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Original Article

Anatomy Section

Determining New Anthropometric Markers for Screening Hypertension in the Caribbean Region

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ABSTRACT

Introduction: The prevalence of hypertension in the Caribbean is high [26% in Saint (St.) Kitts]. It contributes to 51% of deaths secondary to ischemic heart disease and hence being a leading cause of death in the Caribbean region.

Aim: To determine the association between Indices using height, waist, hip, thigh, arm, and wrist circumference (cm) with development of hypertension and to compare existing markers in test subjects and assessing their feasibility as predictive indicators for the development of hypertension.

Materials and Methods: In the present cross-sectional study, a total of 635 subjects were involved in the study which included health centres and health camps in St. Kitts (West Indies). Study was conducted from December 2019 to November 2020. Height to Waist Ratio (HtWR), Arav Body Index (ABI), Waist to Thigh Ratio (WTR) and Wrist to Arm Ratio (WAR) was compared to common existing markers such as Waist to Height Ratio (WHtR), Waist to Hip Ratio (WHR) and Body Mass Index (BMI). Statistical analysis was done using using IBM Statistical Package for the Social Sciences (SPSS) version 23.0.

Results: A total of 635 participants were included with most of the participants (n=540) between age group of 40 to 70 years, 35.4% (n=225) of participants were males and 64.6% (n=410) were females. In the present study, 47.92% (n=304) were non hypertensive and 52.1% (n=331) were hypertensive. In males, Area Under Receiver Operating Curve (AUROC) of HtWR (0.690) and Inverse ABI (0.632) was superior as compared to other anthropometric markers for predicting the development of hypertension and Waist to Thigh Ratio (WTR) (0.687) was superior in females. Among females recommended cut-off values for WTR is 1.6 and among males for HtWR and Inverse ABI were 2.3 and 2.84, respectively.

Conclusion: Height to waist ratio and inverse ABI were more reliable markers in males for predicting the development of hypertension whereas, WTR being more reliable in females in population of St. Kitts. This will help at risk individuals to take preventive measures like lifestyle modification.

Keywords: Anthropometric measures, Arav body index, Height to waist ratio, Receiver operating characteristics

INTRODUCTION

The number of patients with hypertension is likely to grow as the population ages and grow old, since either isolated systolic hypertension or combined systolic and diastolic hypertension occurs in the majority of persons older than 65 years. Hypertension is a major risk factor for cardiovascular diseases in Caribbean region and globally too. It contributes to 51% of deaths secondary to ischemic heart disease and hence being a leading cause of death in the Caribbean region [1]. The rate of occurrence of obesity will also increase the number of hypertensive individuals and can also be associated with early onset of hypertension.

Several reports indicates that there is higher prevalence of hypertension in the Caribbean region. Hypertension affects around 21% of adults from Barbados and Trinidad and Tobago region. 25% of adults are affected in Jamaica [2] and as high as 26% are affected in St. Kitts and Nevis region [3]. Such higher prevalence of hypertension can place a high burden of its known complications and overall health care costs. Reports from many Caribbean regions show prevalence of hypertension among males is higher than females [4].

Risk factors associated with hypertension can be classified as modifiable and non modifiable risk factors. Non modifiable risk factors are those characteristics in the patient which cannot be changed. Hence, not much can be done to address such risk factors. Modifiable risk factors are those which can be intervened and changed such as obesity, high fat intake, high dietary salt consumption, sedentary lifestyle and excessive tobacco or alcohol consumption [5]. Certain dietary habits especially high salt intake is associated with hypertension and cardiovascular diseases. Almost 30% of cases of hypertension is associated with high dietary sodium intake [6,7]. Once the modifiable risk factors are identified then necessary lifestyle modifications can be implemented to control hypertension. The present study assesses the anthropometric indices as a tool to determine the risk of development of hypertension in an individual so that early interventions can be implemented to prevent development of hypertension. Obesity related hypertension and level of leptin and insulin in the body needs further attention and research. Studies have shown activation of Sympathetic Nervous System (SNS) in obese individuals particularly in abdominal fat accumulation particularly in males [8,9]. These findings have great implications for knowing at risk patients with visceral obesity [8].

