Magna Scientia Advanced Research and Reviews

eISSN: 2582-9394

Cross Ref DOI: 10.30574/msarr

Journal homepage: https://magnascientiapub.com/journals/msarr/

(RESEARCH ARTICLE)

Check for updates

Assessment of predisposition of diabetes mellitus among obese individuals in Enugu southeastern, Nigeria

Ifeoma Chinwe Ikegwuonu [1,*], Peace Ginikachukwu Odo [1], Faith Chinasa Abel [1], Obiageri Charity Okereke [1] Blessing Chidimma Okpagu [1] and Samuel Onuzulike Ebede [2]

[1] *Department of Medical Laboratory Sciences, Faculty of Health Sciences and Technology, College of Medicine, University of Nigeria Enugu Campus. Enugu State, Nigeria.*
[2] *Department of Medical Microbiology, University of Nigeria Enugu Campus. Enugu state, Nigeria.*

Magna Scientia Advanced Research and Reviews, 2023, 09(02), 078–085

Publication history: Received on 16 October 2023; revised on 26 October 2023; accepted on 29 November 2023

Article DOI: https://doi.org/10.30574/msarr.2023.9.2.0161

Abstract

Objective: Obesity is an excessive accumulation of fats in fatty tissue to such an extent that it impairs health. It is a world health disorder associated with chronic low-grade systemic and local inflammation which possibly leads to the emergence of diabetes mellitus. This study assessed the predisposition of diabetes mellitus among obese individuals in Enugu, Nigeria.

Methods: One hundred participants(18-65 years) consisting of fifty obese subjects, as test group and fifty normal weight subjects, as control groups were recruited for this cross sectional study. Anthropometric parameters (waist circumference (WC), height, weight, blood pressure (BP)) were measured and body mass index (BMI) calculated. Five milliliters of fasting and 2 hours after meal blood sample were collected from subjects, and used for the analysis of fasting blood glucose (FBG) and 2 hours postprandial (2HPP) blood glucose level respectively using colorimetric method. Data was analyzed and result expressed as mean ± standard deviation (SD).

Results: The results showed a significant increase ($P< 0.05$) in the mean ± SD of WC (103.53 ± 12.10, 78.64 ±7.8), SBP (130.44 ± 20.70, 108.96 ± 12.60), DBP (84.72 ±13.1, 72.32 ± 7.6), FBG (110.16 ± 15.38, 87.26 ± 9.12) and 2HPP (131.72 ± 20.24, 110.78 ± 11.97) in the test and control group respectively. A positive correlation ($P < 0.05$) exist in BMI vs WC, WC vs DBP, SBP vs DBP, DBP vs 2HPP and FBG vs 2HPP. A significant statistical difference in the predisposition rate in both FBG and 2HPP of test group (76%, 34%) and control group (10%, 0%) respectively was observed.

Conclusion: This study suggests that Obesity predisposes an individual to increase blood glucose level.

Keywords: Obesity; Blood glucose; Predisposition; Enugu; Diabetes Mellitus

1. Introduction

Obesity is a medical condition, sometimes considered a disease in which excess body fat has accumulated to such an extent that it negatively affects health [1, 2]. People are classified as obese when their body mass index (BMI), a measurement obtained by dividing a person's weight by the square of the person's height is over 30 kg/m^2; the range 25–30 kg/m^2 is defined as overweight and the range 18-24.9 kg/m^2 as normal weight [3]. Obesity was classified as a disease condition in 2013 by several medical societies, including the American Medical Association and the American Heart Association [4, 5]. In Africa, 18.4% of women and 7.8% of men on the continent live with obesity up from 12% and 4.1%, respectively in 2000. An indication of an upward trend in the rate of obesity [1, 6].

* Corresponding author: Ifeoma Chinwe Ikegwuonu

The prevalence of overweight and obese individuals in Nigeria is of epidemic proportions with 20.3%-35.1% overweight while 8.1%-22.2% was obese [7].

