INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Correlation of Markers of Inflammation with Anthropometric Indices in Obese and Overweight Adults

Dr. Kareem Lookman Olalekan
Consultant Cardiologist, Department of Internal Medicine,
General Hospital Ikorodu, Lagos State, Nigeria
Dr. Kareem Rafiat Adeola
Consultant Chemical Pathologist, Department of Chemical Pathology,
LAUTECH Teaching Hospital, Ogbomoso, Oyo State, Nigeria

Abstract:
Background: Obesity has been found to be associated with low grade inflammation characterized by increased levels of inflammatory cytokines. Various anthropometric measurements have been shown to be associated with complications of obesity. Determining the most exact anthropometric index of overweight and obesity that best correlates with inflammatory markers will be helpful for early prevention of obesity related disorders.
Aim: To determine the correlation between markers of inflammation (hs-CRP and TNF α) with anthropometric indices such as body mass indices, waist circumference and waist hip ratio among study population.
Method: Two hundred and twenty obese and overweight individuals were involved in this study, fifty five normal BMI groups as control recruited from staff of the hospital and patient relatives and community residents within a four month period. The anthropometric measurements include: weight, height, abdominal circumference, waist circumference, hip circumference. Body mass index, Waist hip ratio were calculated from the anthropometric measurements. Serum inflammatory markers (hs-CRP and TNF-α) were measured using enzyme linked immunosorbent assay reagent kit from Span biotech limited.
Results: The study found an increase in the measured markers of inflammation across the stages of obesity using WHO classification based on body mass index (overweight, stage one, stage two and stage three) with significant correlation between the markers of inflammation and anthropometric indices.
Conclusion: There is significant association between markers of inflammation and anthropometric indices (Body mass index, Waist hip ratio, Waist circumference, abdominal circumference) in obese and overweight adults.

Keywords: *Inflammatory markers, Anthropometric indices, High sensitivity C-reactive proteins, Tumour necrosis factor alpha*

1. Introduction

Obesity and overweight are defined as abnormal or excessive fat accumulation that presents a risk to health.[1] Fat accumulation in the body reflects on the body weight relative to the height as measured by the body mass index (BMI). Based on the BMI, obesity is classified into stage 1 with a BMI between 30 and 34.9, stage 2 with a BMI between 35 and 39.9 and stage 3 or morbid obesity with a BMI equal to or greater than 40. Overweight describes BMI between 25 and 29.9.[1] Obesity can be further classified based on the distribution of fat in the body.

A Gynaecoid pattern describes more fat deposition to the hip and this is commoner in women, while an android pattern describes fat deposition to the abdomen known as abdominal obesity.[2]

The waist-hip ratio and abdominal circumference, as measures of obesity take this into cognizance and therefore obesity can also be defined using waist circumference (WC) criterion as an excess of adipose tissues resulting in waist circumference greater than 102cm (40 inches) and greater than 88cm (35 inches) for men and women respectively.[2] Similarly, abdominal overweight refers to the waist circumference between 94-101cm and 80-87cm for men and women respectively.[2]

Inflammation is an intricate network of chemical signals, cell types and factor interactions in response to tissue damage against pathogenic, traumatic or toxic injury. The inflammatory process is the result of a balance between pro- and anti-inflammatory molecules[3] such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), leptin, resistin, monocyte chemoattractant protein-1 (MCP-1), C-reactive protein (CRP) and anti-inflammatory molecule of Adiponectin.[3]

Inflammation, though a physiologic process necessary to restore homeostasis, can be deleterious and associated with disease when it is established chronically or in excess. Obesity is anatomically characterized by an excessive adipose tissue mass.[1]Adipose tissue is not simply a storage depot for energy. Instead, it is a complex, metabolically active tissue that secretes a variety of signaling molecules and pro-inflammatory factors that affect systemic metabolism.[2] Obesity has

been shown to be associated with chronic inflammation, the stimulus for which is the overfeeding which causes excess energy being stored in adipose tissue. Obesity is accompanied by an increased expression of adhesion receptors on adipocytes, followed by an enhanced infiltration of the adipose tissue with inflammatory cells, primarily macrophages.[4] Adipose tissue macrophages, which may constitute up to 40% of all cells within the adipose tissue, are an important source of pro-inflammatory cytokines, such as tumor necrosis factor (TNF)α, interleukin (IL)1,IL6 or monocyte chemo attractant protein 1/CC - chemokine ligand 2 (MCP1/CCL2). These not only contribute to the systemic proinflammatory condition frequently associated with obesity, but may also act locally and adversely affect adipocyte function, e.g. promote the development of insulin resistance.[4] Furthermore, macrophage-secreted chemokines (e.g. MCP1/CCL2 and IL8/CXC ligand 8 [CXCL8]) as well as adipokines (e.g. leptin) are potent angiogenic growth factors, and an enhance vascularization of the adipose tissue could further promote obesity and its metabolic complications by facilitating inflammatory cell recruitment.[4] The inflammatory cytokines, TNF-α and IL-6 acts on the liver to stimulate the secretion of acute-phase reactants which are markers of active inflammation and include fibrinogen, C-reactive protein (CRP), complement, serum amyloid A, haptoglobin, sialic acid, etc.[5] They are also secreted in the endothelial cells. The CRP, which is considered the classic sensitive acute-phase reactant, is a very sensitive systemic marker of inflammation, and its serum concentration increases rapidly in response to a variety of stimuli. This protein is present in low concentrations under normal conditions.[6]