In Jamaica, a Caribbean island, about 28% of hypertensive patients had well controlled blood pressure which were assessed over a period from 1995 to 2013. One of the important reasons contributed to improvement was ease of availability of effective antihypertensive medications like Angiotensin Converting Enzyme (ACE) inhibitors, Angiotensin Receptor Blockers (ARBs) and Calcium Channel Blockers (CCBs) compared to conventional drugs [10]. The uncontrolled hypertension can lead to emergency hypertension which is associated with evidence of end organ damage including stroke, myocardial infarction, cardiac failure, dementia, renal failure, and blindness [11,12].

BMI has been long standing traditional anthropometric markers used worldwide and it defines degree of obesity. There has been increase in trend in exploration of newer markers like waist and hip circumferences, WHR, WHtR among others which can show better relationship with obesity and correlation with development of cardiovascular disorders and Type 2 Diabetes Mellitus (T2DM) [13].

The Waist Circumference (WC) has gathered quiet an attention over the years as a reliable indicator of abdominal adiposity and its relationship with cardiovascular disorder. One of the reasons for emerging anthropometric markers is BMI fails to discern between the muscle mass and body fat, especially abdominal fat in males, hence is not a reliable indicator for obesity and is not a strong discriminator of cardiovascular disease risk factor [14,15]. The markers involving WC like WHR and WHtR are used as markers to establish degree of body fat centralisation [16-18]. Various studies have shown strong correlation of central distribution of body fat with hypertension [16,19,20]. Due to higher prevalence of hypertension in the Caribbean and questionable reliability of the conventional anthropometric markers, there is a need to explore newer and more reliable anthropometric markers, as well as to ascertain the validity of existing markers in screening subjects at risk of development of hypertension.

The primary objective of the study was to evaluate ability of ABI, WTR and WAR in determining association with hypertension. 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 Caribbean population.

MATERIALS AND METHODS

The present cross-sectional population-based study involved subjects utilising all health centres and health fairs in St. Kitts and Nevis region. Ethnicity and sex was self-reported. A written consent was taken from the participant for participation in research study. The study duration was of one year (December 2019 to November 2020). Participants were divided into two groups, as non hypertensive group and hypertensive group. The study was reviewed and approved by Interim Ethics Review Committee (IERC-2019-11-031) under Ministry of health, St. Kitts and Nevis.

Sample size calculation: The sample size was calculated based on prevalence of the hypertension in 26% of the population of St. Kitts and Nevis [3] using $n=z^2pq/e^2$ wherein, n=sample size, p=estimated prevalence of hypertension, q=1-p, z=1.96 for a confidence level (α) of 95% and e^2 is margin of error [21]. $N=1.962\times0.26\times0.74/(0.05)^2=296$. The minimum sample size required was 296 subjects in each group.

Inclusion criteria: Subjects with age between 20 to 70 years and with self-reported history of hypertension and subjects without history of hypertension were included in the study.

Exclusion criteria: Subjects who were pregnant and lactating at the time of study, recorded weight was incomplete or implausible (eg., BMI <15 or >45 kg/m^2; 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 body building and athletic events/sports since past one month were also excluded. Subjects with T2DM were excluded from this study.

Hypertension was defined based on self reported physician-diagnosed hypertension or self reported current intake of anti-hypertensive medication during the seven 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 Organisation (WHO) was used [22].

The WC was measured to the nearest centimeter using a flexible tape with the respondent standing. In females, the abdominal circumference (waist) was measured as the narrowest part of the body between chest and hips and in males 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 were measured in centimeters.

The WHR was determined by dividing WC by hip circumference (cm). WHtR is defined as WC 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. HtWR which is inverse of WHtR was also taken into consideration. TWR was determined by dividing WC by thigh circumference (cm). WAR was determined by dividing wrist circumference by arm circumference. ABI is newer index was measured using following equation: ABI=WC/(Thigh circumference+Height) (all units in cm) [23]. Blood pressure was taken in a seated position and on the right arm by trained health workers who did follow a standardised 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). Mean was compared using independent t-test. Receiver-Operating Characteristic (ROC) curve analysis was used to examine the overall discriminatory power represented by Receiver-Operating Characteristic Curve Analysis (AROC), sensitivity and specificity, and corresponding cut-off points of each of the anthropometric indices for hypertension using IBM SPSS version 23.0.

