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Determination of Boundary Values of Body Mass Index (BMI) for Cardiometabolic Risk Using Waist-To-Height Ratio (WHTR) for a Cross-Section of Adult Nigerian Population in Jos, Nigeria

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Abstract
The measurements of body mass and height to determine the Body Mass Index (BMI) in order to classify individuals whether they are normal, pre-obese or obese may not be sufficient as a primary screening tool for Cardio-metabolic risk assessment. However, it has been established that the Waist-to-Height Ratio (WHtR) will be of greater advantage over BMI in such risk assessments. It is widely assumed that mostly the individuals who are pre-obese and obese will be at risk for Cardio-metabolic diseases based on the BMI classification. But this may not be true as some individuals who are placed on normal category in BMI are found to be at risk based on the WHtR values which are greater than 0.5.Hence there is need to determine the boundary value of BMI for Cardio-metabolic risk using WHtR. This study concludes that for a cross-section of 200 (both male and female) adult Nigerian population of ages 20-67 years in Jos, Nigeria, the boundary value for Cardio-metabolic risk to be 24.45 Kg/m^2. It was also found that the males are at a higher risk for Cardio-metabolic diseases than their female counterparts in this study population. And these boundary values fall within the normal category (18.50 – 24.99 Kg/m^2) of BMI, suggesting that individuals of normal body mass can also be at risk for Cardio-metabolic diseases, in addition to pre-obese and obese categories on BMI classification
Keywords: Body Mass Index, Waist-to-Height Ratio, Cardio-metabolic risk, boundary value.

1. Introduction

The use of Body Mass Index (BMI) has been widely accepted worldwide as one of the major anthropometric index in classifying overweight and obesity of people since the mid- 1990s. However, this takes into consideration the total body mass of an individual rather than the mass of the fat deposited in the abdominal region which is more significant in assessing the cardio-metabolic risk factors. But in the recent past, Waist-to-Height Ratio (WHtR) has emerged as a promising index for identification of subjects at increased cardio-metabolic risk in adults (Ashwell *et al.*,1996; Cox, 1996, Sawa *et al*., 2013). It was suggested that WHtR has several advantages compared to BMI and even Waist Circumference (WC) and Waist-to-Hip Ratio (WHpR) as a simple and rapid screening tool, including its ability to identify health risk in both males and females in different ethnic groups and in all age groups including adults and children (Ashwell and Hsieh, 2005).

The World Health Organization began to use the BMI as a standard to determine not only overweight but also added cut-offs for categories of underweight, normal, pre-obese (overweight) and obesity. They used a BMI of 18.50-24.99 Kg/m^2 to indicate optimal weight, BMI lower than 18.50 Kg/m^2 suggested that the person was underweight while a BMI of between 25.00-29.99 kg/m^2 indicated that the person was overweight. However, BMI above 30.00 Kg/m^2 suggested that the person was obese and over 40.00 Kg/m^2 morbidly obese (WHO, 1998; WHO, 2000). Moreover it has been proposed that a cut-off value of 0.5 for both males and females and individuals of Caucasian, Asian and Central American origin can be used for the prediction of Cardio-metabolic risk. This value was the mean value of the suggested boundary values regarding several Cardiovascular disease (CVD) risk factors (Browning et al,2010). Several studies have been published which used wHtR $\geq$ 0.5 to analyse cardiovascular risk in populations (Parikh *et al.*, 2007; Parikh *et al.*, 2009; Ashwell and Gibson, 2014). It was also concluded that statistical evidences supported the superiority of measure of central obesity especially WHtR over BMI for detecting CVD risk in both males and females (Lee *et al*., 2008). Other recent publications also concluded that WHtR was better at discriminating adverse outcomes such as diabetes and CVDs with BMI or WC (Ashwell , 2011; Margot *et al*, 2013). Since obesity confers physical stress on multiple biologic processes and is associated with an increased risk of developing cardiovascular diseases, type 2 diabetic mellitus, osteoarthritis and certain forms of cancer among other diseases (Aronne and Isoldi, 2007) concentration of risk groups mainly targeted on overweight and obese individuals. However, some who are rated as normal weight on BMI scale can be at risk of cardio-metabolic diseases. This study is therefore to determine the boundary value of BMI for risk assessment using WHtR.