1.1. Materials and Methods

This study is a descriptive cross sectional study carried out at LAUTECH teaching hospital, Ogbomoso. Participants (adults aged from 18 years to 60 years) were selected based on the diagnostic criteria for overweight (BMI 25-29.9kg/m^2), mild (30-34.9kg/m^2), moderate (35-39.9kg/m^2) and severe obesity (40kg/m^2) according to World Health Organization. The control group were age and sex matched individuals with BMI (20 -24.9kg/m^2) selected from the general population.

Ethical clearance was obtained from the ethical review committee of Ladoke Akintola University of Technology Teaching Hospital, Oyo State.

2. Sample Collection, Processing and Laboratory Analysis

2.1. Clinical Evaluation

Each participant had weight, height, abdominal circumference, waist circumference and hip circumference measured using standard instruments.

Height measurement waa taken using a stadiometer to the nearest 0.1m,with the head aligned in the Frankfort horizontal. Three measurements were taken and the average of the measurement was recorded.

A beam balance was used to weigh participants to the nearest 0.1kg. The weight was taken in kilograms (kg). Three measurements were taken and the average of the measurement was recorded.

The waist circumference was measured at the approximate midpoint between the lower-margin of the last palpable rib and the top of the iliac crest along the mid axillary line.

The hip circumference was taken at the level of the greater trochanters with feet placed together.

The abdominal circumference was measured at the level of the umbilicus.

For each of waist, abdominal and hip circumference, three measurements to the nearest 0.1cm was taken; the average was calculated and recorded.

2.1.1. The Following Calculations Were Made

The Body Mass Index was calculated using the following formula[7]:

BMI = weight (kg) / [height (m)]^2

Waist-Hip ratio was calculated using the formula:

Waist circumference (cm)/hip circumference (cm)

2.2. Sample Collection

Five millilitres of blood were withdrawn from the cubital vein dispensed into plain bottle for serum hs-CRP and TNF α levels estimation. Each sample was centrifuged at 3,000 rpm x g for 10 – 15 minutes using Everich centrifuge model 80-2, the centrifuge speed was routinely checked with a strobe tachometer as well as the timer according to College of American Pathologists (CAP) guidelines. The serum obtained was aliquoted into screw cap plane bottle and stored frozen at -20^{0}C, the temperature of the freezer was monitored with the daily check and recording of (National Institute of Standards and Technology) NIST-traceable thermometer immersed in the freezer until the time of analysis.

2.3. Laboratory Analysis of Biochemical Parameters

Serum hs-CRP and Serum TNF alpha were assayed using a double-antibody sandwich Enzyme linked immunosorbent assay Kit from SPAN BIOTECH LIMITED[8] Hong Kong (LOT 2017111501, 2017111502, 2017111503), (LOT NUMBER 2017111504, 2017111505, 2017111506). The assays were done using Labtech LT-4000 microplate Reader at a wavelength of 450nm. Control samples were assayed with each sample batch. Intrabatch and interbatch analysis was also carried out on the samples.

3. Statistical Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) 20.0 package after it has been entered into the software package. Continuous data were presented as mean ± standard deviation and categorical variables were presented as frequencies and percentages.

Appropriate statistical methods were used, such as chi-square, to compare the relationship between qualitative variable. Analysis of variance (ANOVA) was used to assess for significant associations between the means in quantitative variables. Correlation analysis was used to compare relationship between continuous variables.

4. Results

4.1. Demographic Characteristics of Patients and Controls

Two hundred and seventy five participants were recruited for the study consisting of 55 overweight participants (28 males and 27 females), 55 stage 1 obese participants (26 males and 29 females), 56 stage 2 obese participants (27 males and 29 females), 55 stage 3 obese participants (26 males and 29 females) and 54 control participants (28 males and 26 females) with normal range BMI (28 males and 26 females).

Out of the total two hundred and seventy-five participants, 135 were males, while 140 were females.

The study participants and the control were found to be age and sex matched, mean age (male 43.73 ± 9.88 and female 43.54 ± 8.75).