RESULTS

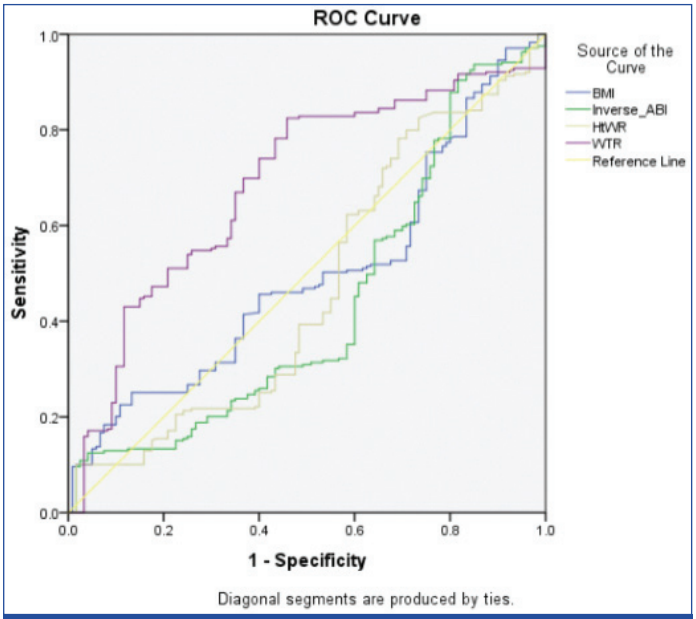
In the present study, out of 635 participants 47.9% were non hypertensive (n=304) and 52.1% (n=331) hypertensive, 15% (n=95) were between age group 20 to 39 years and 85% (n=540) were between age group 40 to 70 years. A 35.4% (n=225) of participants were males and 64.6% (n=410) were females. The study participant's mean weight (Kg), height (cm), WC (cm), hip circumference (cm), thigh circumference (cm), arm circumference (cm) and wrist circumference (cm) were 80.16±18.41, 167.70±11.47, 90.50±13.63, 103.80±15.04, 52.87±11.36, 30.71±6.55 and 16.03±2.44, respectively.

The ABI had lower AROC and was not significant marker in the development of hypertension whereas 1/ABI (Inverse ABI) showed higher AROC and significant association hence, inverse ABI was used in the present study. The means of anthropometric measurements and indices (hypertensive and non hypertensive groups) were subjected to independent sample t-test. There was no significant difference between the mean height between hypertensive (167.84±11.43 cm) and non hypertensive (167.70±11.47 cm) groups. There was no significant difference in weight, thigh, hip, arm circumference, WAR and WTR in either group. Waist, wrist circumference, inverse ABI, BMI, WHR and WHtR was significantly lower in hypertensive group (88.55±14.18, 15.77±2.55, 28.39±6.90, 0.86±.08, 0.52±0.08, respectively) compared to non hypertensive group (92.63±12.70, 16.32±2.29, 29.0±5.97, 0.88±.07, 0.55±0.08, respectively). Mean HtWR and inverse ABI were significantly higher in hypertensive group (1.94±.36, 2.41±.30) compared to non- hypertensive group (1.84±.27, 2.55±.46, respectively) [Table/Fig-1].