In 2020, it was estimated that there were 21 million and 12 million overweight and obese persons in the Nigerian population aged 15 years or more, with an age adjusted prevalence of 20.3% and 11.6% respectively. Obesity and overweight were also found to be higher among urban dwellers (14.4% and 27.2%) compared to rural dwellers (12.1% and 16.4%). [8]. Obesity has individual, socioeconomic, and environmental causes. Some of the known causes are diet, physical inactivity, automation, urbanization, genetic susceptibility, medications, mental disorders, economic policies, endocrine disorders, and exposure to endocrine-disrupting chemicals [1, 7, 8, 9]. Obesity increases mortality and risk for many chronic diseases and health conditions [10]. In Nigeria, nutritional and epidemiological transitions driven by demographic changes, rising income, urbanization, unhealthy lifestyles and consumption of highly processed diets are among the leading contributors to overweight and obesity [11- 12]. In fact, the burden has extended to younger population age groups in the country with about 9% of children aged 5-9 years estimated to be obese or overweight [12-13]. Obesity and overweight are strongly linked with several cardio-metabolic disorders including high blood pressure, high blood glucose, insulin resistance, high blood cholesterols, coronary heart disease, stroke and cancers [8, 13 -16]. As stated by Petrie *et al* [17], hypertension which is one of the clinical implications of obesity causes insulin resistance and increases the risk of developing diabetes mellitus. It causes insulin resistance by altering the delivery of insulin and glucose to skeletal muscle cells, resulting in impaired glucose uptake [18]; the effect is elevated plasma glucose and consequently diabetes mellitus overtime [19].

Diabetes mellitus (DM) is a carbohydrate metabolic disease, involving inappropriately elevated blood glucose levels [20] caused by an absolute or relative insulin deficiency or insensitivity [21]. It is generally characterised by excessive thirst, frequent urination often at night, extreme hunger (polyphagia), numbness of extremities, unexplained weight loss, frequent infections, blurry vision, extreme fatigue and sores that heal slowly [10]. Over time, diabetes can damage blood vessels in the heart, eyes, kidneys and nerves leading to retinopathy and permanent vision loss, nephropathy, neuropathy, foot ulcer and amputation, heart attack and stroke [22]. Diabetes can also lead to gum diseases, hypertension, cancers, gynaecological and sexual problems, nerve and blood vessels damage to the brain and ear leading to dementia and hearing problems [10]. The American Diabetes Association (ADA), an International Expert Committee (IEC), and the WHO recognized plasma glucose measured in the fasting state (≥126 mg/dl [6.9 mmol/l]), glycated haemoglobin (HbA1C) level ≥6.5% (≥48 mmol/l) and 2 hours after an oral glucose load (≥200 mg/dl [≥12.5mmol/l]) as diagnostic criteria for diabetes [23]. The WHO defines high risk individuals as those with fasting blood glucose (FBG) between 100 to 125 mg/dl (5.6 to 6.9 mmol/l), oral glucose tolerance test (OGTT) or 2 hours postprandial between 140-199 mg/dl (8.8-12.4mmol/l); all of which are indication of prediabetes and recommends changes in lifestyle and monitoring glycaemia. A glycated haemoglobin level (HbA1C) of 5.7% to 6.4% also indicates prediabetes [10].

Body mass index and obesity have a strong relationship to diabetes and insulin resistance. In obese individuals, the amount of non-esterified fatty acids, glycerol, hormones, cytokines, proinflammatory markers, and other substances that are involved in the development of insulin resistance, is increased thereby leading to diabetes mellitus [24].

According to WHO, being affected by obesity (BMI of 30-39.9) or morbid obesity (BMI of 40 or greater), greatly increases one's risk of developing type 2 diabetes. In a study conducted among Japanese adults, it was concluded that central obesity (excess of adipose visceral fat) was an independent risk factor for the development of diabetes mellitus as subjects with central obesity had a 72% increased risk of developing diabetes compared to subjects with non-central obesity [25]. As stated by the Centre for Disease Control and Prevention (CDC), the WHO recommends a waist circumference (WC) as a criterion for assessing central obesity. In a study conducted on the prevalence of obesity in Enugu metropolis using 716 subjects consisting of 416 males and 300 females, the prevalence of obesity was 13.1%. Females were mostly affected and obesity peaked at the age of 40-49 years [9].

