

Original Research Article

DISTRIBUTION OF BODY MASS INDEX AND ABDOMINAL OBESITY IN BAYELSA STATE WITH ASSOCIATED INTERLEUKIN-2 GENE EXPRESSION

ABSTRACT

Aims:The aim of the present study was to evaluate the distribution, prevalence and determinants of obesity, overweight and abdominal obesity in Bayelsa State, Nigeria as well as associated IL-2 gene expression.

Study design:A community based cross sectional study design was employed to randomly select 420 participants(aged 18 – 65 years) for the study.

Methodology: The study participants were grouped into normal, overweight and general obesity based on their body mass index (BMI) and sub-grouped into normal and abdominal obesity based on their waist circumference. Weighing scale, metre rule and measuring tape were used to measure weight, height and waist circumference respectively. Real time PCR was used to quantify IL-2 gene expression.

Results:The BMI distribution of adults in Bayelsa State was symmetrical around the mean (27.25 ± 4.12). **Mean waist circumference was 95.27 ± 15.92 (men 97.51 ± 12.38 ; women 93.41 ± 18.15 cm).** The prevalence of obesity, overweight and abdominal obesity were 26.2% (male, 10.7%; females, 15.5%), 35.2% (males, 16.4%; female, 18.8%), and 62.9% (males, 28.1% females, 34.8%) respectively. Compared with the normal group, a significant upregulation of IL-2 gene expression was found in the overweight, general obesity and abdominal obesity groups ($p < 0.05$). Significant association of the following determinants with obesity was found: both sexes, age group 36 - 55 years, working as small and medium scale business entrepreneurs and civil servants. Age group 56 – 65 years and female sex were associated with abdominal obesity.

Conclusion:The present study found a high prevalence of overweight, general obesity and abdominal obesity in Bayelsa State and associated over expression of IL-2 gene. Findings may have implication for IL-2 based biomarker and drug development. Interventions to reduce BMI and waist circumference in Bayelsa State is emphasized in the present study.

Keywords: [Abdominal obesity, BMI, gene expression, interleukin-2, obesity, overweight]

1. INTRODUCTION

Overweight and obesity have grown to become a public health concern with a yearly global mortality of at least 2.8 million attributed to overweight or obesity [1]. Overweight or obesity is defined as abnormal or excessive fat accumulation in the body that presents a risk to health [1]. Based on body mass index (BMI), an individual with BMI between 25 - 29.9 kg/m² is considered overweight, while, ≥ 30 kg/m² is obese [2]. Even though BMI is the common measure for obesity, it has numerous limitations. Firstly, BMI does not provide any information on the distribution of adipose tissues in different parts of the body [3]. Secondly, BMI does not differentiate between adipose tissues, bone mass and muscular tissues [4]. However, the introduction of abdominal obesity measurement accounts for the distribution of adipose tissues around the abdomen which is a better indicator for cardio-metabolic diseases than BMI [2, 5]. In 2015, 37% of death due to noncommunicable diseases in low- and middle-income countries were caused by cardiovascular diseases[6].

The abdominal fat surrounding the liver and other abdominal organs, known as visceral fat, is very metabolically active. The excess macronutrients in the adipose tissues stimulates the adipose tissues to release fatty acids [7], inflammatory mediators [8], and to reduce the production of adiponectin [8]. These result in a proinflammatory state and oxidative stress [8], type II diabetes [9], higher levels of low density lipoprotein cholesterol [10], higher levels of triglycerides [11], and high blood pressure [12]. A previous study carried out among Shanghai women found a relationship between abdominal fatness and risk of death from any cause even in BMI-based normal-weight women, if they were carrying more of that weight around their waist [13].

The World Obesity Federation's 2023 atlas predicts that 51% of the world, or more than 4 billion people, will be obese or overweight within the next 12 years. Rates of overweight and obesity continue to grow in adults and children especially in lower income countries and have grown to epidemic proportions [14]. Thus, community-focused routine monitoring and surveillance of obesity to ascertain current status and trends is necessary to inform better health care service and government intervention [15]. World Health Organization analysis showed a rising trend in obesity in Africa [16]. In Nigeria, obesity is becoming a public health problem despite the constant high burden of underweight [17]. Combating obesity and overweight requires a range of measures [16, 17], however, not enough data on the current state of overweight and obesity in South South Nigeria is available to inform necessary measures.