Variable	Overall (635)	Non hypertensive (n=304)	Hypertensive (n=331)
Height (cm)	167.70±11.47	167.53±11.54	167.84±11.43
Weight (Kg)	80.16±18.41	81.36±18.38	79.06±18.40
Waist (cm)* (p-value <0.001)	90.50±13.63	92.63±12.70	88.55±14.18
Thigh (cm)	52.87±11.36	53.01±7.47	52.74±14.02
Hip (cm)	103.80±15.04	104.67±11.52	103±17.65
Arm (cm)	30.71±6.55	30.66±4.82	30.76±7.82
Wrist (cm)	16.03±2.44	16.32±2.29	15.77±2.55
BMI (kg/m^2)	28.71±6.48	29.0±5.97	28.39±6.90
WHR	0.87±0.08	0.88±0.07	0.86±0.08
WHtR	0.54±0.08	0.55±0.08	0.52±0.08
HtWR* (p-value <0.001)	1.89±0.32	1.84±0.27	1.94±0.36
Inverse ABI* (p-value <0.05)	2.49±0.40	2.41±0.30	2.55±0.46
WTR	1.75±0.29	1.76±0.22	1.74±0.33
WAR	0.53±0.1	0.53±0.07	0.53±1.0

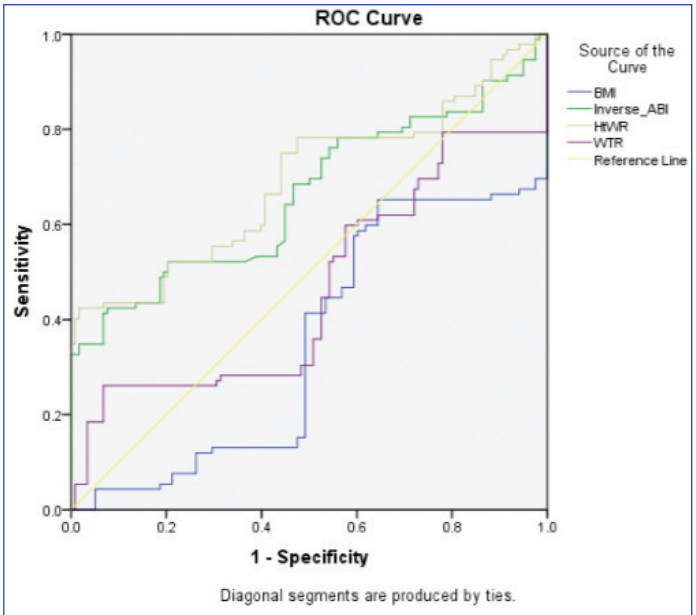
[Table/Fig-1]: Comparison of the means of anthropometric measurements and indices (hypertensive and non hypertensive groups) by using independent student t-test. *Significant difference between the hypertensive and non hypertensive groups; BMI: Body mass index; WHtR: Waist to height ratio; WHR: Waist to hip ratio; Inverse ABI: Aarav body index; HtWR: Height to waist ratio; WTR: Waist to thigh ratio and WAR: Wrist to arm ratio

Inverse ABI, HtWR in males and WTR in females showed superior values of AROC compared to WHtR, WAR and BMI. AROC of BMI and WtHR were low and not significant in both males and females as compared to studies in done in geographical locations of Iraq, Korea, China and Jordan [24-27]. HtWR and Inverse ABI were more reliable markers in males for predicting the development of hypertension whereas, WTR being more reliable in females. The present study has not shown commonly used anthropometric markers such as BMI, WHR and WHtR as reliable in predicting development of hypertension in population of Saint Kitts [Table/Fig-2,3,4] [24-27].



[Table/Fig-2]: Receiver-operating characteristic curve (AROC) Curve in females: Inverse ABI=(height+thigh Circumference)/Waist Circumference, HtWR (height to waist ratio), WTR (Waist to thigh Ratio) and BMI.

The cut-off values for WC, HC, BMI, WHtR, HtWR, WHR, inverse ABI, WTR and WAR was 100.8, 121.4, 24.27, 0.57, 2.30, 0.96, 2.84, 2.0, 0.66 respectively in males. The cut-off values for WC, HC, BMI, WHtR, HtWR, WHR, Inverse ABI, WTR and WAR was 84.4, 122.2, 33.9, 0.54, 1.64, 0.87, 2.13, 1.6, 0.41, respectively in females. Cut-off values of these anthropometric



[Table/Fig-3]: Receiver-operating characteristic curve (AROC) Curve in males: Inverse ABI=(height+thigh Circumference)/Waist Circumference, HtWR (Height to waist ratio), WTR (Waist to thigh Ratio) and BMI.