BMI Class	Male (%)	Female (%)	Total
Normal	28(51.9)	26(48.1)	54
Overweight	28(50.9)	27(49.1)	55
Stage 1	26(47.3)	29(52.7)	55
Stage 2	27(48.2)	29(51.8)	56
Stage 3	26(47.3)	29(52.7)	55
Total	135(49.1)	140(50.9)	275

Table 1: Showing BMI Class and Proportion of Male and Female Participants per Class

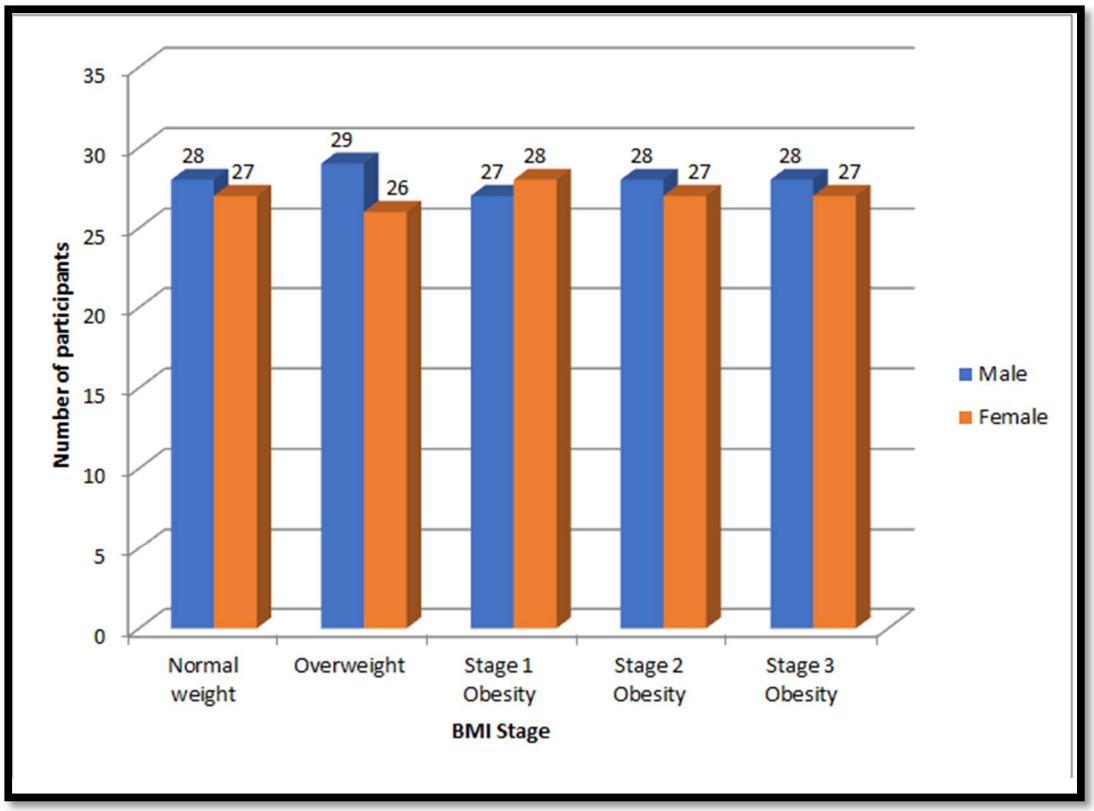

Figure 1: Bar Chart Showing Gender Distribution among the Participants and Control