2. Materials and methods

A cross-section of 200 apparently healthy individuals of 100 males and 100 females between the ages of 20 to 67 years were included in this study. A stratified random approach was used to select the subjects living in and around Jos covering people from different ethnic groups. Nigeria is a country of multi-ethnic groups and has 36 states. This study was designed to cover people living in Jos originating from at least 2/3 of all the states in Nigeria.

Body mass was measured in kg using a weighing balance and height and waist circumference was measured with a measuring tape in cm. Body mass index and Waist-to-Height Ratio were computed for all the subjects using the formulae:

BMI = Body Mass (kg)/Height^2 (m^2) (1)

WHtR = Waist circumference (cm)/Height (cm) (2)

Statistical analysis was carried out using IBM SPSS Version 20. Descriptive statistics and Pearson correlation for all the study parameters, i.e. Age, Body Mass, Height, Waist circumference, BMI and WHtR were carried out. Using Regression method, the slope and interception for the line of best fit between BMI and WHtR was computed. This equation was used to determine the boundary values of BMI for Cardio-metabolic risk by substituting WHtR = 0.5 for males, females and total study population.

3. Results and discussions

The Table 1 shows the BMI and WHtR of all the study population (200 individuals) while Tables 2 and 3 show the descriptive statistics of all the study parameters of three groups and Pearson correlation coefficient comparison between BMI and WHtR with other study parameters respectively. Figures 1, 2 and 3 show the graphs of line of best fit between BMI and WHtR for the 3 groups ; males, females and total.

Table 1 : BMI and WHtR of all the study population.

SEX	AGE(Yrs)	WEIGHT(kg)	HEIGHT(cm)	WAIST(cm)	BMI(kg/m^2)	WHtR
M	29	59	170	78	21.20	0.459
M	25	56	170	78	19.38	0.459
M	25	55	161	77	21.22	0.478
M	23	65	176	79	20.98	0.449
M	20	70	177	78	22.34	0.441
M	58	76	157	105	30.83	0.669
M	54	103	155	121	42.87	0.781
M	31	79	192	83	21.43	0.432
M	25	74	164	86	27.51	0.524
M	22	69	160	79	26.95	0.494
M	46	82	170	92	28.37	0.541
M	35	74	175	82	24.16	0.469
M	31	65	151	91	28.51	0.603
M	32	72	181	84	21.98	0.464
M	25	81	174	91	26.75	0.523
M	55	101	158	124	40.46	0.785
M	25	76	184	87	22.45	0.473
M	23	80	185	125	23.37	0.676
M	39	55	158	82	22.03	0.519
M	42	102	171	113	34.88	0.661
M	40	79	169	105	27.66	0.621
M	50	84	174	97	27.74	0.558
M	30	62	179	82	19.35	0.458
M	35	58	160	78	22.66	0.488
M	40	65	165	85	23.88	0.515
M	39	85	169	97	29.76	0.574
M	30	68	169	81	23.81	0.479
M	36	77	168	97	27.28	0.577
M	20	71	150	74	31.56	0.493
M	38	64	159	84	25.32	0.528
M	25	81	174	91	26.75	0.523
M	55	101	158	124	40.46	0.785
M	25	76	184	87	22.45	0.473
M	23	80	185	123	23.37	0.665
M	20	58	158	77	23.23	0.487
M	22	84	186	84	24.28	0.452

