# Body Mass Index (BMI) and Waist to Height Ratio (WHTR) for Prediction of Cardiovascular Diseases: Women at Higher Risk than Men in Jos

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**Abstract**
The problem of cardiac arrest and stroke in humans leading to paralysis or death are known to relate to the risk for certain diseases such as heart disease, high blood pressure, type II diabetes, gallstone, breathing problems and certain cancers. The risk for such diseases in turn, is correlated to the Body Mass Index (BMI) and Waist to Height Ratio (WHtR) which are strong indicators of visceral/abdominal fat which accumulates around the internal organs affecting the heart, liver and kidneys. However, it is not known whether these major risk factors are higher in males or females. In this work, the weights, heights and waists of 50 volunteers (25 males and 25 females) were carried out on people whose ages ranged between 19 and 75 years with the aid of a weighing balance and a measuring tape. Results show that the Body Mass Indices (BMI) of males ranged between 18.29 and 30.70kg/m$^2$ while that of females ranged between 19.05 and 39.11kg/m$^2$. Waist to Height Ratios for males ranged between 0.4331 and 0.6954 while that for females ranged between 0.4310 and 0.7746. The 2-tailed Pearson correlation coefficient between sex and BMI $(r = 0.299, p < 0.05)$ and that between sex and WHtR $(r = 0.379, p < 0.01)$, both show that females are at more risk than males. Also, BMI and WHtR correlated strongly $(r = 0.909, p < 0.01)$ showing that they are good proxy for body fat percentage. An effective BMI incorporating WHtR was empirically derived.
**Keywords**: Body Mass Index, Waist to Height Ratio, Cardiovascular disease, Diabetes, Stroke

## 1. Introduction

Body mass index (BMI), also called Quetelet index (Garabed, 2007) is considered to be useful in medicine because it provides a paradigm to understand and estimate the risk factors for health problems (Fareed and Afzal, 2014). It is an attempt to quantify the amount of tissue mass (muscle, fat, and bone) in an individual, and then categorize that individual as underweight, normal weight, overweight, or obese based on that value. It was believed to be the best proxy for body fat percentage (BFP) among ratios of weight and height (Keys, 1972) and therefore became an estimate of body fat and a good gauge of risk for diseases that can occur with more body fat. The higher the BMI, the higher the risk for certain diseases such as heart disease, high blood pressure, type II diabetes, gallstones, breathing problems and certain cancers (http://www.nhlbi.nih.gov/health/educational/lose_wt/risk.htm). It is calculated as mass in kilograms divided by the square of height (h) in meters and therefore has units of (kg/m$^2$). That is,

$$\text{BMI} = \frac{W}{h^2} \qquad (1)$$

BMI is a simple, inexpensive and noninvasive surrogate measure of body fat. BMI values below 18.5 show underweight; 18.5 – 24.9 show normal weight; 25.0 – 29.9 show overweight while 30.0 and above show obesity. Although BMI is widely used, its assumptions about the distribution between muscle mass and fat mass are inexact. BMI generally overestimates adiposity on those with more lean body (e.g., athletes) and underestimates excess adiposity on those with less lean body mass. It is particularly inaccurate for people who are very fit or athletic (people who are very muscular, lean and with low body fat) as their high muscle mass can classify them in the overweight or obese category by BMI, but are classified as having a normal weight using the body fat percentages (BFP) because their BFP frequently falls in the 10-15% (Romero-Corral, 2008). Due to the fact that the BMI values do not take into account the distribution of fat in the body, some studies, have found that measures of abdominal obesity, principally, waist circumference (WC), waist-to-hip ratio (WHR), and more recently, waist-to-height ratio (WHtR) in particular predict more reliably fat distribution in the body and are therefore more closely related to cardio vascular disease (CVD) morbidity and mortality than is BMI (Rajesh *et al*., 2014; Margot *et al.,* 2013). The WHtR is the ratio of the waist to the height written as:

$$\text{WHtR} = \frac{\text{waist}}{\text{height}} \qquad (2)$$

WHtR values of less than 0.4 indicate underweight; 0.40 to 0.49 indicate normal weight; 0.50 to 0.55 indicate overweight; 0.55 to 0.60 indicate obesity stage I and above 0.60 is for obesity stage II (Sung *et al*., 2010). The WHtR is important because it accounts for levels of visceral fat which accumulates around the internal organs and is particularly closely linked to conditions like stroke and heart disease. Abdominal fat affects organs like the heart, liver and kidneys more adversely than fat around the hips and bottom, in terms of cardio metabolic risk. Higher values of WHtR indicate higher risk of obesity-related cardiovascular diseases; it is correlated with abdominal obesity (Lee *et al.*, 2008). The idea of using waist to height ratio to predict cardio metabolic risk is not new, but is coming to prominence as more studies reveal its value of predicting an accurate lifespan. It also has the simplicity of the health message "keep your waist circumference to less than your height" (Ashwell and Browning, 2011). The WHtR is quickly becoming the medical community's favored method to evaluate a person's health. However, reviews of the literature conducted to assess which measure of adiposity is most strongly associated with CVD yielded inconsistent conclusions (Margot *et al.,* 2013). While WHtR is considered to be superior to BMI since it focuses on fat distribution in the body, it is fairly uncommon because it is possible to have a relatively flat abdomen yet have large amounts of fat elsewhere in the body. Such an individual may be falsely led to believe that they are in fine health in this scenario. A research conducted in China reveals that male subjects had significantly greater waist circumference, height and weight than female subjects; hence BMI and WHtR values were significantly smaller in males than in females (Yong *et al*., 2011 and Wang *et al.*, 2009). Other researches (Shu *et al*., 2014; Margaret *et al*., 2014; Fasanmade and Okubadejo, 2007; Xin, *et al*., 2014; Grazyna *et al*., 2014; Sung *et al*., 2013 ; Burt *et al.,* 1995; Daughterty *et al.,* 2011 and Sharaye *et al.,* 2014) reveal that both BMI and WHtR give good indications for CVD with WHtR as a better indicator than BMI. In this work, both the BMI and the WHtR were used to estimate which sex is at a higher risk of cardiovascular disease than the other.

## 2. Materials and Methods

The materials used in this work included fifty (50) human participants, weighing balance and a tape graduated in meters. The participants were recruited from within Jos South Local Government Area of Plateau State, Nigeria, using the stratified random sampling method targeted at obtaining participants of ages ranging from 19 to 75 years. The participants (25males and 25 females) have different occupations. All were nonsmokers with normal blood pressure and without diabetes. They were taken to the Jos University Teaching Hospital (JUTH) for assessment. Having obtained clearance from the ethical committee of the hospital, measurements of mass of the participants using the weighing balance and recorded in kilograms (kg), waist and height using a tape and recorded in meters (m) were carried out. The participants were made to remove their shoes and cloths so that accurate measurements were taken. Specifically, to measure the waist circumference of the participants accurately, the participants were made to breathe out as their waist, mid-way between the lower rib and the iliac crest (the top of the pelvic bone at the hip), were measured with the tape in meters.

## 3. Results

At the end of the entire procedures, measurements of results were done as follows:
The Weights, Heights and Waists of the subjects were taken, while their Body Mass Indices (BMI) and Waist to Height Ratios (WHtR) were then calculated using equations 1 and 2, and the results are shown in table 1. The results in tables 1 were analyzed using IBM SPSS (Statistical Packages for the Social Sciences) tool to find out correlations between any two or more sets of variables. Table 2 shows the correlations among the variables using the 2-tailed Pearson's correlation. The Pearson's correlations with one asterisk show that correlation is significant at the 0.05 level, while those with two asterisks show that correlation is significant at the 0.01 level.