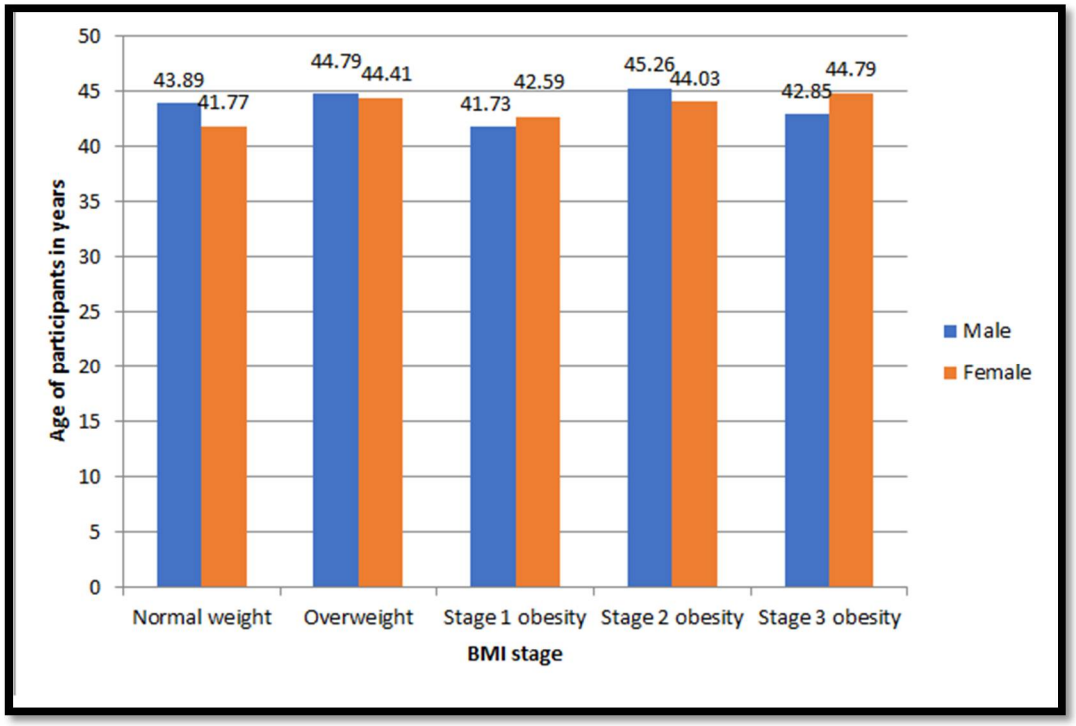

Figure 2: Age and Sex Distribution of Study Participants and Control across Various Stages of Obesity and Control

4.2. Anthropometric Measurements

The weight of the study participants increase across the stages of obesity: overweight, stage 1, stage 2, stage 3 (73.60 ± 6.67, 86.18 ± 7.51, 92.45 ± 7.53, 105.58±6.10). This is very highly significant ($p<0.001$) as compared with control {(normal BMI) 59.70 ± 9.79)}, whereas the height was higher in control (1.65 ± 0.10) and decreases down the stages of obesity (1.64 ± 0.07, 1.64 ±0.07, 1.58 ± 0.06, 1.57± 0.04); this is also very highly significant ($p<0.001$).

The waist circumference increases from overweight to stage 2(95.25 ± 6.28,103.25 ± 6.52,112.38 ± 8.69) but a slight fall was seen in stage 3(109.92 ± 6.54) though was found to be very highly significant as compared with waist circumference in the control participants which was found to be lower than that of all the stages of obesity (78.65±8.33).

The mean hip circumference increases from overweight to stage 3(105.47 ± 5.64,114 ± 6.23, 122.32 ±3.63, 133.27 ± 16.33) as compared with control participants (93.56 ± 6.43); this was also found to be significant ($p<0.001$). The mean body mass index also increase from overweight to stage 3(27.31 ± 1.35, 32.16 ± 1.79, 36.98 ± 0.92, 42.87 ± 1.73 respectively, $p<0.01$) which is also very highly significant as compared with control participants (21.92 ± 2.12). The mean waist hip ratio increased from overweight to stage 3(0.90 ± 0.06, 0.91 ± 0.06, 0.92 ± 0.01, 0.98 ± 0.10 respectively, $p<0.01$) which is very highly significant when compared with the control participants (0.84 ± 0.06).

Waist hip ratio across different sex in this study shows increased waist hip ratio in the male participants at the different stage of obesity when compared with the females at the same stage of obesity. (WHR males normal range 0.9, females 0.85)

Variables	C (N=54) Mean ± SD	OW (N=55)Mean ± SD	S1 (N= 55) Mean ± SD	S2 (N=56)	S3 (N=55)		Post Hoc Test§
Weight	59.70 ± 9.79	73.60 ± 6.67	86.18 ± 7.51	92.45 ± 7.53	105.58 ± 6.10	<0.001	C<OW, C<S1, C<S2,C<S3,OW<S 1, OW<S2, OW<S3,S1<S2, S1<S3, S2<S3
Height	1.65 ± 0.10	1.64 ± 0.07	1.64 ± 0.07	1.58 ± 0.06	1.57 ± 0.04	<0.001	C>S2, C>S3, OW>S2, OW>S3,
WC	78.65 ± 8.33	95.25 ± 6.28	103.25 ± 6.51	112.38 ± 8.69	109.92 ± 6.54	<0.001	C<OW, C<S1, C<S2, C<S3, OW<S1, OW<S2, OW<S3, S1<S2, S1<S3