M	26	61	175	78	19.92	0.446
M	20	58	158	77	23.23	0.487
M	30	68	179	84	21.22	0.469
M	21	62	174	77	20.48	0.443
M	21	58	165	76	21.30	0.461
M	23	77	184	81	22.74	0.44
M	20	75	172	81	25.35	0.471
M	27	66	165	78	24.24	0.473
M	22	63.5	168	81	22.50	0.482
M	27	62	176	78	20.02	0.443
M	25	64	174	78	21.14	0.448
M	28	76	188	83	21.50	0.442
M	22	89	182	92	26.87	0.506
M	24	59	165	75	21.67	0.455
M	23	65	170	79	22.49	0.465
M	22	71	168	86	25.14	0.512
M	27	82	168	99	29.05	0.589
M	20	55	169	64	19.26	0.379
M	29	80	181	90	24.42	0.497
M	22	54	161	72	20.83	0.447
M	27	63	170	76	21.80	0.447
M	24	74	172	80	25.01	0.465
M	22	58	170	69	20.07	0.406
M	22	68	170	78	23.53	0.459
M	25	80	176	92	25.83	0.523
M	32	55	167	80	19.72	0.479
M	20	80	173	85	26.73	0.491
M	20	62	159	77	24.52	0.484
M	35	65	170	85	22.49	0.500
M	22	75	178	78	23.67	0.438
M	25	70	173	80	23.39	0.462
M	23	60	167	80	21.51	0.479
M	22	61	171	76	20.86	0.444
M	22	73	168	84	25.87	0.500
M	21	70	168	83	24.80	0.494
M	22	81	170	76	28.03	0.447
M	23	82	172	93	27.72	0.541
M	22	65	173	87	21.72	0.503
M	34	62	172	92	20.96	0.535
M	23	68	167	85	24.38	0.509
M	21	58	160	86	22.66	0.538
M	32	94	185	105	27.47	0.568
M	46	77	172	97	26.03	0.564
M	24	59	164	84	21.94	0.512
M	48	59	162	84	22.48	0.519
M	28	91	181	101	27.78	0.558
M	50	65	167	95	23.31	0.569
M	34	90	186	103	26.02	0.554
M	25	70	173	80	23.39	0.462
M	23	60	167	80	21.51	0.479
M	22	61	171	76	20.86	0.444
M	22	73	168	84	25.87	0.500
M	21	70	168	83	24.80	0.494
M	22	81	170	76	28.03	0.447
M	25	58	169	73	20.31	0.432
M	22	63	160	77	24.61	0.481
M	22	52	165	75	19.10	0.455
M	35	67	165	89	24.61	0.539
F	26	106	170	106	36.68	0.624

F	23	61	152	88	26.40	0.579
F	25	53	157	73	21.50	0.465
F	24	55	157	75	22.31	0.478
F	35	53	159	71	20.96	0.447
F	20	59	147	80	27.30	0.544
F	33	72	158	91	28.84	0.576
F	35	82	164	95	30.49	0.579
F	27	50	157	69	20.29	0.440
F	27	68	166	79	24.68	0.476
F	22	76	158	89	30.44	0.563
F	30	73.5	173	84	24.56	0.486
F	26	73	171	96	24.97	0.561
F	21	65.5	173	94	21.89	0.543
F	44	84	160	101	32.81	0.631
F	35	71.5	163	90	26.91	0.552
F	26	97.5	164	110	36.25	0.671
F	35	102	160	111	39.84	0.694
F	30	96.5	170	98	33.39	0.577
F	21	56.5	165	80	20.75	0.485
F	20	71	164	86	26.40	0.524
F	20	50	161	79	19.29	0.491
F	44	99	166	109	35.93	0.657
F	29	116.5	161	121	44.94	0.752
F	29	60	162	95	22.86	0.586
F	30	80.5	165	96	35.26	0.582
F	36	85	163	97	31.99	0.595
F	37	92	160	110	35.94	0.688
F	24	70	159	66	27.69	0.415
F	28	80	171	91	27.36	0.532
F	30	95	178	100	29.98	0.562
F	50	81	163	102	30.49	0.626
F	32	75	159	101	29.67	0.635
F	20	50	156	70	20.55	0.449
F	25	74	162	85	28.20	0.525
F	25	64	157	86	25.97	0.548
F	23	52	164	68	19.33	0.415
F	28	73	168	85	25.87	0.506
F	24	61	155	74	25.39	0.477
F	22	62	160	76	24.22	0.475
F	51	73	165	94	26.81	0.570
F	46	51	160	68	19.92	0.425
F	25	47	157	70	19.07	0.446
F	67	83	183	101	24.78	0.552
F	23	66	164	74	25.54	0.451
F	26	84	157.5	104	33.86	0.660
F	25	55	156	80	22.06	0.513
F	45	53	160	76	20.70	0.475
F	20	71	164	77	26.40	0.470
F	24	60	169	76	21.01	0.450
F	47	80	159	100	31.64	0.629
F	33	105	167	112	37.45	0.671
F	32	67.5	156	90	27.74	0.577
F	21	87	187.5	94	24.75	0.501
F	31	79	149	108	35.58	0.725
F	27	75	165	92	27.55	0.558
F	22	50	150	80	22.22	0.533
F	25	57	156	71	23.42	0.455
F	30	70	156	95	28.76	0.609
F	42	80	155	96	33.30	0.619