Overweight or obesity is a state of low-grade chronic inflammation [18]. Inflammation is a physiological response used to restore a stable internal environment destabilized by diverse stimuli; however, inflammatory state chronically established or over produced causes harmful effects [19]. Interleukin 2 (IL-2) plays a central pleiotropic role in inflammatory response [20]. IL-2 is a glycoprotein produced by immune cells to enhance and amplify the functions of T-cell, natural killer cells, macrophages and B-cells in response to adverse internal and external stimuli. IL-2 promotes cytotoxicity of immune cells and is used as a therapeutic cytokine in cancer patient [20]. Previous studies have showed an upregulation of IL-2 among hypertensive and diabetic subjects [21, 22]. However, the role of IL-2 in overweight and obesity is yet to be fully established. Therefore, the aim of the present study was to investigate the association of IL-2 gene expression with overweight, general obesity and abdominal obesity among adults in Bayelsa State, Nigeria. The distribution, prevalence and determinants of overweight, general obesity and abdominal obesity were also evaluated.

2. MATERIAL AND METHODS

2.1 Study location

The study location was Bayelsa State, Nigeria. Bayelsa is a core state in the South-South Niger Delta region of Nigeria. It is located on latitude 5.152239 and longitude 6.192479. Bayelsa State was created in 1996 and was carved out of Rivers State, making it one of the newest states in the federation of Nigeria. Bayelsa State shares boundary with Rivers State to the East and Delta State to the west, with the waters of the Atlantic Ocean dominating its southern borders. Bayelsa State has a total area of 10, 773 km². The State comprises eight Local Government Areas (LGA), they are Ekeremor, Kolokuma/Opokuma, Yenegoa, Nembe, Ogbia, Sagbama, Brass and Southern Ijaw. Sagbama LGA was randomly selected for the present study [23, 24].

2.2 Study design and population

A cross sectional multistage random sampling study design was employed to select 420 study participants [25]. Based on BMI, selected study participants were grouped into three: normal (BMI, 18.5 – 24.9 kg/m²), overweight (BMI, 25.0 – 29.9 kg/m²) and general obesity (BMI, 30.0 kg/m² and above) [2]. Study participants were further sub-grouped based on waist circumference into two subgroups: normal (waist circumference < 88 cm for women and < 102 cm for men) and abdominal obesity (waist circumference > 88 cm for women and > 102 cm for men) [2]. A structured questionnaire was used to obtain sociodemographic variables. Adults, 18 years old and above were included in the study while pregnant women were excluded from the study [26]. Sample size was determined using the formula below [27].

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where n_0 is the sample size; e is the desired level of precision (i.e. the margin of error), 0.05; P is the expected prevalence or proportion, which was estimated from a previous study as 0.48 [17]; q is $1 - P$ which is 0.52; Z -value was found in a Z table, Z -value at 95% confidence interval was 1.96.

$n_0 = ((1.96)^2 (0.48) (0.52)) / (0.05)^2 = 3.84 \times 0.25 / 0.0025 = 0.38 / 0.0025 = 383.39$. Assuming a non-response rate of 10% the sample size was made up to 421 and rounded up to 420.

2.3 Measurement of overweight and general obesity

The BMI formula, weight in kilogram divided by the square of height in metres was used for the measurement of overweight and general obesity. Overweight was measured as BMI between 25 – 29.9 kg/m²; while, general obesity was measured as BMI ≥ 30 kg/m² and normal BMI was between 18.5 – 24.9kg/m². Weight was measured using the Camry mechanical personal weighing scale (Model, BR2018), while height was measured using a metre rule [2].

2.4 Measurement of abdominal obesity

Waist circumference was obtained by horizontally wrapping a measuring tape around the largest part of the abdomen (below the umbilicus). Each study participant was allowed to breathe out normally and measurement was taken. The tape was held lightly so as not to compress the skin. Measurement for men, a waist circumference more than 102cm (40in) was taken as measure of abdominal obesity, while for women, waist circumference more than 88cm (34.6in) was taken as measure of abdominal obesity [2].

2.5 Extraction of total RNA from human peripheral blood mononuclear cells

Total RNA was extracted from human peripheral blood mononuclear cells following the manufacturer's protocol for Total RNA Mini Kit (Geneaid, New Taipei city, Taiwan) as previously described [21, 22].

2.6 Complementary DNA (cDNA) synthesis

The extracted RNA was reverse transcribed into complementary DNA (cDNA) using FireScript Reverse Transcriptase cDNA synthesis kit (Solis BioDyne, Tartu Estonia) following the manufacturer's instruction. The reverse transcriptase PCR cycling conditions were: primer annealing at 25^oC for 10 min, reverse transcription at 48^oC for 15 min, inactivation at 85^oC for 5 min [21, 22].