Receiver-Operating Characteristic Curve (AROC) (95% Confidence interval)				
Parameters	**Study**	**Overall**	**Males**	**Women**
BMI	Present study	0.474 (0.426, 0.522)	0.350 (0.274, 0.426)	0.497 (0.435, 0.559)
	Mansour AA and Al-Jazairi MI [24]	-	0.700 (0.680, 0.65)	0.650 (0.640, 0.670)
	Wang Q et al., [25]	0.593	-	-
	Khader Y et al., [26]	-	0.680 (0.600, 0.760)	0.740 (0.690, 0.790)
	Lee JW et al., [27]	-	0.580	0.570
Inverse ABI	Present study	0.496 (0.448, 0.544)	0.662 (0.585, 0.740)*	0.435 (0.370, 0.500)
HtWR	Present study	0.504 (0.456, 0.551)	0.690 (0.615, 0.766)*	0.469 (0.403, 0.534)
WTR	Present study	0.565 (0.518, 613)*	0.464 (0.381, 0.546)	0.687 (0.629, 0.745)*
WAR	Present study	0.447 (0.400, 0.495)	0.498 (0.412, 0.585)	0.502 (0.438, 0.566)
WHR	Present study	0.481 (0.433, 0.528)	0.445 (0.357, 0.533)	0.557 (0.494, 0.619)
	Mansour AA and Al-Jazairi MI [24]	-	0.730 (0.710, 0.740)	0.700 (0.680, 0.710)
	Wang Q et al., [25]	0.671 (0.568, 0.775)	-	-
	Khader Y et al., [26]	-	0.690 (0.640, 0.780)	0.750 (0.700, 0.800)
	Lee JW et al., [27]	-	0.620	0.680
WHtR	Present study	0.496 (0.449, 0.544)	0.310 (0.234, 0.385)	0.531 (0.466, 0.597)
	Mansour AA and Al-Jazairi MI [24]	-	0.760 (0.76, 0.780)	0.730 (0.710, 0.740)
	Wang Q et al., [25]	0.682 (0.591, 0.772)	-	-
	Khader Y et al., [26]	-	0.720 (0.660, 0.790)	0.810 (0.760, 0.850)
	Lee JW et al., [27]	-	0.620	0.680

[Table/Fig-4]: AROC characteristics of the newer and existing Anthropometric indices. This table compares the AROC of Inverse ABI (Aarav body index)=(height+thigh Circumference)/ Waist circumference; HtWR (height to waist ratio); TWR: Thigh to waist ratio; WAR: Wrist to arm ratio; BMI: Body mass index; WHtR: Waist to height ratio and WHR: Waist to hip ratio; AROC values were subjected to Mann-Whitney U test considering Null hypothesis: true area=0.5; *Significant association with hypertension (p<0.001)

measurements and indices were comparable to that of various studies [Table/Fig-5] [24-29].

Anthropometric markers	Sex	Present study	Lee JW et al., [27]	Wang Q et al., [25]	Mansour AA and Al-Jazairi MI [24]	Khader Y et al., [26]	Gupta S and Kapoor S. [28]	Sarry El Din AM et al., [29]
WC	Male	100.8	83.33	84.5*	95	100	92	95.75
	Female	84.4	80.37		95	92	91.3	87.75
HC	Male	121.4	-	-	-	104	-	-
	Female	122.2	-	-	-	102	-	-
BMI	Male	24.27	25.63	25.4*	24.9	27	22.8	27.98
	Female	33.91	23.59		26.5	30	28.8	30.0
WHtR	Male	0.57	0.49	0.51*	0.55	-	0.56	0.57
	Female	0.54	0.51	-	0.59	-	0.43	0.65
HtWR	Male	2.30	-	-	-	-	-	-
	Female	1.64	-	-	-	-	-	-
WHR	Male	0.96	0.88	0.85*	0.92	0.93	0.9	0.92
	Female	0.87	0.86		0.91	0.85	0.78	0.81
Inverse ABI	Male	2.84	-	-	-	-	-	-
	Female	2.17	-	-	-	-	-	-
WTR	Male	2.0	-	-	-	-	-	-
	Female	1.6	-	-	-	-	-	-
WAR	Male	0.66	-	-	-	-	-	-
	Female	0.41	-	-	-	-	-	-