**Table 1: Body Mass Index (BMI) and Waist to Height Ratio (WHtR)**

| S/N | AGE (yrs) | SEX | WEIGHT (Kg) | HEIGHT (m) | WAIST (m) | BMI ($Kgm^{-2}$) | WHtR |
|---|---|---|---|---|---|---|---|
| 01 | 19 | 2 | 48.0 | 1.520 | 0.790 | 20.76 | 0.5197 |
| 02 | 22 | 2 | 66.5 | 1.690 | 0.810 | 23.28 | 0.4793 |
| 03 | 23 | 2 | 86.0 | 1.660 | 1.030 | 31.21 | 0.6205 |
| 04 | 24 | 1 | 71.0 | 1.730 | 0.780 | 23.72 | 0.4509 |
| 05 | 25 | 2 | 42.0 | 1.485 | 0.640 | 19.05 | 0.4310 |
| 06 | 25 | 2 | 59.0 | 1.625 | 0.750 | 22.34 | 0.4615 |
| 07 | 26 | 1 | 52.0 | 1.600 | 0.740 | 20.31 | 0.4625 |
| 08 | 26 | 1 | 56.0 | 1.690 | 0.780 | 19.61 | 0.4615 |
| 09 | 27 | 1 | 70.0 | 1.720 | 0.745 | 23.66 | 0.4331 |
| 10 | 29 | 1 | 66.0 | 1.715 | 0.800 | 22.44 | 0.4665 |
| 11 | 30 | 1 | 69.0 | 1.730 | 0.810 | 23.06 | 0.4682 |
| 12 | 37 | 2 | 63.0 | 1.600 | 0.830 | 24.61 | 0.5188 |
| 13 | 39 | 1 | 77.0 | 1.675 | 1.000 | 27.45 | 0.5970 |
| 14 | 40 | 2 | 92.0 | 1.635 | 1.060 | 34.42 | 0.6483 |
| 15 | 41 | 1 | 55.5 | 1.655 | 0.720 | 20.26 | 0.4351 |
| 16 | 38 | 1 | 69.0 | 1.665 | 0.870 | 24.89 | 0.5225 |
| 17 | 42 | 2 | 63.0 | 1.455 | 0.950 | 29.76 | 0.6529 |
| 18 | 45 | 2 | 88.0 | 1.500 | 1.130 | 39.11 | 0.7533 |
| 19 | 45 | 1 | 80.0 | 1.710 | 1.010 | 27.35 | 0.5906 |
| 20 | 47 | 2 | 60.0 | 1.540 | 0.850 | 25.30 | 0.5520 |
| 21 | 47 | 2 | 63.0 | 1.590 | 1.030 | 24.92 | 0.6478 |
| 22 | 48 | 2 | 68.0 | 1.610 | 0.880 | 26.23 | 0.5466 |
| 23 | 48 | 2 | 65.0 | 1.670 | 0.850 | 23.31 | 0.5090 |
| 24 | 48 | 2 | 60.0 | 1.600 | 0.850 | 23.44 | 0.5313 |
| 25 | 49 | 1 | 73.0 | 1.750 | 0.880 | 23.84 | 0.5029 |
| 26 | 48 | 1 | 61.0 | 1.640 | 0.790 | 22.68 | 0.4817 |
| 27 | 50 | 2 | 54.0 | 1.595 | 0.870 | 21.23 | 0.5455 |
| 28 | 50 | 2 | 80.0 | 1.555 | 1.020 | 33.09 | 0.6560 |
| 29 | 52 | 1 | 90.0 | 1.730 | 1.100 | 30.07 | 0.6358 |
| 30 | 52 | 2 | 74.0 | 1.670 | 1.000 | 26.53 | 0.5988 |
| 31 | 52 | 2 | 86.0 | 1.575 | 1.220 | 34.67 | 0.7746 |
| 32 | 53 | 1 | 57.0 | 1.580 | 0.770 | 22.83 | 0.4873 |
| 33 | 54 | 1 | 70.0 | 1.510 | 1.050 | 30.70 | 0.6954 |
| 34 | 54 | 2 | 87.0 | 1.560 | 1.240 | 35.75 | 0.7949 |
| 35 | 42 | 1 | 91.0 | 1.730 | 1.040 | 30.41 | 0.6012 |
| 36 | 56 | 2 | 55.0 | 1.535 | 0.810 | 23.34 | 0.5277 |
| 37 | 57 | 2 | 90.0 | 1.590 | 1.140 | 35.60 | 0.7170 |
| 38 | 58 | 1 | 88.0 | 1.710 | 1.050 | 30.10 | 0.6140 |
| 39 | 58 | 1 | 88.0 | 1.695 | 1.080 | 30.63 | 0.6372 |
| 40 | 58 | 2 | 65.0 | 1.550 | 0.950 | 27.06 | 0.6129 |
| 41 | 60 | 1 | 56.0 | 1.560 | 0.830 | 23.01 | 0.5301 |
| 42 | 61 | 1 | 84.0 | 1.770 | 1.050 | 25.81 | 0.5932 |
| 43 | 62 | 2 | 87.0 | 1.610 | 1.040 | 33.56 | 0.6460 |
| 44 | 65 | 1 | 51.0 | 1.670 | 0.740 | 18.29 | 0.4431 |
| 45 | 65 | 1 | 54.0 | 1.590 | 0.820 | 21.36 | 0.5157 |
| 46 | 65 | 1 | 54.0 | 1.500 | 0.800 | 24.00 | 0.5333 |
| 47 | 45 | 2 | 77.0 | 1.640 | 1.010 | 28.63 | 0.6159 |
| 48 | 46 | 1 | 65.0 | 1.640 | 0.850 | 24.17 | 0.5183 |
| 49 | 75 | 2 | 52.0 | 1.520 | 0.850 | 22.51 | 0.5592 |
| 50 | 59 | 1 | 78.0 | 1.755 | 0.940 | 25.33 | 0.5356 |