Variables	C (N=54) Mean ± SD	OW (N=55)Mean ± SD	S1 (N= 55) Mean ± SD	S2 (N=56)	S3 (N=55)		Post Hoc Test§
HC	93.56 ± 6.43	105.47 ± 5.64	114.01 ± 6.23	122.32 ± 3.63	133.27 ± 16.33	<0.001	C<OW, C<S1, C<S2, C<S3, OW<S1, OW<S2, OW<S3, S1<S2, S2<S3
BMI	21.92 ± 2.12	27.31 ± 1.33	32.16 ± 1.79	36.98 ± 0.92	42.87 ± 1.73	<0.001	C<OW, C<S1, C<S2, C<S3, OW<S1, OW<S2, OW<S3, S1<S2, S1<S3,S2<S3,
WHR	0.84 ± 0.06	0.90 ± 0.06	0.91 ± 0.06	0.92 ± 0.07	0.98 ± 0.10	<0.001	C<OW, C<S1, C<S2, C<S3, OW<S3, S1<S3, S2<S3

*Table 2: Anova Table Showing Anthropometrics Measures Across the Stages of Obesity and Normal Bmi (Control) Key: C= Control, Ow= Overweight, S1= Stage One Obesity, S2= Stage Two Obesity, S3= Stage Three Obesity, Sd= Standard Deviation, Wc= Waist Circumference, Hc= Hip Circumference, Bmi= Body Mass Index, Whr= Waist: Hip Ratio. * Statistical Significance among Various Stages of Obesity and Normal Weight. § Post Hoc Test with Bonferroni's Correction.*

