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Waist-height ratio: How well does it predict glucose intolerance and systemic hypertension?

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ABSTRACT

Aim: The aim of this study is to assess whether WHtR is a better predictor of glucose intolerance and systemic hypertension than some other obesity indices.
Methods: This is a cross-sectional observational study among four hundred (4 0 0) participants in a Northern Nigerian population. Four (4) participants were eventually excluded due to incomplete data, therefore data from three hundred and ninety six (3 9 6) participants were used in the final analysis. The study assessed whether WHtR is a better predictor of glucose intolerance and systemic hypertension compared to some other obesity indices. Participants were recruited after due consent, then bio-data, blood pressure levels, and some anthropometric measurements were obtained. Subsequently, plasma glucose levels (fasting [FPG] and 2-hour post 75 g glucose load [2HrPPG]) were measured. Data was entered into Microsoft Excel, then analyzed using IBM SPSS version 23.
Results: Data from three hundred and ninety six (3 9 6) participants (4 excluded due to incomplete details) were analyzed. Logistic regression of obesity indices showed that WHtR was the best predictor of glucose intolerance with odds ratio (OD) of 20.74 (CI 2.80-155, $p < 0.001$), followed by WC with OD of 1.89 (CI 1.83-3.94, $p < 0.001$), then WHR with OD of 1.69 (CI 1.06-8.22, $p = 0.009$). The least but significant predictor of glucose intolerance was BMI with odds ratio of 1.12 (CI 1.06-3.18, $p < 0.001$).

Furthermore, logistic regression of obesity indices showed that WHtR was the strongest predictor of systemic hypertension with OD of 2.32 (CI 4.85-14.96, $p < 0.001$), followed by BMI (OD 1.99, CI 1.96-2.05, $p = 0.031$), then WC (OD 1.95, CI 1.90-1.99, $p = 0.020$). The weakest predictor of systemic hypertension was WHR (OD 1.26, CI 0.04-1.88, $p = 0.181$).
Conclusion: WHtR had the highest predictive power for both glucose intolerance and systemic hypertension compared to BMI, WC, and WHR.

1. Introduction

Waist-height ratio (WHtR) is defined as waist circumference divided by height, both measured in the same units. The WHtR is a measure of the distribution of body fat where higher values indicate higher risk of obesity-related cardiovascular diseases. [1–3] Schneider et al. [4] followed 11,000 subjects for up to eight years, then concluded that WHtR is

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a much better measure of the risk of heart attack, stroke or death than the more widely used body mass index.

Furthermore, a systematic review by Browning et al. [5] showed that a WHtR of over 0.5 is critical and signifies an increased risk. They concluded that WHtR may be advantageous because it avoids the need for age-, sex- and ethnic-specific boundary values. Ashwell et al. [6] corroborated that the waist-to-height ratio (WHtR) is an alternative anthropometric index of central obesity that circumvents the limitations of WC. They asserted that it is a rapid and effective global indicator for health risks of obesity and its use could simplify the international public health message on obesity. They further stressed that due to the inclusion of height into the index, any potential confounding of cardio-metabolic risk by height is avoided.

In a similar vein, WHtR has been shown to denote cardiometabolic risk among individuals who are not obese according to other anthropometric indices. [7–11] Li et al. [8] reported that WHtR was a greater predictor of diabetes, hypertension, and dyslipidaemia compared to BMI or WC. They added that patients of either sex with a normal BMI or WC level, but with an elevated WHtR, had higher levels of various cardiometabolic risk factors when compared to those with normal BMI, WC, and WHtR.

In a study of some urban Nigerians, Olatunbosun et al. [9] reported that WHtR was predictive of plasma glucose and diastolic blood pressure while WC was mainly predictive of glucose intolerance. In other Nigerian studies, Oguoma et al, Adejumo et al, and Akinlade et al. reported that WHtR significantly predicted metabolic syndrome. In addition, Ononamadu et al, Ambakederemo et al, and Muluvhu et al. showed that females had significantly higher BMI, WC, and WHtR than males.