F	31	70	160	77	27.34	0.481
F	32	75	160	88	29.30	0.550
F	20	56	150	71	24.89	0.473
F	24	55	150	83	24.44	0.553
F	41	67	160	86	26.17	0.538
F	38	115	168	116	40.75	0.691
F	35	83	184.5	99	24.38	0.537
F	29	76	183.5	96	22.57	0.523
F	22	74	181.5	99	22.46	0.546
F	27	58.5	177.5	86	18.57	0.485
F	35	83.5	165.5	105	30.47	0.634
F	35	58.5	158	86	23.43	0.544
F	23	55.5	152.5	78	23.87	0.512
F	25	71.5	157.5	79	28.82	0.502
F	29	77.5	151.5	92	33.77	0.607
F	31	81	165.5	97	29.57	0.586
F	28	95	160	101	37.11	0.631
F	28	75.5	159	94	32.04	0.591
F	32	75.5	158	93	30.24	0.589
F	28	65	150	86	28.89	0.573
F	51	65	162	99	24.77	0.599
F	28	55.5	162.5	78	21.02	0.480
F	28	76.5	162.5	92	28.97	0.566
F	34	77	164.5	96	28.46	0.584
F	35	65.5	154	92	27.62	0.597
F	20	66.5	167.5	90	23.70	0.537
F	25	63.5	164	74	23.61	0.451
F	24	66.5	165	76	24.43	0.461
F	32	86.5	170.5	98	29.76	0.575
F	56	84.5	157	104	34.28	0.662
F	22	86	169	103	30.11	0.61
F	50	108	163	125	40.65	0.767
F	25	56	148	77	25.57	0.520
F	23	52	154	70	21.93	0.455
F	24	64	160	84	25.00	0.525
F	24	52	166	71	18.87	0.428
F	48	62	151	90	27.19	0.596
F	24	88	178	95	27.77	0.533
F	41	62.5	165	79	22.96	0.478
F	23	66	155	86	27.47	0.535
M	55	88	170	102	30.45	0.600
M	36	63	167	80	22.59	0.479
M	33	80	177	82	25.54	0.463
M	22	86	170.5	95	29.58	0.557
M	32	60	165.5	70	21.91	0.423
M	36	84	180	95	25.93	0.528

Table 2: Descriptive Statistics

		MINIMUM	MAXIMUM	MEAN	STD DEVIATION
AGE (yrs)	MALE	20	58	28.94	9.496
	FEMALE	20	67	30.33	9.119
	TOTAL	20	67	29.63	9.312
WEIGHT (kg)	MALE	52.0	103.0	71.135	11.7540
	FEMALE	47.0	116.5	72.110	15.5529
	TOTAL	47.0	116.5	71.623	13.7589
HEIGHT (cm)	MALE	150.0	192.0	170.270	8.3365
	FEMALE	147.0	187.5	162.250	8.1456
	TOTAL	147.0	192.0	166.260	9.1512
WAIST (cm)	MALE	64.0	125.0	86.180	12.2741
	FEMALE	66.0	125.0	89.260	12.9464
	TOTAL	64.0	125.0	87.720	12.6773
BMI (kg/m^2)	MALE	19.10	42.87	24.5999	4.26903
	FEMALE	18.57	44.94	27.4439	5.50171
	TOTAL	18.57	44.94	26.0218	5.11433
WHtR	MALE	0.379	0.785	0.50755	0.075746
	FEMALE	0.415	0.767	0.55005	0.076876
	TOTAL	0.379	0.785	0.52854	0.078861