A recent meta-analysis reported that approximately 5.8% (about 6 million) of adult Nigerians are living with diabetes mellitus [26]. The prevalence of diabetes is growing primarily due to the rising prevalence of obesity globally; obesity and diabetes mellitus have caused many deaths [27]. At least 2.8 million people each year die as a result of being overweight or obese and 1.5 million deaths are directly attributed to diabetes [2]. These data have made diabetes mellitus a very significant medical condition to study among obese individuals in Enugu metropolis southeastern Nigeria.

2. Material and methods

2.1. Study Design/Selection

This cross sectional study involved a total number of one hundred (100) adult human volunteers aged (18-65 years) from Enugu metropolis. The study comprised of fifty (50) obese individuals as test subjects and fifty (50) normal weight individuals as control subjects. Informed consent was obtained from each participant. Questionnaires were distributed and duly filled by the participants before commencement of the study.

2.2. Inclusion and Exclusion Criteria

2.2.1. Inclusion criteria for test group

Apparently healthy subjects with BMI of 30kg/m^2 and above, ages 18 - 65 years old

2.2.2. Inclusion criteria for control group

Apparently healthy subjects with BMI of 18.5 to 24.9Kg/m^2, ages 18 - 65 years old

2.2.3. Exclusion Criteria for both test and control groups

Diagnosed diabetic patient, subjects on medications, pregnant women and known hypertensive subjects.

2.3. Ethical Considerations and Informed Consents

Ethical approval was duly obtained from the ethics committee of the University of Nigeria Teaching Hospital, Ituku-Ozalla, Enugu with Ref no: (UNTH/HREC/2023/05/603). Written consent of willingness to participate in the study as subject was obtained from all the participants.

2.4. Anthropometric Measurements

2.4.1. Measurements of Body Mass Index (BMI)

The weight, height and BMI of the respondents were recorded. A digital weighing scale ((Hana FAO1419)) was used to measure the body weight (kg). A stadiometer was used to measure height (m); and the BMI was calculated by dividing the weight (kg) by the square of height (m^2). The waist circumference was measured in cm using a measuring tape.

2.4.2. Measurements of Blood Pressure (BP)

A standardized automatic BP monitor (ANDON MODEL KD-595) was used to take the blood pressure measurements in two readings after the participants have been sat undisturbed for a minimum of five minutes and the average record was used.

2.5. Blood Collection/Handling

A fasting blood sample was obtained after overnight fasting of 10-12 hours for the measurement of fasting blood glucose level. Blood sample was also obtained two hours after eating for 2 hours' postprandial glucose level. Blood (5mls) was collected from the volunteers by venipuncture using sterile needle and disposable syringe which was immediately transferred into a sterile well labelled fluoride oxalate bottle and mixed properly. It was spun at 5000 rpm for 5 minutes and plasma separated and used for the assay.

2.6. Laboratory Analyses

2.6.1. Glucose Estimation

Estimation was done using Glucose Oxidase Method, with the manufacturer's instructions dully followed.

2.7. Data Analysis

Data obtained from this study were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25 of Windows IBM Inc. Chicago, IL, USA. Results were presented as mean ± standard deviations. Student's independent T-test was used to calculate differences between means. The relationships between parameters were obtained using correlations and chi-square.

3. Results

Table 1: **S**hows the Anthropometric parameters of obese and normal weight subjects. The result shows a significant increase (P < 0.05) in the mean ± standard deviation of systolic blood pressure (130.44 ± 20.7, 109.96 ± 12.6), diastolic blood pressure (84.72 ± 13.10, 72.32 ± 7.6), body mass index (33.0 ± 3.8, 21.71 ± 13.1), waist circumference (103.53 ± 12.1, 78.64 ± 7.8) of obese and normal weight subjects respectively.