With regards to systemic hypertension, Ononamadu et al. [11] reported that the mean values of BMI, WHtR, and WC studied increased from normotension, through prehypertension to hypertension in both genders. Abiodun et al. and Wariri et al. also showed that BMI, WC, and WHtR were positively correlated with blood pressure.

Though WHtR is not commonly used in routine clinical practice to assess obesity, the aim of this study is to assess whether it is a better predictor of glucose intolerance and systemic hypertension than some other obesity indices. Screening using obesity index that best predict glucose intolerance and systemic hypertension will aid in early adoption of measures that will prevent or delay glucose intolerance and systemic hypertension.

2. Materials and methods

This was a cross-sectional observational study carried out in Zaria, Northern Nigeria. Zaria is a major city in Kaduna State of Northern Nigeria. The predominant occupation of the men includes farming and trading while the women are mainly housewives who engage in domestic works.

This study was approved by the Ethics Committee of Ahmadu Bello University Teaching Hospital Zaria in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Three hundred and ninety six (3 9 6) participants who satisfied the inclusion criteria were enrolled after four (4) participants were excluded due to incomplete data. Inclusion criteria included subjects who were not previously known to have diabetes within the age of 18 to 70 years while exclusion criteria included subjects known to have diabetes mellitus, subjects on medications that affect glucose metabolism such as steroids, thiazides, beta blockers or HIV protease inhibitors, and subjects who declined consent.

Sample selection was achieved by cluster random sampling from ten (10) communities in Zaria. Subsequently, forty (40) participants were selected in each community by simple random sampling. However, four (4) participants were excluded from final enrolment due to incomplete data. The essence and procedures of the study were explained to each subject and consent subsequently obtained before enrolment. Data collected included bio-data, blood pressure, some anthropometric indices, and laboratory investigation results (FPG, 2hrPPG).

Measurements of obesity indices were carried out by the investigator assisted by trained health personnel. The standing height of each participant was measured using a stadiometer (Seca 213 portable stadiometer, Seca North

Table 1 – Characteristics of the study population with respect to gender.

	F	M	Total		
Variable	Mean(SD)	Mean(SD)	Mean(SD)	t	p-value
AGE(yrs)	41.26(11.17)	39.54(9.41)	40.44(10.39)	−1.645	0.101
BMI(Kg/m^2)	27.33(5.93)	26.77(5.87)	27.07(5.90)	-0.941	0.347
WC(cm)	88.09(11.63)	87.72(12.98)	87.91(12.28)	-0.297	0.767
WHR	0.90(0.15)	0.97(0.16)	0.93(0.16)	4.769	<0.001
WHtR	0.56(0.09)	0.55(0.10)	0.56(0.09)	−1.337	0.182
SBP(mmHg)	132.42(21.80)	129.30(21.79)	130.93(21.83)	−1.425	0.155
DBP(mmHg)	81.99(14.94)	82.02(13.62)	82.01(14.31)	0.021	0.983
MAP(mmHg)	98.80(15.16)	97.78(14.77)	98.31(14.97)	-0.678	0.498
FPG(mmol/L)	5.22(2.27)	5.12(2.10)	5.17(2.19)	-0.466	0.641
2HrPPG(mmol/L)	6.60(3.62)	6.42(3.18)	6.51(3.41)	-0.542	0.588

F = female, M = male, SD = standard deviation, BMI = body mass index, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio, SBP = systolic blood pressure, DBP = diastolic blood pressure, MAP = mean arterial pressure, FPG = fasting plasma glucose, 2-hour post 75 g glucose load plasma glucose, t = student ‘t’ test.

America, USA). The head was positioned in the Frankfort horizontal position then the height measured to the nearest 0.1 cm. [12]

A beam balance (Seca 700 series, Seca North America, USA) was then used to weigh the participants in kilograms. They were asked to wear only light clothings, stand in the center of the scale platform with hands at the sides, looking straight ahead, and weight evenly distributed. The weight was then recorded in kilograms to the nearest 0.5 kg. The body mass index (BMI) in kg/m^2 was calculated by dividing weight (kg) by the square of height (m^2). Overweight was defined as BMI of 25.0–29.9 kg/m^2 and obesity as BMI of $\geq$30.0 kg/m^2. Waist circumference (WC) was measured using a measuring tape (NON 171330, 72″, Medline industries Inc., USA). Each subject was instructed to cross the arms and place the hands on opposite shoulders. The WC was measured to the nearest 0.1 cm mid-way between the iliac crest and the costal margin along the mid-axillary line. According to

Table 2 – . Prevalence of general and central obesity with respect to gender.