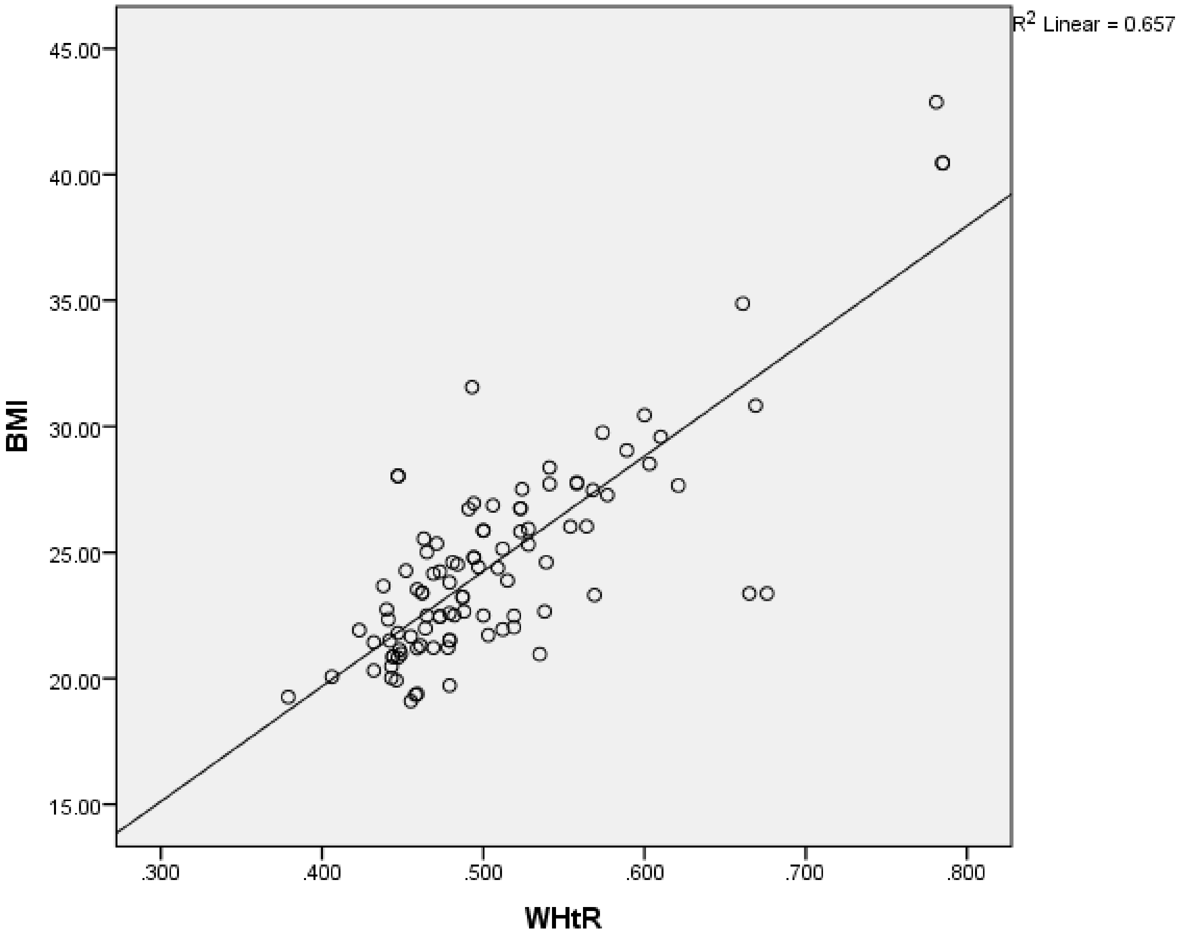

Figure 1: Graph of BMI against WHtR for Males (n = 100)

