has not found to be in general reliable marker which opens avenue of search for newer markers which can better access the presence of Abdominal fat and associated CVD, T2DM and hypertension. WAR, one of the newer markers, showed limited evidence of reliability whereas ABI, Inverse ABI, TWR has been found to be potential reliable markers in identifying individuals at-risk of development of T2DM. There is more research needed in different geographical locations and ethnicity to affirm its usefulness globally.

Our results have shown, to determine risk of T2DM ABI, WHtR, BMI and WTR as superior Anthropometric marker compared to WAR and WHR. ABI index of less than 0.32 in Indian population reduces the likelihood of development of type 2 Diabetes mellitus. Exercise and lifestyle modifications can reduce the waist circumference and can help in reducing ABI index. We conclude that ABI, WHtR and WTR could be a more reliable tool for identifying individuals at risk of developing type 2 DM. Exercise and lifestyle modifications can address the modifiable risk factors can delay or prevent development of chronic diseases such hypertension and Diabetes.

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