Obesity class		BMI		WC		WHR		WHtR	
		F	M	F	M	F	M	F	M
Normal	Count	12	10	50	131	42	79	51	64
	% within sex	5.8%	5.3%	24.2%	69.3%	20.3%	41.8%	24.6%	33.9%
	% of Total	3.0%	2.5%	12.6%	33.1%	10.6%	19.9%	12.9%	16.2%
Obese	Count	132	112	157	58	165	110	156	125
	% within sex	63.8%	59.3%	75.8%	30.7%	79.7%	58.2%	75.4%	66.1%
	% of Total	33.3%	28.3%	39.6%	14.6%	41.7%	27.8%	39.4%	31.6%
Total	Count	207	189	207	189	207	189	207	189
	% within sex	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	% of Total	52.3%	47.7%	52.3%	47.7%	52.3%	47.7%	52.3%	47.7%

F = female, M = male, BMI = body mass index, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio.

Table 3 – Prevalence of glucose intolerance among obese persons by different obesity indices.

Obesity class		BMI		WC		WHR		WHtR	
		G.Int	normal	G.Int	normal	G.Int	normal	G.Int	Normal
Normal	Count	0	22	28	153	21	100	5	110
	% within Oclass	0.0%	100.0%	15.5%	84.5%	17.4%	82.6%	4.3%	95.7%
	% of Total	0.0%	5.6%	7.1%	38.6%	5.3%	25.3%	1.3%	27.8%
Obese	Count	90	154	77	138	84	191	100	181
	% within Oclass	36.9%	63.1%	35.8%	64.2%	30.5%	69.5%	35.6%	64.4%
	% of Total	22.7%	38.9%	19.4%	34.8%	21.2%	48.2%	25.3%	45.7%
Total	Count	105	291	105	291	105	291	105	291
	% within Oclass	26.5%	73.5%	26.5%	73.5%	26.5%	73.5%	26.5%	73.5%
	% of Total	26.5%	73.5%	26.5%	73.5%	26.5%	73.5%	26.5%	73.5%

G.Int = glucose intolerance, Oclass = obesity class (normal, obese), BMI = body mass index, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio.

Table 4 – Prevalence of systemic hypertension among obese persons by different obesity indices.

Obesity class		BMI		WC		WHR		WHtR	
		HTN	normal	HTN	normal	HTN	Normal	HTN	Normal
Normal	Count	4	18	66	115	47	74	36	79
	% within Oclass	18.2%	81.8%	36.5%	63.5%	38.8%	61.2%	31.3%	68.7%
	% of Total	1.0%	4.5%	16.7%	29.0%	11.9%	18.7%	9.1%	19.9%
Obese	Count	101	143	92	123	111	164	122	159
	% within Oclass	41.4%	58.6%	42.8%	57.2%	40.4%	59.6%	43.4%	56.6%
	% of Total	25.5%	36.1%	23.2%	31.1%	28.0%	41.4%	30.8%	40.2%
Total	Count	158	238	158	238	158	238	158	238
	% within Oclass	39.9%	60.1%	39.9%	60.1%	39.9%	60.1%	39.9%	60.1%
	% of Total	39.9%	60.1%	39.9%	60.1%	39.9%	60.1%	39.9%	60.1%

Oclass = obesity class (normal, obese), BMI = body mass index, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio, HTN = hypertension.

International Diabetes Federation (IDF), values ≥94 cm for male subjects and ≥80 cm for female subjects were used to define central obesity. [13]

Each subject was asked to stand up with feet together and weight evenly distributed on both feet, the hip circumference was then measured to the nearest 0.1 cm with a measuring tape placed around the hip at the level of the greater trochanters. If the greater trochanter was not palpable, the largest horizontal girth around the buttocks was used. [14] Waist-hip ratio (WHR) was obtained by dividing WC(cm) by hip circumference (cm). According to the World Health Organization (WHO), Values >0.9 for males and 0.85 for females are indicative of central obesity. The waist-height ratio (WHtR) was computed by dividing waist circumference (cm) by height (cm). WHtR of ≥0.5 was used to define obesity [5].