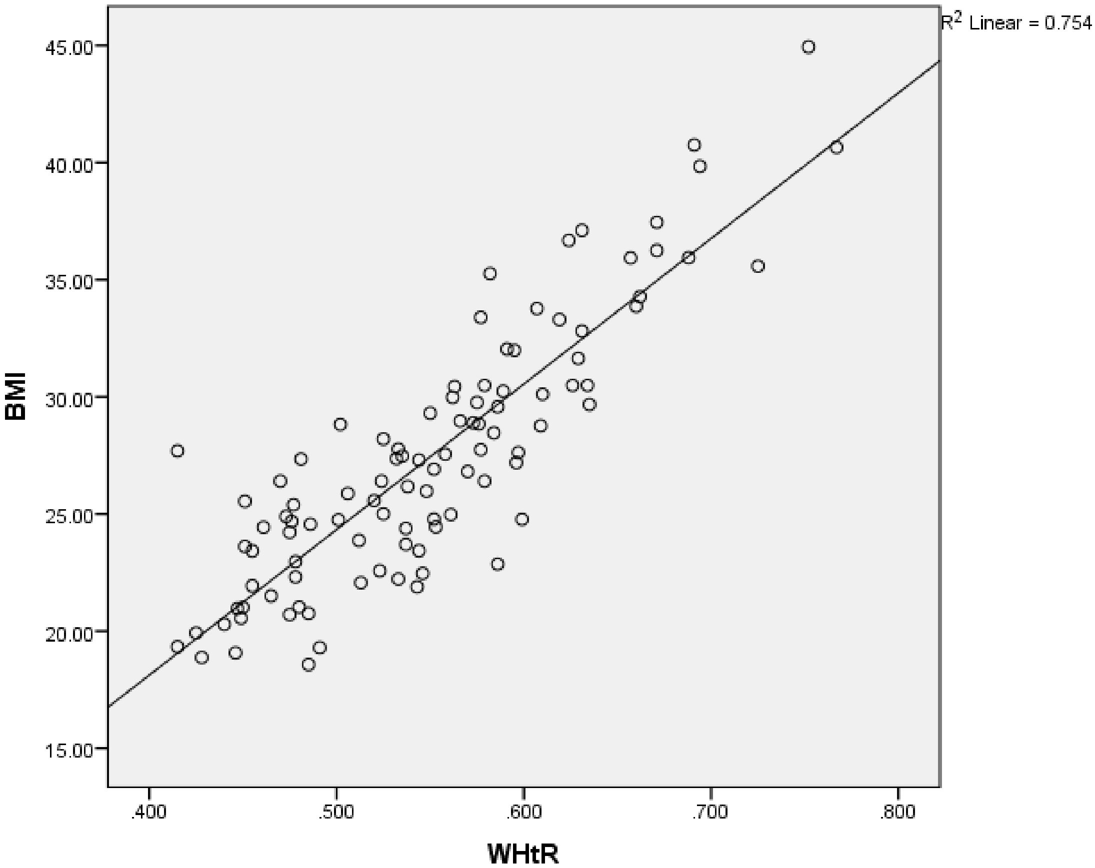

Figure 2 : Graph of BMI against WHtR for Females (n = 100)