2.7 IL-2 gene expression determination

The manufacturer's protocol for 5x HOT FIREPol EvaGreen qPCR Supermix (Solis BioDyne, Tartu, Estonia) was followed for IL-2 gene expression analysis. Custom designed primers synthesized by Genewiz (South Plainfield, New Jersey) were used. GAPDH forward and reverse primer sequences: 5' GTCTCCTCTGACTTCAA-3' and 5' ACCACCCTGTTGCTGTA-3'. IL-2 forward and reverse primer sequences: 5' AAGAATCCCAA ACTA ACCAGGAT3' and 5' TCTAGACATGAAGATGTTTCAGTTCTC3' were used as previously described [21, 22]. The reaction mixture contained 4 µl of PCR supermix, 1 µl primer mix, 4 µl of cDNA template, and 11 µl of water. Applied Biosystem StepOne Plus real-time polymerase chain reaction machine coupled with stepone plus software (Thermo Fisher Scientific, California, USA) was used for analysis. Cycling conditions were: initial activation at 95^oC for 12 min, followed by 40 cycles of denaturation at 95^oC for 15 s, annealing at 53^oC for 30s and elongation at 72^oC for 30s.

2.8 Statistical analysis

SPSS 27 was used for data analysis. Descriptive parameters were presented as percentages. Chi square test and logistics regression were used to test for significant association between categorical variables. 2^{-ΔΔCt} method was used to quantify IL-2 gene expression [28]. T-test was used to test for significant difference between means and significant level was set at ($P < 0.05$).

3. RESULTS AND DISCUSSION

3.1 BMI distribution of adults in Bayelsa State, Nigeria

Figure 1 shows the BMI distribution of adults in Bayelsa State, Nigeria. The mean and median BMI were 27.25± 4.12 and 27kg/m² respectively. **This similarity in mean and median shows that the BMI distribution of adults in Bayelsa State is symmetrically distributed around the mean. Community based BMI distribution among adults in Nigeria especially in South-South Nigeria is sparse in literature. The present study has thus helped to fill the gap in research which might inform appropriate interventions.**