Subsequently, oral glucose tolerance test was performed for each subject. Subjects were asked to take normal diet with no carbohydrate restriction 72 h prior to test. They then fasted for 8–12 h overnight prior to test day (water was allowed). At 0900 h, blood samples for fasting plasma glucose were drawn from each subject's antecubital vein.

Each subject was then given a 75 g anhydrous glucose load in 250 ml of water to drink within 5 min. Two hours after the oral glucose load, venous blood from each subject was again drawn for plasma glucose determination using the glucose oxidase method. The WHO criteria was used in the diagnosis of impaired fasting glucose (FPG 6.1–6.9 mmol/L), impaired glucose tolerance (2hrPPG 7.8–11.0 mmol/L), and diabetes mellitus (FPG ≥ 7.0 mmol/L and/ or 2hrPPG ≥ 11.1 mmol/L).

Data were entered into Microsoft Excel, then subsequently analyzed using International Business Machines, Statistical Package for Social Sciences (IBM SPSS) version 23 released on March 4, 2015 by IBM SPSS Company. Results were expressed as means ± standard deviation at 95% confidence interval. Student't' test was used to compare continuous variables while chi square was used to compare categorical variables. Spearman's correlation was used to test for association amongst BMI, WC, WHR, WHtR, blood pressures, and blood glucose. P-value was taken as significant when less than or equal to 0.05.

3. Results

Four hundred (4 0 0) participants were initially enrolled for the study, but data from four (4) participants were excluded from the analysis due to incomplete details. Therefore, data from three hundred and ninety six (3 9 6) participants were used in the analysis.

The mean age of participants was 41.26 ± 11.17 years with no significant difference between the mean ages of male and female participants. The mean BMI of females (27.33 ± 5.93 kg/m^2) was higher than that of males (26.77 ± 5.87 kg/m^2) though not significant (p = 0.347). The females had a mean waist circumference (WC) of 88.09 ± 11.63 cm which was within range of central obesity while that of the males was 87.72 ± 12.98 cm which was within normal range. Mean waist-hip ratios (WHRs) of the females and

Table 5 – Correlation of plasma glucose and blood pressure with obesity indices.

	BMI		WC		WHR		WHtR		SBP		DBP		FPG		2HrPPG	
	R	p	R	p	r	p	R	p	R	p	r	p	R	p	r	p
BMI	1.00	.	0.241	<0.001	0.24	<0.001	0.39	<0.001	0.18	<0.001	0.14	0.004	0.42	<0.001	0.29	<0.001
WC	0.24	<0.001	1.00	.	0.68	<0.001	0.91	<0.001	0.06	0.203	0.09	0.091	0.28	<0.001	0.25	<0.001
WHR	0.24	<0.001	0.68	<0.001	1.00	.	0.64	<0.001	0.03	0.598	0.07	0.165	0.27	<0.001	0.18	<0.001
WHtR	0.39	<0.001	0.91	<0.001	0.64	<0.001	1.00	.	0.15	0.003	0.17	0.001	0.44	<0.001	0.36	<0.001
SBP	0.18	<0.001	0.06	0.203	0.03	0.598	0.15	0.003	1.00	.	0.61	<0.001	0.34	<0.001	0.29	<0.001
DBP	0.14	0.004	0.09	0.091	0.07	0.165	0.17	0.001	0.61	<0.001	1.00	.	0.27	<0.001	0.23	<0.001
FPG	0.42	<0.001	0.28	<0.001	0.27	<0.001	0.44	<0.001	0.34	<0.001	0.27	<0.001	1.00	.	0.68	<0.001
2HrPPG	0.29	<0.001	0.25	<0.001	0.18	<0.001	0.36	<0.001	0.29	<0.001	0.23	<0.001	0.68	<0.001	1.00	.