SEX; 1 – Male, 2 - Female

**Table 2: Correlations**

| | | SEX | WEIGHT | WAIST | BMI | WHtR |
|---|---|---|---|---|---|---|
| SEX | Pearson Correlation | 1 | .007 | .223 | .299* | .379** |
| | Sig. (2-tailed) | | .959 | .119 | .035 | .007 |
| | N | 50 | 50 | 50 | 50 | 50 |
| WEIGHT | Pearson Correlation | .007 | 1 | .855** | .863** | .696** |
| | Sig. (2-tailed) | .959 | | .000 | .000 | .000 |
| | N | 50 | 50 | 50 | 50 | 50 |
| WAIST | Pearson Correlation | .223 | .855** | 1 | .909** | .950** |
| | Sig. (2-tailed) | .119 | .000 | | .000 | .000 |
| | N | 50 | 50 | 50 | 50 | 50 |
| BMI | Pearson Correlation | .299* | .863** | .909** | 1 | .909** |
| | Sig. (2-tailed) | .035 | .000 | .000 | | .000 |
| | N | 50 | 50 | 50 | 50 | 50 |
| WHtR | Pearson Correlation | .379** | .696** | .950** | .909** | 1 |
| | Sig. (2-tailed) | .007 | .000 | .000 | .000 | |
| | N | 50 | 50 | 50 | 50 | 50 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

## 4. Discussion

Results from the correlations in table 2 show that the BMI is strongly correlated positively with the Weight and WHtR at the 0.01 significant level with a $p < 0.01$. These observations mean that the BMI increases with an increase in the values of the Weight and WHtR or vice versa. The graphs of BMI against Weight and WHtR are shown in figures 1 and 2 resulting in the following regression equations:

$$y = 0.31x_1 + 4.57 \quad (3)$$

$$y = 48.32x_2 - 1.09 \quad (4)$$

Where $y$ the BMI is while $x_1$ and $x_2$ are the Weight and the WHtR respectively