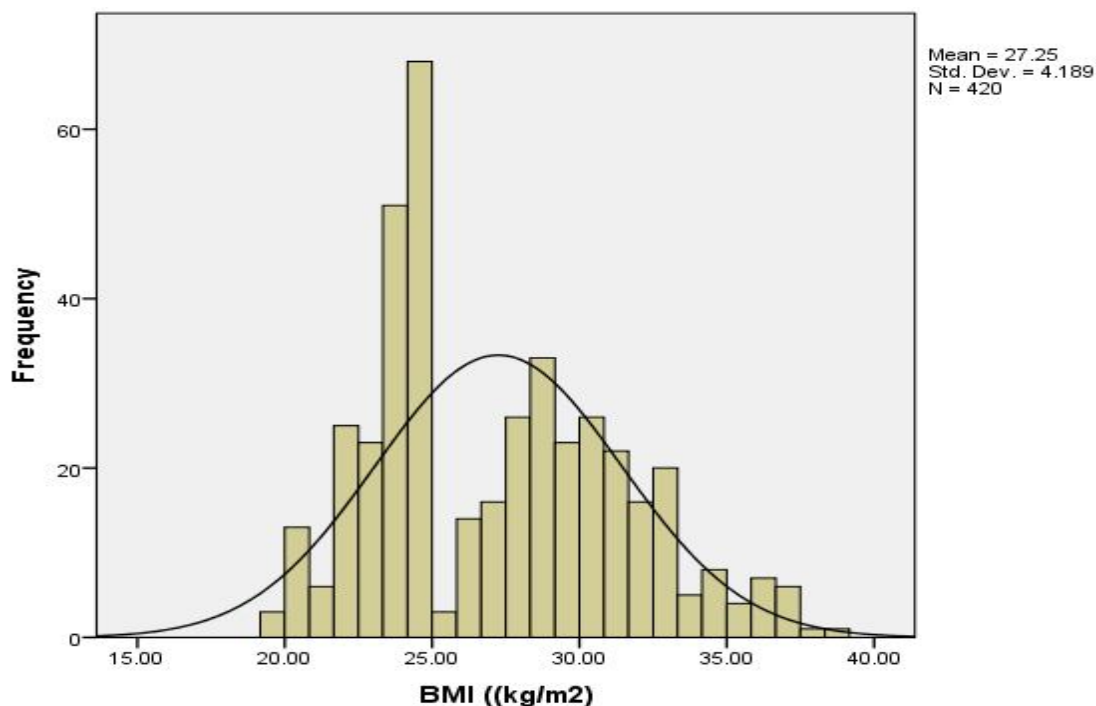


Figure 1. BMI distribution of adults in Bayelsa State, Nigeria

3.2 Prevalence and determinants of overweight and obesity among adults in Bayelsa State, Nigeria

The prevalence and determinants of overweight and general obesity among adults in Bayelsa State, Nigeria is presented in Table 1. The prevalence of overweight and general obesity were 35.2% and 26.2% respectively. Age related increase in body mass index was found among adults in Bayelsa State, Nigeria. Being a female, age 36 years and above, working as a civil servant and small and medium entrepreneurs were associated with obesity and overweight ($P < 0.05$). The prevalence of overweight and general obesity found in the present study was higher than findings of previous studies [29]. This reaffirms the rising trend in overweight and obesity and suggest the need to make interventions available for overweight and obese subjects [15].

Table 1 Prevalence and determinants of overweight and obesity among adults in Bayelsa State, Nigeria

	Normal	Overweight	Obesity	Normal vs	Normal vs
BMI (kg/m²)	(18.5 – 24.9)	(25 – 29.9)	(≥ 30)	overweight	obesity
Determinants	N (%)	N (%)	N (%)		
Sex					
Male	76 (18.10)	69 (16.43)	45 (10.71)	.23	.04
Female	86 (20.48)	79 (18.81)	65 (15.48)	.002	.01

Age

18 – 25	35 (8.33)	20 (4.76)	23 (5.48)	.046	.12
26 – 35	43 (10.24)	35 (8.33)	42 (10.00)	.37	.91
36 – 45	49 (11.67)	29 (6.91)	19 (4.52)	.03	<.001
46 – 55	39 (9.29)	29 (6.91)	22 (5.24)	.23	.03
56 - 65	12 (2.86)	11 (2.62)	12 (2.86)	.84	1.00

Occupation

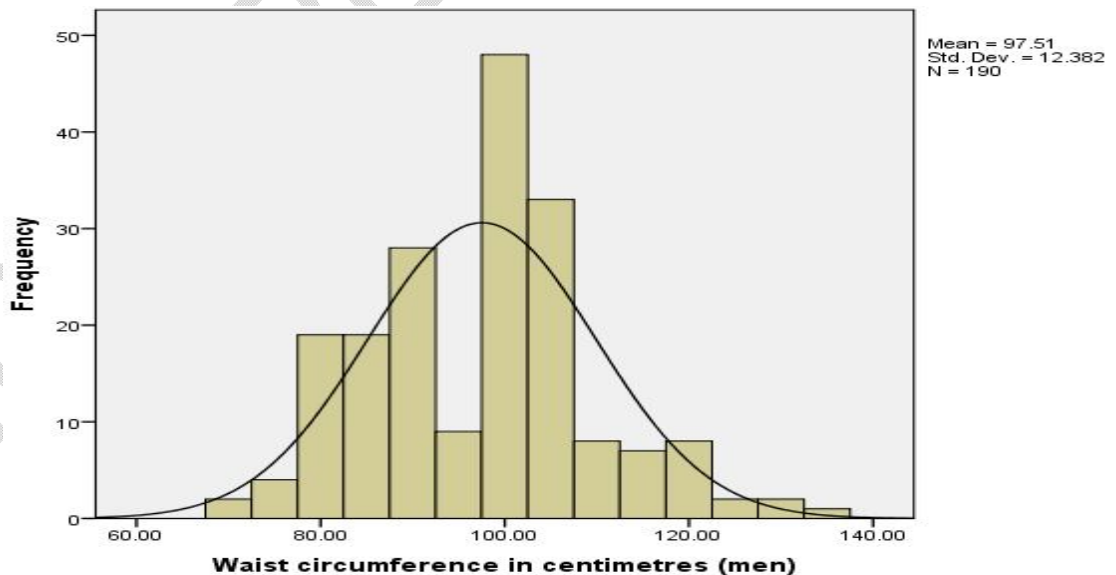
None	18 (4.23)	14 (3.33)	14 (3.33)	.48	.48
Farming / fishing	63 (15.00)	59 (14.04)	45 (10.71)	.72	.09
SMEs	48 (11.43)	24 (5.71)	29 (6.90)	.01	.03
Civil servant	27 (6.43)	13 (3.10)	9 (2.14)	.03	.004
Student	22 (5.24)	14 (3.33)	21 (5.00)	.19	.89