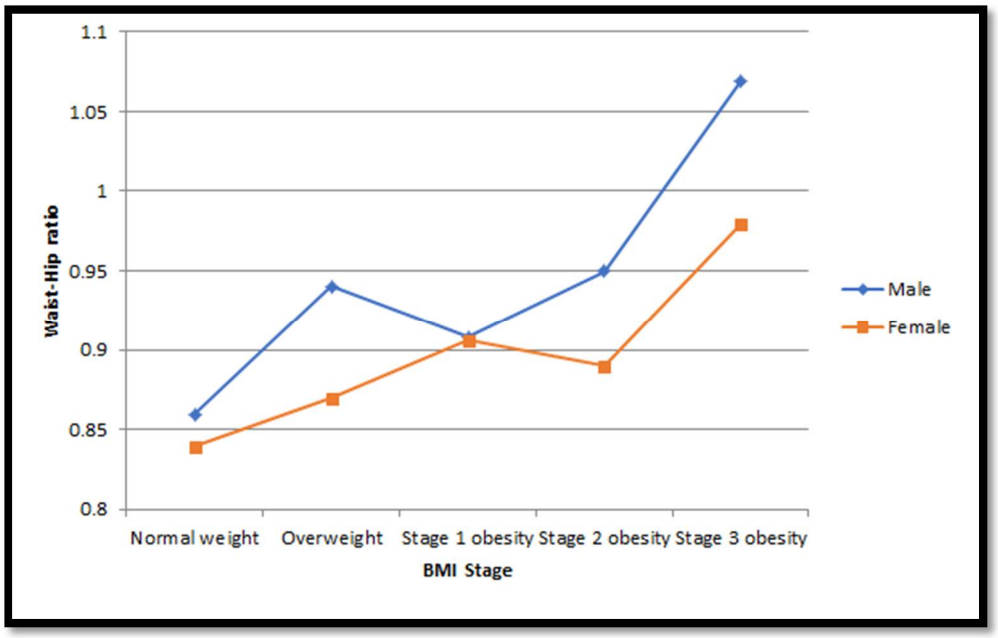

Figure 3: Waist Hip Ratio across Different Sex

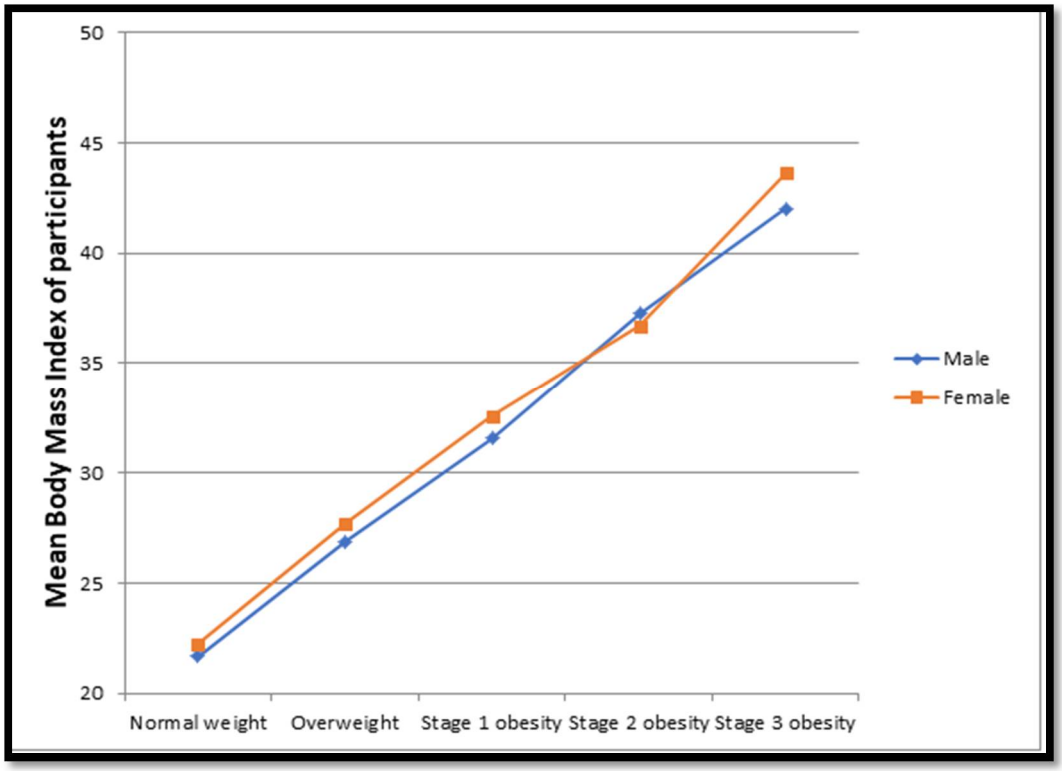

Figure 4: BMI of Participants across Various Stages of Obesity

4.3. The Inflammatory Markers across the Stages of Obesity and the Normal BMI Controls

Table 4: The Serum hs-CRP in the controls was found to be low and falls to the low cardiovascular risk group (hs-crp value <1ng/ml) while hs-crp levels increase across the stages of obesity in the participants, overweight participants fall into the intermediate cardiovascular risk group (hs-crp value between 1-3mg/ml) and stages 1-3 participants fall into high cardiovascular risk group (hs-crp>3ng/ml) and was statistically significant.

The serum TNF-α in the controls was found to be within the normal reference range (TNF-α 1.2-15.3pg/ml) and increases across the stages of obesity above the reference range and was found to be statistically significant. This is shown in table 4.

Variables	C (N=54) Mean ± SD	OW (N= 55) Mean ± SD	S1 (N= 55) Mean ± SD	S2 (N=56) Mean ± SD	S3 (N=55) Mean ± SD	p-value	Post Hoc Test§
Serum hs-CRP	0.93 ± 0.10	2.35 ± 0.44	3.27 ± 0.51	5.50 ± 0.74	6.97 ± 1.19	<0.001*	C<OW, C<S1, C<S2, C<S3, OW<S1, OW<S2, OW<S3, S1<S2, S1<S3, S2<S3
Serum TNF-α	6.57 ± 0.89	28.88 ± 4.67	33.36 ± 7.65	40.08 ± 1.04	51.92 ± 4.46	<0.001*	C<OW, C<S1, C<S2, C<S3, OW<S1, OW<S2, OW<S3, S1<S2, S1<S3, S2<S3

*Table 3: ANOVA Table Showing Inflammatory Markers across the Stages of Obesity and Normal Weight Key: C= Control, OW= Overweight, S1= Stage One Obesity, S2= Stage Two Obesity, S3= Stage Three Obesity, SD= Standard Deviation, Hs-CRP= Highly Sensitive C - reactive protein, TNF-A = Tumour Necrosis Factor Alpha. *Statistical Significance among Various Stages of Obesity and Normal Weight. §Post Hoc Test with Bonferroni's Correction*

4.4. Correlation of Inflammatory Markers with Anthropometric Indices

Table 4 showed the correlation of the inflammatory markers with anthropometric indices of obesity measured: Weight, BMI and WC showed high correlation with the inflammatory markers and statistical significance (r 0.8, p value<0.001, r 0.9 p value <0.001, r 0.7 p value<0.001) respectively.

WHR and HC showed a fair correlation with the inflammatory markers and statistical significance. (r 0.5, p value <0.001, r 0.5, p value <0.001).

Inflammatory markers showed a fair correlation with height but statistical significance (r 0.4.p value <0.001).

Variables	Plasma hs-CRP r (p-value)	Plasma TNF-α r (p-value)
Weight	0.834(<0.001) *	0.859(<0.001) *
Height	0.382(<0.001) *	0.298(<0.001) *
WC	0.729(<0.001) *	0.785(<0.001) *
HC	0.555(<0.001) *	0.599(<0.001) *
BMI	0.922(<0.001) *	0.903(<0.001) *
WHR	0.451(<0.001) *	0.490(<0.001) *

Table 4: Correlation between Plasma Hs-CRP, Plasma TNF-Alpha and Anthropometric Measures
*Key: R= Pearson's Correlation Coefficient, WC= Waist Circumference, HC= Hip Circumference, BMI= Body Mass Index, WHR= Waist: Hip Ratio. * Statistical Significance among Various Stages of Obesity and Normal Weight.§ Post Hoc Test with Bonferroni's Correction*

5. Discussion

Obesity has long been acknowledged as a significant contributing factor in the development of various chronic diseases such as cardiovascular disease, hypertension, type 2 diabetes mellitus, stroke, osteoarthritis and certain cancers.[9,10] As a risk factor for non-communicable diseases, obesity has become a global public health concern with more than one billion adults estimated to be overweight and over 400 million of them obese.[11]

It has been observed that raised concentrations of inflammatory markers especially hs-CRP in healthy subjects predicted the incidence of some of these chronic diseases. The knowledge of the presence of these inflammatory markers can be helpful in predicting the incidence of these chronic diseases.