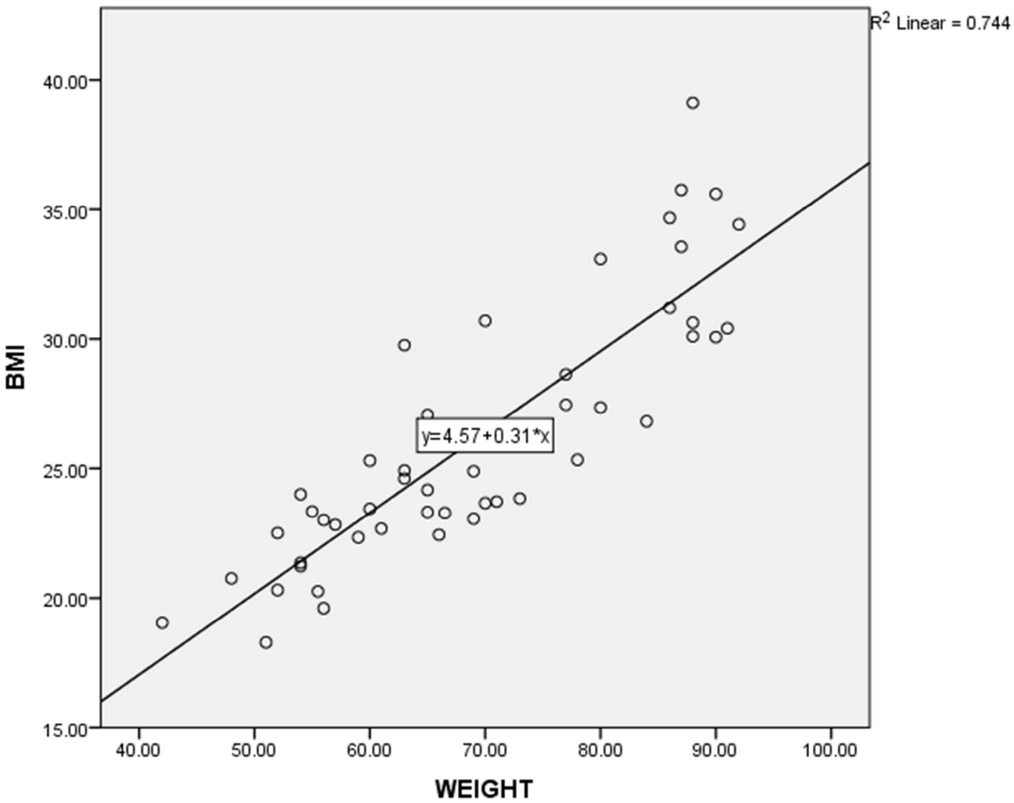


Figure 1: Graph of Body Mass Index (BMI) against Weight

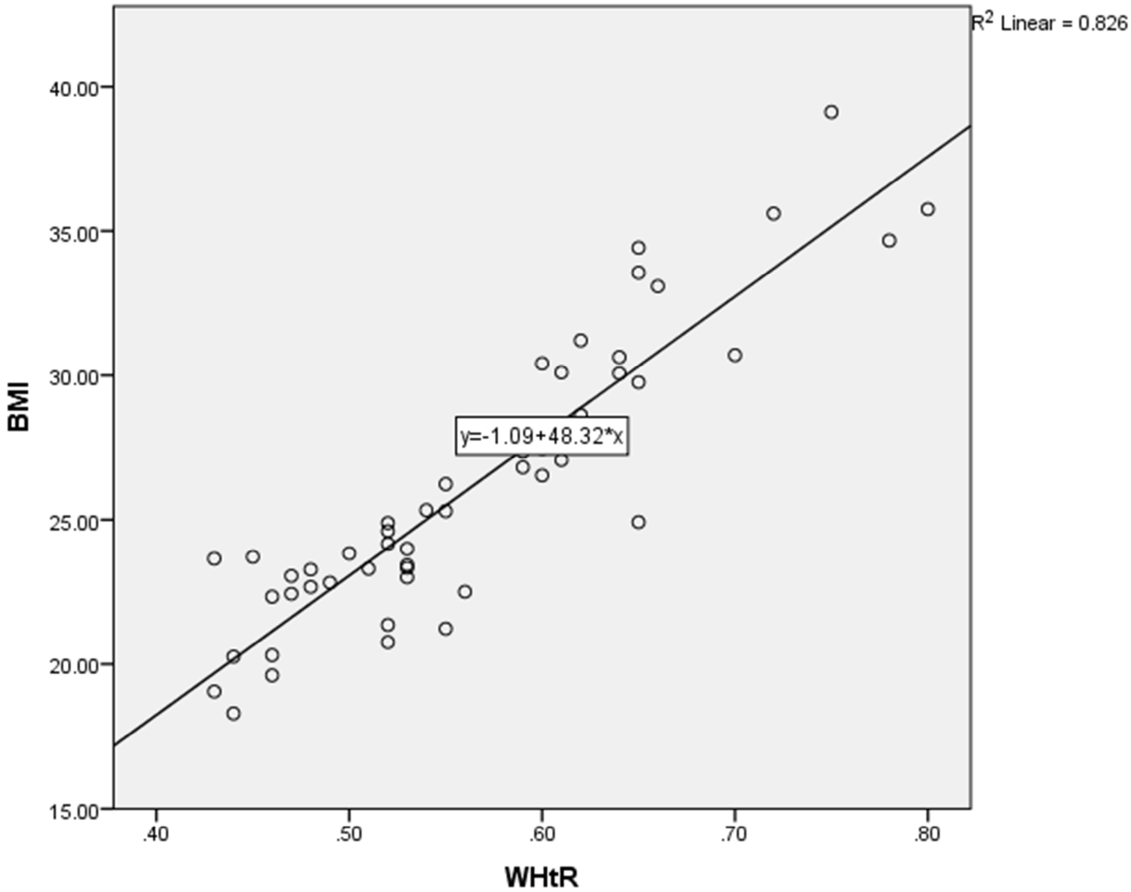


Figure 2: Graph of Body Mass Index (BMI) against Waist to Height Ratio

Equations (3) and (4) give

$$y = 0.155x_1 + 24.160x_2 + 1.740 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5$$

From equation 5, the BMI can be estimated if the Weight and WHtR of a subject are known.