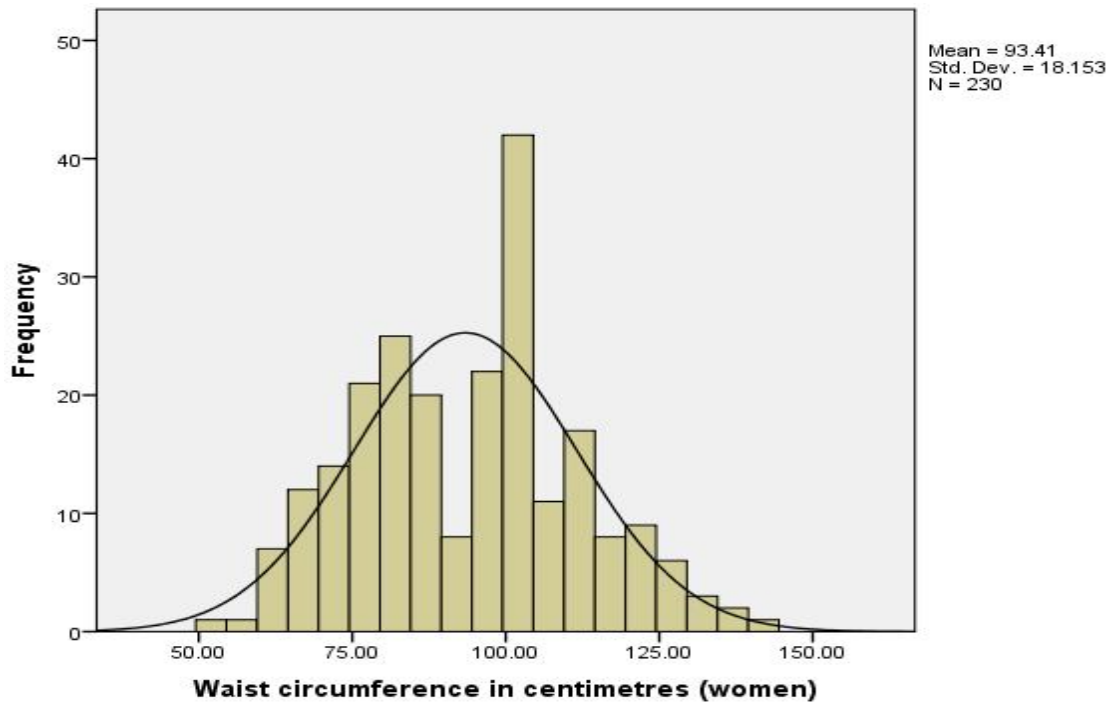
N = number of participants; SMEs: small and medium entrepreneurs; vs: versus

3.3 Waist circumference distribution of adults in Bayelsa State, Nigeria

Figure 2 shows the waist circumference distribution of a) men and b) women in Bayelsa State, Nigeria. The mean waist circumference was 95.27 ± 15.92 cm (men 97.51 ± 12.38 ; women 93.41 ± 18.15 cm). The mode was 102 cm (men 102 cm; women 102 cm) and median 98.50 cm (men 100 cm; women 96.5 cm). A high mean waist circumference was found.

(a)





(b)

Figure 2 Waist circumference distribution of a) men and b) women in Bayelsa State, Nigeria

3.4 Prevalence and correlates of abdominal obesity among adults in Bayelsa State, Nigeria

Presented in Table 2 is the prevalence and correlates of abdominal obesity among adults in Bayelsa State, Nigeria. A high prevalence of abdominal obesity was found. Also, a significant difference in waist circumference was found between age groups, sex and occupation types. Age group 56 – 65 years, being a female and a small and medium scale entrepreneur were associated with abdominal obesity ($P < 0.05$). A strong positive linear correlation was found between BMI and waist circumference ($r = 0.81, P < 0.01$). This corroborates the use of abdominal obesity as a strong risk factor / marker for cardio-metabolic diseases [2, 5] and indicates that both measures accurately predicted obesity. The prevalence of abdominal obesity found in the present study was higher than the combined prevalence of overweight and general obesity. This means that some normal weight participants in the present study also had abdominal obesity. According to findings of a previous research, more than half of Americans with normal BMI also have abdominal obesity [30]. Abdominally obese individuals have a substantially increased risk of cardio-metabolic complications [2] and according to American Heart Association waist size predicts heart attack better than BMI especially among women [31]. Furthermore, the prevalence of abdominal obesity found in the present study was higher than findings of previous studies [17, 32]. Again, this reaffirms a rising trend in the prevalence of abdominal obesity.