Table 1 Anthropometric parameters of obese and normal weight subjects

Groups	**Systolic blood Pressure (SBP) (mmHg)**	**Diastolic blood Pressure (DBP) (mmHg)**	**Body mass Index (BMI) (kg/m^2)**	**Waist circumference (WC) (cm).**
Obese subjects N=50	130.44 ± 20.7	84.72 ± 13.1	33.0 ± 3.8	103.53 ± 12.1
Normal weight subjects N= 50	109.96 ± 12. 6	72.32 ± 7.6	21.72 ± 2.1	78.64 ± 7.8
t- statistics	5.986	5.776	18.608	12.256
P- Value	0.000*	0.000*	0.000*	0.000*

Values are given as mean ± SD * = significant values (p <0.05)

Table 2: Shows the fasting blood glucose (FBG) and 2 hours postprandial (2HPP) of obese and normal weight subjects. The result shows a significant increase (P < 0.05) in the mean ± standard deviation of FBG (110 ± 15.38, 87.26 ± 9.12) and 2HPP (131.72 ± 20.24, 110.78 ± 11.97) of the obese and normal weight subjects respectively.

Table 2 Fasting blood glucose (FBG) and 2 hours postprandial (2HPP) levels of obese and normal weight subjects

Groups	**FBG (mmol/l)**	**2HPP (mmol/l)**
Obese subject N = 50	6.1 ± 15.38	7.32 ± 20.24
Normal weight subject N = 50	4.85 ± 9.12	6.15 ± 11.97
t – statistics	9.055	6.298
P – value	0.000*	0.000*

Values are given as mean ± standard deviation * = significant values (P< 0. 05)

Table 3 Relationship between BMI, SBP, DBP, WC, FBG, 2HPP in obese subjects

Parameters N = 50	**r (Pearson)**	**P – values**
BMI verses WC	0.645	0.000*
BMI verses SBP	0.118	0.414
BMI verses DBP	0.199	0.166
BMI verses FBG	0.122	0.399
BMI verses 2HPP	0.153	0.290
WC verses SBP	0.229	0.110
WC verses DBP	0.317	0.025*
WC verses FBG	0.091	0.530
WC verses 2HPP	0.235	0.101
SBP verses DBP	0.770	0.000**
SBP verses FBG	- 0.112	0.439
SBP verses 2HPP	0.121	0.403
DBP verses FBG	0.091	0.531
DBP verses 2HPP	0.382	0.006**
FBG verses 2HPP	0.711	0.000**

* = Correlation is significant at 0•05 level. ** = Correlation is significant at 0•01 level.

Table 3. Shows the relationship between the systolic blood pressure (SBP), diastolic blood pressure (DBP), body mass index (BMI), waist circumference (WC), fasting blood glucose (FBG), 2 hours postprandial (2HPP) in the obese subjects. There exists a positive significant correlation ($P < 0.05$) in the BMI vs WC ($r = 0.645$, $P = 0.00$), WC vs DBP ($r = 0.317$, $P = 0.025$), SBP vs DBP ($r = 0.770$, $P = 0.000$), DBP vs 2HPP ($r = 0.382$, $P = 0.006$) and FBG vs 2HPP ($r = 0.711$, $P = 0.000$) while there was no significant correlation between the other parameters ($P>0.05$).

Table 4 shows the rate of predisposition of diabetes mellitus in obese and normal weight subjects compared using chi-square. The results presented shows that the predisposition rate was higher in obese subjects compared to the normal weight subjects according to the FBG criterion (>5.6mmol/L) and 2HPP (>8.8mmol/L). The FBG criterion gave a significant predisposition rate of 76% and 10% ($X = 44.431$, $P = 0.000$) while 2HPP criterion gave a significant predisposition rate of 34% and 0% ($X= 20.482$, $P = 0.000$) in the obese and normal weight subjects respectively.