BMI = body mass index, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio, SBP = systolic blood pressure, DBP = diastolic blood pressure, FPG = fasting plasma glucose, 2-hour post 75 g glucose load plasma glucose, r = coefficient of correlation, p = level of significance.

males were 0.90±0.15 and 0.97±0.16 respectively which were within central obesity ranges. Similarly, the females and males showed mean waist-height ratio (WHtR) within central obesity range (0.56±0.09 vs 0.55±0.10, p = 0.182). There were no significant differences between mean values of systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), fasting plasma glucose (FPG), and 2-hour post 75 g glucose load plasma glucose (2HrPPG) of male and female participants (Table 1).

The prevalence of obesity by WHtR criterion was highest at 71.0% (females 39.4%, males 31.6%) followed by WHR criterion at 69.5% (females 41.7%, males 27.8%), then BMI at 61.6% (females 33.3%, males 28.3%). The least prevalence of obesity was by WC criterion at 54.2% (females 39.6%, males 14.6%). The prevalence of obesity by all criteria was significantly greater among the females compared to males (p < 0.001). The prevalence of obesity by WHtR was significantly higher than the prevalence by WHR (p < 0.001), BMI (p < 0.001), and WC (p < 0.001) [Table 2].

The prevalence of glucose intolerance among obese persons by WHtR criterion was highest at 25.3%, followed by BMI at 22.7% (p < 0.001), then WHR at 21.2% (p = 0.001). The least prevalence of glucose intolerance among obese persons was by WC at 19.4% (p < 0.001) (Table 3).

The prevalence of systemic hypertension among obese persons was highest at 30.8% when WHtR was used to assess obesity, followed by WHR criterion at 28.0% (p < 0.001), then BMI at 25.5% (p = 0.002). The least prevalence of systemic hypertension obtained among obese persons was 23.2% (p < 0.001) when WC was used to assess obesity (Table 4).

Spearman's correlation shows that FPG correlated significantly with WHtR (r = 0.44, p < 0.001), BMI (r = 0.42, p < 0.001), WC (r = 0.28, p < 0.001), and WHR (r = 0.27, p < 0.001) in descending order of strength of correlation. Similar pattern of correlation was shown between 2HrPPG and WHtR (r = 0.36, <0.001), BMI (r = 0.29, p < 0.001), WC (r = 0.25, p < 0.001), and WHR (r = 0.18, p < 0.001). SBP and DBP correlated significantly with BMI and WHtR and weakly with WC and WHR. [Table 5].

Logistic regression of obesity indices showed that WHtR was the best predictor of glucose intolerance with odds ratio (OD) of 20.74 (CI 2.80-155, p < 0.001), followed by WC with OD of 1.89 (CI 1.83-3.94, p < 0.001), then WHR with OD of 1.69 (CI 1.06-8.22, p = 0.009). The least but significant predictor of glucose intolerance was BMI with odds ratio of 1.12 (CI 1.06-3.18, p < 0.001) [Table 6].

Logistic regression of obesity indices showed that WHtR was the strongest predictor of systemic hypertension with OD of 2.32 (CI 4.85–14.96, p < 0.001), followed by BMI (OD 1.99, CI 1.96-2.05, p = 0.031), then WC (OD 1.95, CI 1.90-1.99, p = 0.020). The weakest predictor of systemic hypertension was WHR (OD 1.26, CI 0.04-1.88, p = 0.181) [Table 7].

4. Discussion

This study compared waist-height ratio (WHtR) to some obesity indices in terms of correlational strength with glucose intolerance and systemic hypertension. The relative ability of these obesity indices to predict glucose intolerance and systemic hypertension was also assessed. Preliminary review of data showed that mean values of BMI for male and female participants were within overweight range while mean value of WC for female was within obesity range and for male within normal limits. The mean values of WHtR and WHR for both males and females were within obesity ranges. This means that WHtR and WHR would likely indicate higher

Table 6 – Logistic regression of obesity indices as predictors of glucose intolerance.