[Table/Fig-5]: Cut-off values of the new and existing Anthropometric markers for development of hypertension using Youden index in males and females, and comparison with other studies [24-29].
WC: Waist circumference; HC: Hip circumference; BMI: Body mass index; WHtR: Waist to height ratio; WHR: Waist to hip ratio; Inverse ABI: Aarav body index, HtWR: Height to waist ratio; TWR: Thigh to waist ratio and WAR: Wrist to arm ratio; *Results from both the sexes combined

DISCUSSION

BMI has been weakest predictor of the hypertension as compared to other markers and the data is comparable to studies by Wang Q et al., and Lee JW et al., has contrasting evidence [25,27] with that of Mansour AA and Al-Jazairi MI and Khader Y et al., [24,26]. Authors determine that BMI is not reliable marker in determining development of hypertension, but it was more reliable in predicting T2DM [23].

A study in Tehran showed WC as an important marker in predicting development of hypertension but this study did not show the significant association [30]. In the present study, WHR and WHtR did not show strong association in determining development of hypertension as shown by other studies compared in [Table/Fig-4]. Interestingly, inverse of WHtR i.e., HtWR and Inverse ABI (in males) showed significant association in development of hypertension.

Shi J et al., noted in their study in China that thigh circumference was negatively correlated with systolic and diastolic blood pressure. Individuals with larger thigh circumference group had lower risk of hypertension in both overweight individuals and obese individuals [31]. Larger thigh circumference tends to reduce WTR and risk of hypertension. In this study, WTR is significantly associated with the development of hypertension in females but not in males.

HtWR (0.690) and inverse ABI (0.662) had the highest AUROC value in males and WTR (0.687) in females among other compared adiposity indices such as WHtR, WHR, WAR and BMI. The results were contrasting in the present study compared to those done in geographical locations of Iraq, Korea, China and Jordan [24-27]. This may be due to the present study population was predominantly of African descent and significant variation in some of the anthropometric markers is expected, for example in hip circumference and BMI. More studies in the other Caribbean regions are needed to support these results.

The cut-off values with sensitivity and specificity for HtWR, inverse ABI and WTR were 2.3 (0.424, 0.966), 2.84 (0.424, 0.915) and 2.0 (0.261, 0.805) in males and 1.64 (0.782, 0.444), 2.13 (0.904, 0.287) and 1.6 (0.824, 0.433) in females, respectively. Among females, with WTR>1.6, 67% (n=197) had hypertension, 33% (n=97) did not have hypertension. Among males with HtWR of > 2.3, 91% (n=39) had hypertension and 9% (n=4) did not. For inverse ABI of >2.84, 81% of males (n=34) had hypertension and 19% (n=9) did not.

Limitation(s)

The limitations of the present study were inclusion of younger population, as the chronic diseases such as hypertension and T2DM usually onset at an age of 40 years and above [32]. Since this was a health-centre based study, the likelihood of hypertension was more among the participants which possibly contributed to the high prevalence rate. The results were just representative of a smaller proportion of the Caribbean population, so more studies are needed in different geographical location within the Caribbean region to get a better picture.

CONCLUSION(S)

The present study results have shown WTR, HtWR and Inverse ABI in both males and females as superior anthropometric marker compared to WHtR, WAR, WHR and BMI. HtWR of less than 2.3 (males), Inverse ABI of less than 2.8 (males), and WTR of less than 1.6 (females) reduces the likelihood of development of hypertension. Exercise and lifestyle modifications can address the modifiable risk factors can delay or prevent development or progression of hypertension. We conclude that HtWR, Inverse ABI and WTR could be a more reliable tool for identifying individuals at risk of development of hypertension and will help them to take preventive measures like lifestyle modification. Authors 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.

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