Table 4 The rate of predisposition of diabetes mellitus in obese and normal weight subjects compared using chi square

Criterion	No of subjects	Prediabetes/ diabetes	Non prediabetes /non diabetes	Predisposition rate (%)	Chi square (X)	P – value
FBG	50 obese	38	12	76	44.431	0.000*
>5.5 mmol/L	50 normal weight	5	45	10		
2HPP	50 obese	17	33	34	20.482	0.000*
>8.8mmol/L	50 normal weight	0	50	0		

* = Significant value ($P< 0.05$)

4. Discussion

Obesity and overweight are strongly linked with several cardio-metabolic disorders including high blood pressure, high blood glucose, insulin resistance, high blood cholesterols, coronary heart disease, stroke and cancers [1, 8, 13 -16]. This study examined some predisposition factors of diabetes mellitus in relation to blood glucose (FBG and 2HPP) in apparently healthy obese and normal weight individuals including undiagnosed diabetic individuals. The general predisposition of diabetes was studied by estimating the prevalence of prediabetes and diabetes among this population and the correlation between anthropometric parameters and blood glucose (FBG and 2HPP).

This study in table 1 shows that obese individuals have higher blood pressure (both systolic and diastolic), and a larger waist circumference compared to normal weight subjects. These differences indicate potential health risks associated with obesity. The rise in blood pressure could be as a result of increase visceral fat (high WC) where fats accumulate within and around the kidney leading to the alteration of renin-angiotensin system causing increasing salt retention and elevated blood pressure. This finding agrees with previous studies by [1, 28-29]. The increase WC in obese subjects could be as a result of increase lipid accumulation within and around the liver and the abdominal skeletal muscle which could result from ingestion of fatty and energy laden processed food as well as sedentary lifestyle. This finding is in line with previous study [30], where 89% of obese females and 47% of obese males had a waist circumference above the 90th percentile and high waist circumference was said to be linked to health risks like hypertension and diabetes (usually type 2). Even in those with normal metabolic profiles, a higher waist circumference increased the risk of hypertension by 24-59% [30].

Table 2 of this study estimated the blood glucose level of the obese individuals; there exist significant increase ($p< 0•05$) in both fasting blood glucose (FBG) and 2 hours postprandial (2HPP) levels between obese and normal-weight subjects, as indicated by the low p-values and high t-statistics. Both FBG and 2HPP levels were higher in obese subjects compared to normal weight subjects, suggesting that these groups have different glucose metabolism profiles and obese subjects could be more predisposed to diabetes mellitus than the normal weight subjects. This rise in blood glucose level could be as a result of insulin resistance and reduced dehydroepiandrosterone sulfate (DHEAS) which is common in obese subjects. Again the higher blood pressure level of the obese subjects in this study can cause insulin resistance by altering the delivery of insulin and glucose to skeletal muscle cells, resulting in impaired glucose uptake. This finding is in line with other previous studies [18, 19, 24-25]. In a study conducted by Akter *et al* [31] on the Effect of obesity on fasting blood glucose, it was found that fasting serum glucose is significantly increased in both male and female obese persons.

This study also assessed the relationship between the different parameters in the obese individuals. There exist significant ($P < 0.05$) positive correlations between BMI vs WC, DBP vs WC, SBP vs DBP, DBP vs 2HPP, and FBG vs 2HPP. This showed that an independent increase in WC in obese individuals was associated with an increase in BMI as well as in DBP while an independent increase in DBP was associated with an increase in SBP and 2 HPP. Again there was association between FBG and 2HPP showing that as one was increasing the other was also increasing. This finding agrees with the work of Chen *et al* [32], who reported a positive correlation between obesity and diabetes.