The adipose tissue produces a variety of hormones and cytokines and thereby actively participates in a network of biomarkers that may be relevant for the development of CVD.[12]

Researchers have found that plasma levels of CRP, TNF-α and IL-6: markers of inflammation are elevated in subjects with obesity.[13]

This research work measured the inflammatory markers (hs-crp and TNF-α) and the correlation of these inflammatory markers with increasing BMI.

The mean ages between the control and study groups in this study had no significant statistical difference and this allowed for comparison among the study participants. There was no significant statistical difference in gender (sex) participation in each of the study groups. The participants were age and sex matched.

The mean weight, BMI, WC, WHR of the participants was higher than the controls which are statistically significant; this is expected since the study participants are the obese and overweight with increased deposition of adipose tissue. The anthropometric indices of obesity measured, all correlated with hs-crp and all showed statistical significance (<0.001). Weight and BMI shows a reasonably high correlation with hs-crp which is similar to what has been found and discussed in literatures.[13,14] Yahaya (Northern Nigeria) in his study found a similarly significant and independent association between BMI and hs-crp of participants.[15] Obesity is a known cause of increased level of CRP in plasma.[15] This may be due to the fact that adipocytes of obese individuals' release of pro-inflammatory cytokines (IL 6) stimulate hepatic production of hs-CRP. Also Khan R *et al* found that CRP levels were consistently elevated over the increasing grades of obesity as Pearson correlation coefficient showed a significant association of CRP with BMI.[16] Ferranti and Rifai 2002 also found that CRP increased in individuals with higher BMI.[17] Soyoye *et al* found positive correlation of hs-crp with all anthropometric indices of obesity studied with highest correlation in weight to height ratio.[18]

This study also found that waist circumference had a strong correlation with hs-CRP, while waist hip ratio (WHR) had a fair correlation with hs-CRP, but highly statistically significant. A number of studies also found WHR to correlate weakly with hs-CRP but with strong correlation with WC, for example, Nirmitha D.*et al* in their study found no correlation between WHR and hs-CRP but correlation between hs-CRP and BMI.[19]

Waist circumference represent the visceral adipose tissue deposition, visceral adipose tissue is metabolically more active and secrete more cytokines and hormones that are relevant for CVD compared with subcutaneous adipose tissue.[12] Some studies have shown that abdominal adiposity is associated with elevation of CRP levels, independent of body mass index (BMI), which is a measure of general adiposity. The proportion of people with elevated hs-CRP was significantly higher in those individuals with abdominal adiposity than control subjects, although they had a similar BMI.[19] Although a number of studies found WHR to correlate better with inflammatory markers than BMI[20,21], in this study we found that BMI correlated better than WHR; this is probably because the rate of visceral fat accumulation differs according to the gender and ethnic background, being more prominent in white men, African American women, and Asian Indian and Japanese men and women.[21]Such differences may explain the variation in the cardio metabolic risk between different populations.

TNF-α also shows statistical significance with the measured anthropometric indices, TNF-α shows strong correlation with BMI and also high statistical significance was found; this is similar to what Carmen M. and Gurrola D found increasing TNF-α with increasing weight; this supports the essential role of obesity in TNF-α production.[22] Also, Berbergoli and Laimer *et al* displayed elevated TNF alpha in obese subjects.[23] In this study, TNF-α correlated with WC and WHR and a highly statistically significant; this complements the fact that these inflammatory markers are also produced by visceral adipose tissue. Tumour necrosis factor-alpha is a pro-inflammatory cytokine that exerts numerous effects in adipose tissue, including lipid metabolism and insulin signaling, and circulating levels are increased with obesity and decreased with weight loss.[24]

6. Conclusion

Anthropometric indices, especially BMI and Waist circumference, can serve as a predictor of inflammatory states and further predicts occurrence of chronic non-communicating diseases.