Table 2. Prevalence and determinants of abdominal obesity among adults in Bayelsa State, Nigeria

Determinants	Normal	Abdominal obesity	Normal vs abdominal obesity
	N (%)	N (%)	P-value
Sex			
Male	96	94	.89
Female	87	143	<.001
Age			

18 – 25	34	44	.26
26 – 35	50	70	.07
36 – 45	48	49	.92
46 – 55	40	50	.30
56 – 65	11	24	.03
Occupation			
None	23	23	1.00
Farming / fishing	72	95	.08
SMEs	46	55	.03
Civil servant	22	27	.37
Student	20	37	.48

N = number of participants; SMEs: small and medium entrepreneurs

3.5 Association of Interleukin-2 gene expression with overweight and obesity

A significant upregulation in interleukin-2 gene expression was found among obese and overweight subjects compared with the normal group ($p < 0.05$). Findings from this study corroborates a previous finding where elevated adipose tissue was associated with IL-2 gene expression among obese subjects and correlated with metabolic inflammation and insulin resistance [20]. Further study is needed to fully establish the relationship between increase in inflammatory cytokines and obesity [31]. However, findings from the present study indicate that IL-2 plays a pivotal role in the progression of inflammation in overweight and obese conditions.

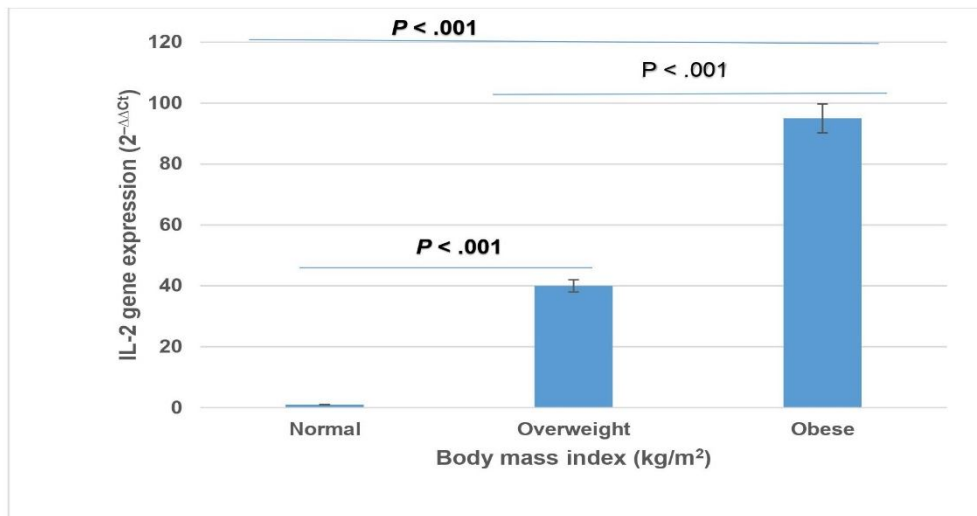


Figure 3 Upregulation of Interleukin-2 gene expression among overweight and obese adults in Bayelsa State, Nigeria Results are presented as mean fold change \pm standard deviation ($2^{-\Delta\Delta C_t}$). P value represents significant difference between groups (Normal body mass index = 18.5 – 24.9 kg/m²; overweight, 25 – 29.9 kg/m² and obese, ≥ 30 kg/m²).

3.6 Association of Interleukin-2 gene expression with abdominal obesity

Figure 4 shows the association between interleukin-2 gene expression and abdominal obesity among adults in Bayelsa State, Nigeria. A significant difference in IL-2 gene expression was found between normal abdominal size and abdominally obese subjects ($p < 0.001$). Previous studies have showed a high level of IL-2 among other metabolic

diseases such as diabetes and hypertension [21, 22]. However no report on the gene expression level of IL-2 among abdominal obese subjects has been previously reported. This novel findings suggests that IL-2 might be a potent target for the treatment and management of abdominal obesity among adults. Obesity and its associated diseases are major problems globally [1, 2].

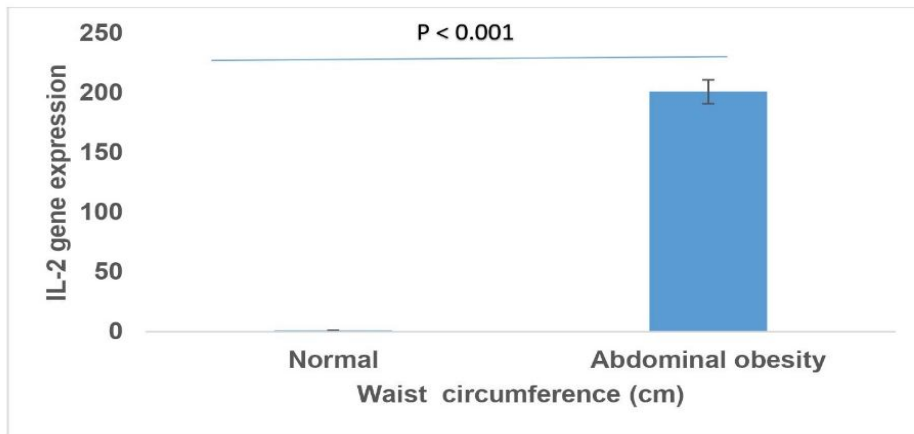


Figure 4 Interleukin-2 gene expression in relation to abdominal obesity among adults in Bayelsa State, Nigeria Results are presented as mean fold change \pm standard deviation ($2^{-\Delta\Delta Ct}$). P-value represents significant difference between groups ($p < 0.001$).