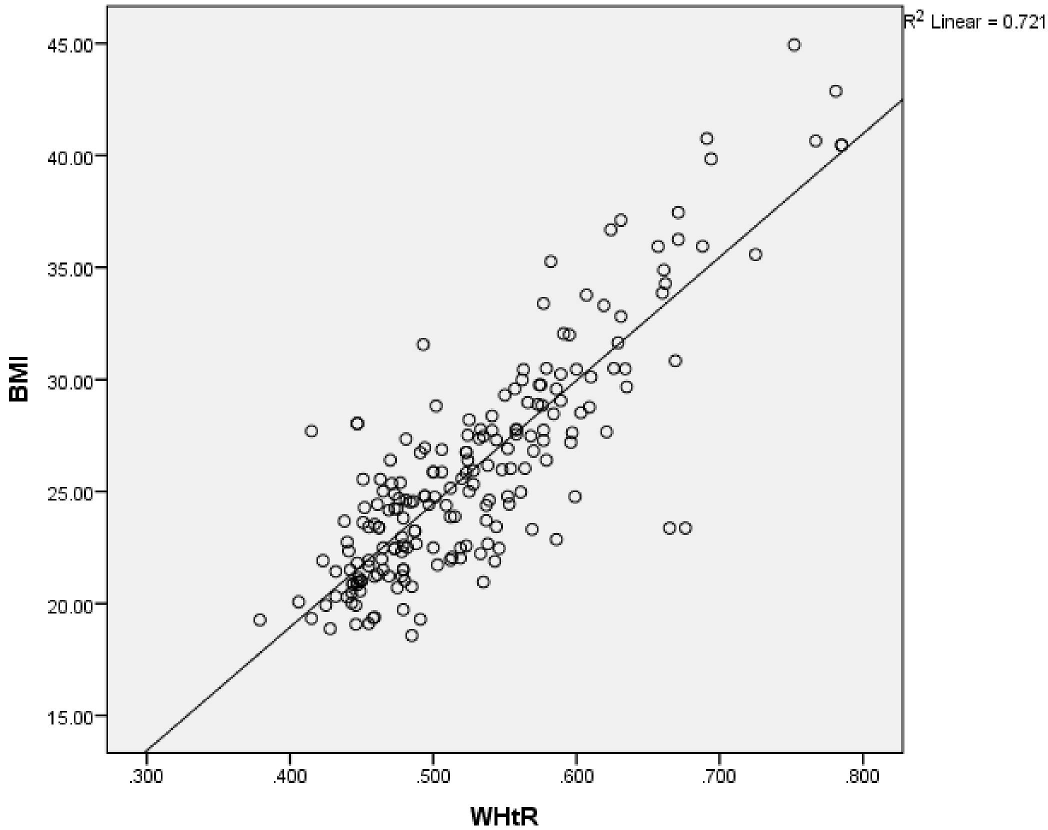

Figure 3 : Graph of BMI against WHtR for Total subjects (n = 200)

Results from descriptive statistics show that the mean age for the total study population (n= 200) is found to be 29.630 ± 9.312 years while the mean weight and height are 71.6230 ± 13.7589 kg and 166.2600 ± 9.1512 cm respectively. The mean waist circumference is 87.7200 ± 12.6773 cm. The BMI and WHtR were computed using equations 1 and 2 respectively and the mean values were found to be 26.02180 ± 5.11433 kg/m^2 and 0.528540 ± 0.078861 respectively. Significant differences of both BMI and WHtR mean values of the males and the females can be seen with female values higher than that of males.

From the Fig.1 and Fig.2, the lines of best fit between BMI and WHtR for males and females respectively were obtained as:

BMI = 45.861 (WHtR) + 1.414 (3)

BMI = 62.135 (WHtR) - 6.734 (4)

From these equations boundary values of BMI can be obtained by substituting WHtR = 0.5 which is universally accepted for both males and females for cardio-metabolic risk. Therefore, the corresponding BMI values for cardio-metabolic risk are 24.2545 kg/m^2 for males and 24.3335 kg/m^2 for females in this study population. This shows that both males and females are at risk before they reach 24.99 kg/m^2 which is the cut-off mark for overweight according to BMI classification and the males are at higher risk than females. This means that both male and female healthy normal weight adults can be at risk before they can reach the overweight stage. The relationship between BMI and WHtR for the total study population found from the regression graph of figure 3 was,

BMI = 55.070 (WHtR) - 3.085 (5)

This gives a boundary value of BMI equal to 24.45 kg/m^2 for cardio-metabolic risk for the 200 adults (both males and females) used in the study. This suggests that the boundary value of 24.99 kg/m^2 between normal weight and overweight is no longer acceptable in the study population to be used under BMI for risk assessment of cardiovascular diseases and diabetes.

From the correlations, age and waist circumference were found to be positively correlating at 0.01 level of significance with WHtR better than BMI, while height is negatively correlating at 0.01 level of significance with WHtR better than BMI. However, weight is found to be better correlating with BMI than WHtR at 0.01level of significance. Also, BMI and WHtR have a very strong correlation of r = 0.849 at 0.01 level of significance. Table 3 shows the summary of correlation coefficients (Pearson) of all the parameters of the total study population used in this research.

Table 3: Summary of Correlation coefficients of 200 (both male and female) participants.

Correlations

		BMI	WHtR	AGE	WEIGHT	HEIGHT	WAIST
BMI	Pearson Correlation	1	.849**	.408**	.835**	-.259**	.763**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	200	200	200	200	200	200
WHtR	Pearson Correlation	.849**	1	.538**	.699**	-.241**	.929**
	Sig. (2-tailed)	.000		.000	.000	.001	.000
	N	200	200	200	200	200	200
AGE	Pearson Correlation	.408**	.538**	1	.353**	-.084	.513**
	Sig. (2-tailed)	.000	.000		.000	.240	.000
	N	200	200	200	200	200	200
WEIGHT	Pearson Correlation	.835**	.699**	.353**	1	.304**	.823**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	200	200	200	200	200	200
HEIGHT	Pearson Correlation	-.259**	-.241**	-.084	.304**	1	.130
	Sig. (2-tailed)	.000	.001	.240	.000		.067
	N	200	200	200	200	200	200
WAIST	Pearson Correlation	.763**	.929**	.513**	.823**	.130	1
	Sig. (2-tailed)	.000	.000	.000	.000	.067	
	N	200	200	200	200	200	200