7. References

i. Adeyemo A, Luke A, Cooper R, Wu X, Tayo B, Zhu X, et al. A genome-wide scan for body mass index among Nigerian families. Obes Res 2003; 11:266-273.
ii. Rodríguez-Hernández H, Simental-Mendía LE, Rodríguez-Ramírez G, Reyes-Romero MA. Obesity and Inflammation: Epidemiology, Risk Factors, and Markers of Inflammation. *Int. J. Endocrinol.*2013**:**1–11.
iii. Charo IF, Ransohoff RM. The many roles of chemokines and chemokine resceptors in inflammation. *N Engl J Med.*2006;354**:**610–621
iv. Katrin S,Stavros V.Konstantinides. Review Article Update on the Cardiovascular Risk in Obesity: Endocrine and Paracrine Role of the Adipose Tissue. *Hellenic J.Cardiol.*2011; 52:327–336.
v. Pickup JC. Inflammation and Activated Innate Immunity in the Pathogenesis of Type 2 Diabetes.Diabetes Care.2004;27:813-823.
vi. Pepys MB,Hirschfield GM *etal.* C-reactive protein: a critical update. *J. Clin. Invest.* 2003;111**:**1805–1812.
vii. Du Bois D, Du Bois EF. A formula to estimate the approximate surface area if height and weight be known. *Nutrition*1989;5**:**303-311..
viii. Span Biotech Limited. Human high sensitivity c-reactive protein(hs-crp). *Elisa Kit Cat NO* **:**UK-W1160
ix. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *J Am Med Assoc.*1999;282:1523.
x. Capuccio FP, Kerry SM, Adeyemo A, Luke A, Amoah AG,Bovet P etal. Body size and blood pressure: an analysis of Africans and the African diaspora. *Epidemiology.*2008;19**:**38-46.
xi. *International Association for the study of Obesity (IASO*).2009;33:1-192.
xii. Pischon T. Use of obesity biomarkers in cardiovascular epidemiology.*Dis Markers.*2009;26**:**247–263.
xiii. Haverkate F, Thompson SG, Pyke SD, Gallimore JR, Pepys MB.Production of C-reactive protein and risk of coronary events in stable and unstable angina. European Concerted Action on Thrombosis and Disabilities Angina Pectoris Study Group. *Lancet*1997;349**:**462–466.
xiv. Mendall MA, Patel P, Ballam L, Strachan D, Northfield TC.C-reactive protein and its relation to cardiovascular risk factors: A population based cross sectional study. *BMJ* . 1996;312**:**1061–1065.
xv. Yahaya, I. A. Distribution of Plasma C-reactive Protein Measured by High-sensitivity Assay in Healthy Nigerian Adults.*Sub-Saharan Afr Journal Med.*2014;1**:**26-30
xvi. Khan R,Haque SF. The inflammatory markers: C-Reactive Protein and TNF-α predict Cardiovascular risks in obese North Indian subjects. *Biomed. Res.*2011;22**:**475.
xvii. Ferranti SD, Rifai N. C-reactive protein and cardiovascular disease: a review of risk prediction and interventions. *Clin Chim Acta.*2002317**:**1–15.
xviii. Soyoye D, Kolawole B,Ikem R,Enikuomehin A.Relationship between high-sensitivity c-reactive protein and anthropometric indices of obesity. *Endocr. Abstr.* 2015;**38:**235.
xix. Dev N,Marcus SR.High sensitive C-reactive protein , an independent and early novel inflam- matory marker in healthy obese women.*Biomedical Research.*2012;23**:**73–77.
xx. Lapice E, Maione S,Patti L,Cipriano P,Rivellese AA,Riccardi G etal. Abdominal adiposity is associated with elevated C-reactive protein independent of BMI in healthy nonobese people. *Diabetes Care* .2009;32**:**1734–36.
xxi. Hiuge-SA, Kishida K, Funahashi T, Ishizaka Y, Oka R, Okada M. Reduction of visceral fat correlates with the decrease in the number of obesity-related cardiovascular risk factors in Japanese with Abdominal Obesity (VACATION-J Study). *J. Atheroscler.Thromb.* 2012;19**:**1006–18.
xxii. Gurrola-Diazz CM, Sanchez-Enriquez S, Oregon-romero E,Garcia-Lopez PM,Garzon de la Mora P,Bastidas-Ramirez BE etal. Establishment of a Cut-Point Value of Serum TNF- a Levels in the Metabolic Syndrome. *J Clin Lab Anal.*2009; 56**:**51–56.
xxiii. Berberoglu M. Evaluation of the correlation between serum tumor necrosis factor-alpha and relative body mass index (RBMI) in childhood. *J Pediatr Endocrinol Metab.*2001;14**:** 543–47.
xxiv. Petrášová D,Bertkova I, Petrasova M, Hijova E, Marekova M, Babinska I *etal.* Biomarkers associated with obesity and overweight in the roma population residing in eastern slovakia.*Cent Eur J Public Health.*2014;22:18–21.