Although decades of research have yielded several treatments for various metabolic and non-communicable diseases [32, 33, 34], yet, a rising trend in cardio-metabolic and non-communicable diseases is still been observed [1, 15]. The present study reemphasizes the importance of routine measurement of one's BMI and waist circumference for normal healthy living. It also showed that evaluation of systemic IL-2 level might help monitor the progress of inflammation among obese and overweight adults. Furthermore, the present study showed that genetic predisposition and the influence of sociodemographic factors contribute to the development of obesity and abdominal obesity. Also, as revealed in the present study, changes in the expression of genes are involved in the predisposition to weight gain and obesity.

4. CONCLUSION

The present study found a high prevalence of overweight, general obesity and abdominal obesity among adults in Bayelsa State, Nigeria. An upregulation of IL-2 gene expression was found among overweight, obese and abdominally obese adults, however, the highest expression of IL-2 mRNA transcript was found among adults with abdominal obesity. Sex (both males and females) and the following categories of adults were found to be significantly obese compared with other groups: small and medium scale business entrepreneurs, civil servants and adults within age group 36 - 55 years. Age 56 - 65 years and female sex were associated with abdominal obesity. Findings of the present study suggest that IL-2 might be a potent target or biomarker for the treatment and monitoring of inflammation among overweight, whole body obese and abdominally obese adults. Interventions to raise awareness on the toxic effect of overweight, general obesity and abdominal obesity is highly recommended.

ETHICAL APPROVAL AND CONSENT

Ethical approval for the study was obtained from the Bayelsa State Primary Health Care Ethics Committee in Sagbama LGA. Voluntary informed consent was obtained from each participant and they were assured of confidentiality.

REFERENCES

1. World Health Organization. Obesity. Geneva, Switzerland. 2021.
2. World Health Organization. Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation Geneva, 8-11 December 2008, Geneva, Switzerland. 2011.
3. Nuttall FQ. Body Mass Index: Obesity, BMI, and Health: A Critical Review. *Nutr Today*. 2015;50(3):117-128.
4. Centers for Disease Control and Prevention. Body Mass Index: Considerations for Practitioners"Atlanta, Georgia. Assessed: 2nd August 2011. Available: <https://www.cdc.gov/obesity/downloads/bmiforpractitioners.pdf>