**. Correlation is significant at the 0.01 level (2-tailed).

4. Conclusion and Recommendations

Cardio-metabolic diseases are rapidly increasing among people, both adults and children alike all over the world. The measurements of weight and height to determine the body mass index to place an individual as underweight, normal weight, overweight or obese will no longer be suitable for preliminary risk assessment of cardio-metabolic diseases. However, waist-to-height ratio is widely gaining acceptance as a better and more reliable predictor of cardio-metabolic risk against body mass Index among people. This study attempted to establish the boundary value of body mass index using the waist-to-height ratio cut-off point for a cross section of adult Nigerian population in Jos, Nigeria. It was found that in males, BMI of 24.2545 kg/m^2 will be at risk while in females, it was 24.3325 kg/m^2.Total study population shows the risk BMI boundary value starts from 24.45 kg/m^2. This suggests that some of the normal weight individuals of BMI 18.50 - 24.99 kg/m^2 under BMI classification are no longer safe and can be at risk of cardio-metabolic risk.

It is therefore suggested that individuals in normal weight category under BMI classification are also to be screened for possible cardio-metabolic risks using fasting blood glucose and lipid profiles for early detection and prevention of such diseases. Also the governments in each country should promote healthy lifestyles through their various primary healthcare programmes in order to avoid premature death among their citizens. It is therefore recommended that a similar study be carried out in different cities of Nigeria and other parts of the world.

REFERENCES

Aronne L.J.and Isoldi K.K. (2007).Overweight and Obesity: Key components of Cardiometabolic risk. Clin. Cornerstone 8(3): 29-37.

Ashwell M., Cole T.J., Dixon A.K. (1996). Ratio of waist circumference to height is strong predictor of intra-abdominal fat.Br. Med. J. 313(7056): 559-560.

Ashwell M. (2011). Charts based on Body mass index and waist-to-height ratio to assess the health risk of obesity: A Review. The open obesity Journal, 3, 78-84.

Ashwell M. and Gibson S. (2014). A proposal for a primary screening tool.'Keep your waist circumference to less than half your height'. BMC Medicine. 12:207

Ashwell M. and Hsieh S.D. (2005). Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the internal public health message on obesity. Int. J. Food Sc. Nutr. 56(5): 303-309.

Browning L.M., Hsieh S.D., Ashwell M. (2010).A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value.Nutr.Res.Rev. 23(2): 247-269.

Cox B.D., Whichelow M. (1996).Ratio of waist circumference to height is better predictor of death than body mass index. Br.Med.J. 313(7070): 1487.

Lee C.M., Huxley R.R., Wildman R.P., Woodward M. (2008). Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI.A meta-analysis. J.Clin. Epidemiol. 61: 646-653.

Margot S., Mark S., Tremblay S., Connor G., Ian J. (2013). Abdominal obesity and cardiovascular disease risk factors within body mass index categories. Canadian Journal of Statistics; Health Report 23 (2): 82-87.

Parikh R.M., Joshi S.P., Pandia K. (2009).Index of central obesity is better than waist circumference in defining metabolic syndrome. Metab. Syndr. Relat. Disord: 525-527.

Parikh R.M., Joshi S.P., Menon P.S., Shah N.S. (2007). Index of central obesity- A noval parameter. Med Hypotheses. 68: 1272-1275.

Sawa S.C., Lamnisos D. and Kafatos A.G. (2013). Predicting Cardiometabolic risk: Waist-to-height ratio or BMI. A meta-analysis. Diabetes Metab.Syndr.Obes.6: 403-419.

World Health Organization. (1995). Physical Status: the use and interpretation of anthropometry. Report of a WHO expert committee. WHO Technical Report series 854. Geneva.

World Health Organization. (1998). Obesity: Preventing and managing the global epidemic. Report of a WHO Consultation on obesity. Geneva.