The correlations table also shows a positive correlation between sex with BMI and WHtR. By this, it means that the BMI and WHtR are higher in women than in men. The bar-charts in figures 3 and 4 show a larger percentage of females with high values of BMI and WHtR.

 

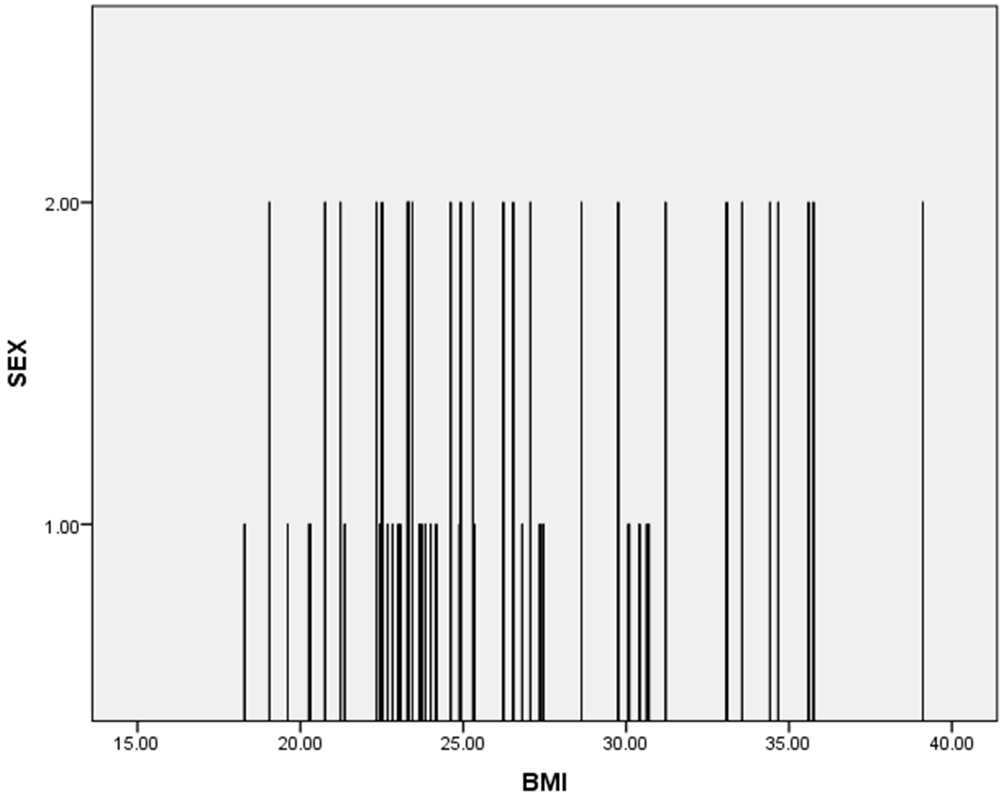


Figure 3: A bar-chart representing the BMI for males and females

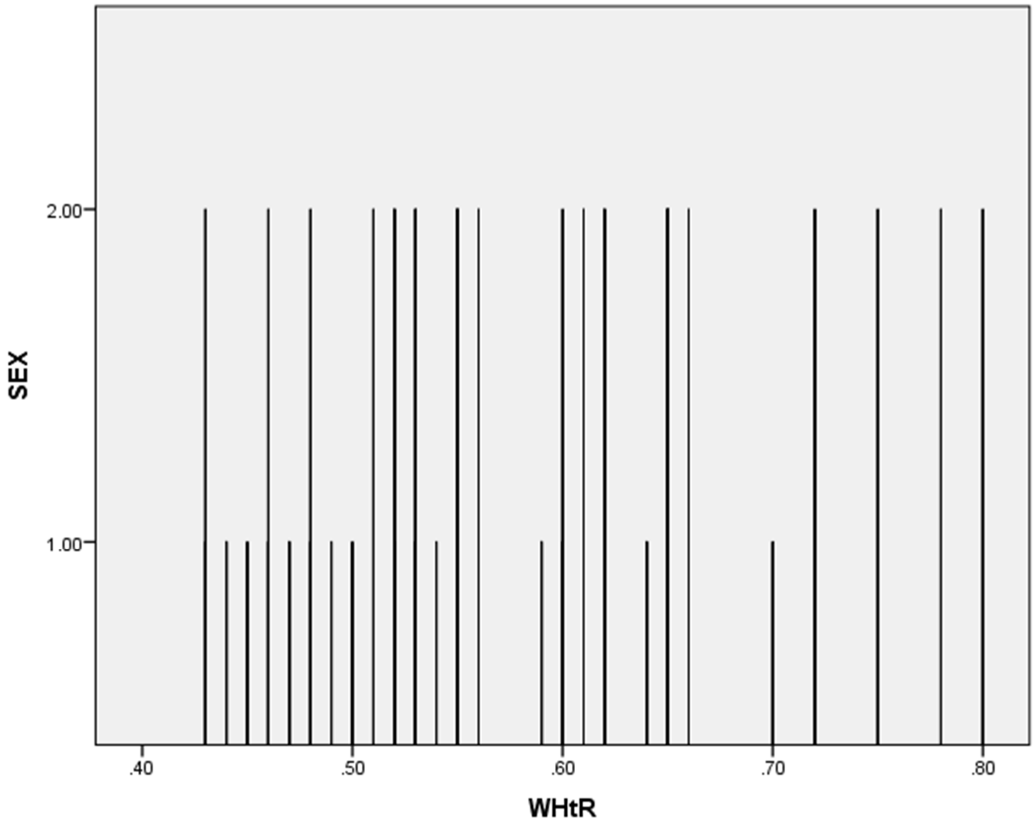


Figure 4: A bar-chart representing the WHtR for males and females

In figure 5, females have a lager sector in the pie-chart than males. These results all imply that females are more obese than males.

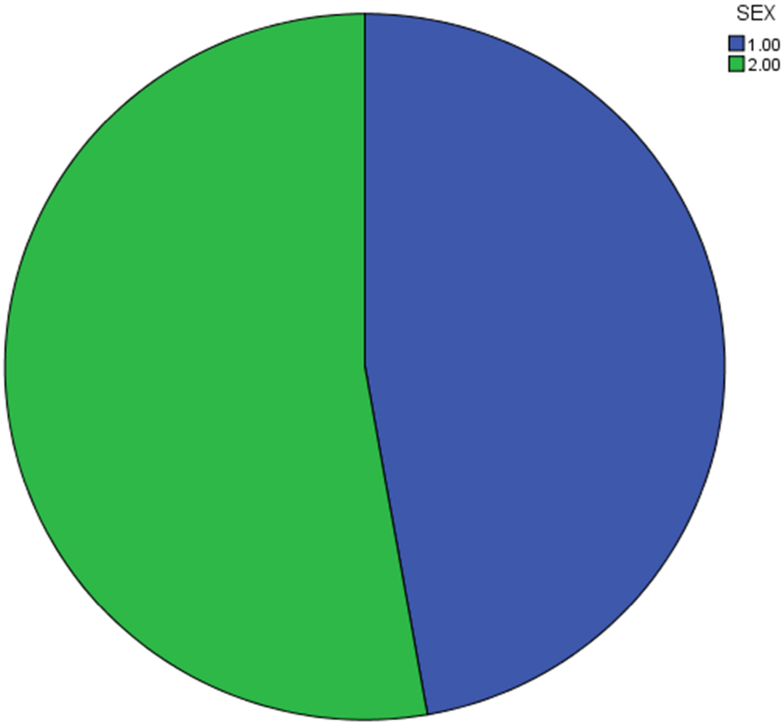


Figure: A pie-chart representing BMI and WHtR for males and females

**5. Conclusion, Suggestions and Recommendations**

Measurements of BMI and WHtR for males and females revealed that women are more over-weight and obese than men, hence are more liable to heart attack and stroke. This conclusion is believed to be true because women in sub-Saharan Africa including Nigeria consume a lot of sweet and fast foods than men besides their inability to exercise their body regularly. Apart from lack of checking food consumption and exercise, another risk factor of CVD is depression. Women have a lot of life problems such as divorce, widowhood and the after mat of crises leading to untold hardship and depression. All these risk factors contribute to the higher values of BMI and WHtR in women than in men making them at high risk of heart attack and stroke. It is therefore advisable for women to reduce the intake of sweet and fast foods and to get involved in regular exercise. These will help in reducing and burning the fats accumulated in their bodies. It is recommended that health awareness should be conducted regularly by health workers in schools, worship centers and other public places on checking the risk of CVD. Finally, the government and other philanthropic individuals and organizations should have a scheme for helping the widows and educating families and communities on the dangers of divorce and involving in communal/religious crises.

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