5. Dhawan D, Sharma S. Abdominal Obesity, Adipokines and Non-communicable Diseases. *J Steroid BiochemMol Biol.* 2020;203.
6. WHO Africa. Cardiovascular diseases, Noncommunicable diseases. Geneva, Switzerland. 2023.
7. Spalding K. Bernard S. Näslund EM. Salehpour G. L. Possnert L. Appelsved K. Fu K. Alkass H. Druid A. M. Thorell M. Ryden PA. Impact of fat mass and distribution on lipid turnover in human adipose tissue. *Nat Commun.* 2017;8:15253.
8. Ellulu MS Patimah I. Khaza'ai H. Rahmat A. Abed Y. Obesity and inflammation: the linking mechanism and the complications. *Arch Med Sci.* 2017;13(4):851-863.
9. Lee JJ. Beretvas SN. Freeland-Graves JH. Abdominal adiposity distribution in diabetic/prediabetic and nondiabetic populations: a meta-analysis. *J Obes.* 2014.
10. Luo Y. Ma X. Shen Y. Hao Y. Hu Y. Xiao Y. Bao Y. Jia W. Positive relationship between serum low-density lipoprotein cholesterol levels and visceral fat in a Chinese nondiabetic population. *Plos ONE* 2014.
11. Huang CY. Huang HL. Yang KC. Lee LT. Yang WS. Huang KC Tseng FY. Serum triglyceride levels independently contribute to the estimation of visceral fat amount among nondiabetic obese Adults. *Medicine.*2015;94:23.
12. Goswami B. Reang T. Sarkar S. Sengupta S. Bhattacharjee B. Role of body visceral fat in hypertension and dyslipidemia among the diabetic and nondiabetic ethnic population of Tripura-A comparative study. *J Family Med Prim Care.*2020;9(6):2885-2890.
13. Zhang XO. Shu G. Yang G. Abdominal adiposity and mortality in Chinese women. *Arch Intern Med.* 2007;167:886-892.
14. World Obesity Federation. World Obesity Atlas 2023. London, United Kingdom. 2023
15. World Obesity. Obesity monitoring and surveillance – what is being done? Accessed 2020. Available: <https://www.worldobesity.org/news/obesity-monitoring-and-surveillance-what-is-being-done>.
16. World Health Organization Africa. **Obesity rising in Africa, WHO analysis finds. WHO Africa, Geneva, Switzerland. 2022.**
17. Were JM. Kyeremeh E. Annor BO. Campbell MK. Stranges, S. Abstract MP23: Does Predictors Of Overweight/obesity Among Women Vary Based On The Residential Setting? A Multilevel Analysis Of Repeated Cross-sectional Data In Nigeria. *Circulation.* 2022;145(1).
18. Hotamisligil G.S. Inflammation, metaflammation and immunometabolic disorders. *Nature.* 2017;542:177–185.
19. 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.
20. Kochumon S. Al Madhoun A. Al-Rashed F. Thomas R. Sindhu S. Al-Ozairi E. Al-Mulla F. Ahmad R. Elevated adipose tissue associated IL-2 expression in obesity correlates with metabolic inflammation and insulin resistance. *Sci Rep.* 2020;10:1.
21. Ogbole FA. Harold BA. Association of undiagnosed pre-diabetes and type-2 diabetes mellitus with interleukin-2 mRNA expression among adults in Bayelsa State, Nigeria. *IJRR.* 2023; **10(5): 210 – 215.**
22. Ogbole FA. Igwe CU. Onuoha CH. Moroyei BE. Upregulation of interleukin-2 among hypertensive subjects in Bayelsa State, Nigeria. *IJRR.* 2023; **10(6):1.11.**
23. Ogbole FA. Oyelana O. Health risk assessment of the drinking water from Sagbama River, Bayelsa State, Niger Delta, Nigeria. *IJSER.* 2020;1(9):806 – 810.
24. Niger Delta Budget Monitoring Group. Overview of Bayelsa State. Accessed: 2022. Available: <https://www.nigerdeltabudget.org/overview-of-bayelsa/>
25. Ogbole FA. Fatusi AO. Co-occurrence of health risk behaviours for communicable and non-communicable diseases in a tertiary institution in South West Nigeria. *IJSR.*2020;7(1):10-14.
26. Ogbole FA. Urinalysis for Dehydration, Kidney Injury and Urinary Tract Infection Assessment in Rural Riverside, Bayelsa State, Nigeria. *IJSRT.* 2021;6(12):806 – 810.
27. Charan J. Biswas T. How to calculate sample size for different study designs in medical research. *Indian J. Psychol Med.* 2013;35(21):121-126.
28. Livak KJ. Schmittgen TD. Analysis of relative gene expression data using real-time quantitative PCR and the $2^{-\Delta\Delta Ct}$ Method. *Methods.* 2001;25(4):402-408.
29. Otovwe A. Prevalence of obesity among adults in Issele-Uku, Delta State Nigeria. *Alexandria J. Med.* 2018;54(4):463 – 468.
30. Bosomworth NJ. Normal-weight central obesity: Unique hazard of the toxic waist. *Can Fam Physician.* 2019;65(6):399-408.
31. Febrario MA. Role of interleukins in obesity: implications for metabolic disease. *Trends EndocrinolMetab.* 2014;25(6).
32. Chukwuonye II. Chuku A. John C. Ohagwu KA. Imoh ME. Isa SE. Ogah OS. Oviasu E. Prevalence of overweight and obesity in adult Nigerians – a systematic review. *Diabetes MetabSyndrObes.* 2013;6:43–47.
33. Ogbole FA. Crown OO. Olayeriju OS Olaleye MT. Akindahunsi AA. Hepatoprotective and antidyslipidemic effect of methanolic extract of *Garcinia kola* leaves on streptozotocin-induced diabetic rats. *IJEAST.* 2019;4(4):1-5.
34. Eghianruwa KI. Oridupa OA Saba AB. Medicinal Plants Used for Management of Hypertension in Nigeria. *ARRB.* 2016;11(3):1-10.

35. Ogbole FA. Crown OO. Olayeriju OS. Olaleye MT. Akindahunsi AA. Antidiabetic effect of methanolic extract of *Garcinia kola* leaves on streptozotocin-induced diabetic rats. *GSJ*; 2019;7(4):634 – 641.

UNDER PEER REVIEW