	B	S.E.	Wald	Df	p-value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
BMI	0.111	0.029	14.884	1	<0.001	1.118	1.056	3.183
WC	0.121	0.032	14.556	1	<0.001	1.886	1.832	3.943
WHR	0.372	1.264	0.087	1	0.009	1.689	1.058	8.215
WHtR	28.338	4.565	38.543	1	<0.001	20.736	2.795	155.000
Constant	−9.294	1.302	50.933	1	<0.001	0.000		

BMI = body mass index, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio, B = regression coefficient, SE = standard error, p-value = level of significance, Exp(B) = odds ratio, CI = confidence interval.

Table 7 – Logistic regression of obesity indices as predictors of systemic hypertension.

	B	S.E.	Wald	Df	p-value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
BMI	0.004	0.021	0.034	1	0.031	1.994	1.964	2.045
WC	0.057	0.024	5.442	1	0.020	1.945	1.901	1.991
WHR	−1.353	1.012	1.788	1	0.181	1.259	0.036	1.878
WHtR	12.457	3.233	14.843	1	0.000	2.319	4.848	14.962
Constant	−1.251	0.866	2.085	1	0.149	0.286		

BMI = body mass index, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio, B = regression coefficient, SE = standard error, p-value = level of significance, Exp(B) = odds ratio, CI = confidence interval.

prevalence of obesity. In the same vein, further analysis showed that the prevalence of obesity by WHtR was significantly higher than that of WHR, BMI and WC. This was supported by Ashwell et al. [6] Owolabi et al. [10] and Akinlade et al. [15].

The higher prevalence of obesity among the female participants was made more significant by WHtR. These women who were mainly housewives demonstrated higher obesity levels likely due to their sedentary lifestyle. Ononamadu et al. [16] and Ambakederemo et al. [17] also demonstrated higher levels of obesity among women when WHtR was used along with other obesity indices.

However, does the high prevalence of obesity detected by WHtR translates to better ability to predict glucose intolerance and systemic hypertension? The prevalence of glucose intolerance among obese persons by WHtR criterion was highest compared to that of obese persons by BMI, WHR, or WC criterion. In a similar vein, correlational studies showed that WHtR had the highest strength of correlation with FPG and 2HrPPG compared to BMI, WC, and WHR. Furthermore, logistic regression analysis showed that WHtR had the highest odds ratio for glucose intolerance compared to WC, WHR, and BMI respectively in descending order of odds ratio. The higher power of predictability of WHtR compared to other obesity indices has been espoused by several studies [18–24].

Concerning systemic hypertension and obesity indices, the prevalence of systemic hypertension among obese persons by WHtR criterion was highest compared to that of obese persons by BMI, WHR, or WC criterion. In addition, BMI and WHtR were significantly correlated to SBP and DBP while WC and WHR showed no significant correlation with SBP and DBP. Ononamadu et al. [16] also reported significant correlation between SBP/ DBP and BMI/ WHtR. Furthermore, logistic regression showed that WHtR had the highest odds ratio for systemic hypertension followed by BMI, then WC. However, WHR had the least and non-significant odds for systemic hypertension. This is in keeping with reports from several studies. [16,25–27].

The outstanding ability of WHtR to predict glucose intolerance and systemic hypertension may be due to the fact that WHtR combines the advantages from two important variables viz waist circumference, a component of WC/WHR and height, an important denominator of BMI. This was similarly espoused by Ashwell et al. [6] where they posited that WHtR is a rapid and effective global indicator for health risks of obesity and its use can simplify the international public health message on obesity.

Limitations include non-assessment of other obesity indices like body adiposity index, abdominal height measurement etc. and non-assessment of other components of the metabolic syndrome like dyslipidaemia.

5. Conclusion

WHtR was most sensitive in diagnosing obesity compared to BMI, WC, and WHR. In addition, WHtR had the highest predictive power for both glucose intolerance and systemic hypertension compared to BMI, WC, and WHR.

6. Recommendation

We recommend that WHtR be used routinely for screening purposes in communities and all healthcare facilities. This will be easy to implement because WHtR is easy to measure and avoids the need for age, ethnic, or sex-related cut offs. This will help in the early recognition of obesity, hence early adoption of measures to curtail the growing prevalence of glucose intolerance and systemic hypertension.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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