The predisposition of diabetes mellitus among the two groups (obese and normal weight subjects) was assessed using Chi-square and it was found that obese subjects had a 76% and 34% predisposition rate of diabetes mellitus when compared to the normal weight subjects that had 10%, 0% in FBG and 2HPP respectively. This finding agrees with the previous works by [33-34] which reported a higher predisposition of diabetes mellitus among obese individuals when compared to normal weight subjects. In a similar study on the association between body weight and the prevalence of diabetes mellitus in Sri Lanka,12% of obese subjects were found to be diabetic while 2% of normal weight subjects were diabetic showing a 10% increase prevalence of diabetes among obese than the normal subjects [35].

5. Conclusion

This study observed that there was an increase in waist circumference, blood pressure (systolic and diastolic) and blood glucose (fasting and 2 hours postprandial) level in obese individuals when compared to normal weight individuals. The study also concludes that obese individuals have a higher predisposition rate of diabetes mellitus than normal weight individuals. Hence, the need for regular evaluation of blood glucose level in obese subjects to avert hyperglycaemia complications.

Compliance with ethical standards

Acknowledgments

The authors wish to appreciate all the participants and everyone who contributed in any way to the success of this research work.

Disclosure of conflict of interest

The authors declare no conflict of interest, financial or otherwise.

Statement of ethical approval

Ethical approval was duly obtained from the ethics committee of the University of Nigeria Teaching Hospital, Ituku-Ozalla, Enugu with Ref no: UNTH/HREC/2023/05/603.

Statement of informed consent

Informed consent was obtained from all participants in this study before commencement.

References

[1] Ifeoma Chinwe Ikegwuonu , Chidera Darlington Afoenyi , Adanna Perpetua Ikebudu, Patrick Tobenna Ikegwuonu, Ifesinachi Joel Agbo, Ifeanyi Emmanuel Arinze and Ifeanyi Emmanuel Ugwuoke. Assessment of serum electrolytes levels of obese individuals in Enugu southeastern, Nigeria. *World Journal of Advanced Research and Reviews.* 2023; 19(01): 934-941 DOI: https://doi.org/10.30574/wjarr.2023.19.1.1342

[2] Wikipedia. 2023. Obesity. https://en.m.wikipedia.org/wiki/Obesity

[3] World Health Organisation. Obesity and Overweight. 2021; Accessed on 5th June 2022. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

[4] Pollack A. A.M.A. Recognizes Obesity as a Disease. Sugary diets and weight problems remain a central health issue. 2013; Accessed 7th June 2022. https://www.nytimes.com/2013/06/19/business/ama-recognizes-obesity-as-a-disease.html

[5] Ryan, D. H., & Kahan, S. Guideline Recommendations for Obesity Management. The Medical clinics of North America, 2018; 102(1):49–63.

[6] Adepoju P. Key to addressing obesity in Africa lies in education, food systems. Future of food systems. 2021; Accessed 16th May 2022. https://www.devex.com/news/key-to-addressing-obesity-in-africa-lies-in-education-food-systems-99644/amp

[7] Chukwuonye, I. I., Chuku, A., John, C., Ohagwu, K. A., Imoh, M. E., Isa, S. E., Ogah, O. S., and Oviasu, E. Prevalence of overweight and obesity in adult Nigerians - a systematic review. Diabetes, metabolic syndrome and obesity : targets and therapy, 2013; 6:43–47.

[8] Adeloye D, Ige-Elegbede J. O, Adebiyi A. O. Estimating the prevalence of overweight and obesity in Nigeria in 2020: A systematic review and meta-analysis. Ann Med 2021; 53(1); 495–507.

[9] Okoronkwo C. U, Okereke H. C, Ulasi A. E, Nwachukwu N. Prevalence of Overweight and Obesity in Enugu Metropolis, Nigeria. *Journal of Medical Research and Health Sciences*. 2018; 3(3): 1-6.

[10] Centers for Disease Control and Prevention. Health Effects of Overweight & Obesity. 2022. https://www.cdc.gov/healthyweight/effects/index.html

[11] Steyn NP, Mchiza ZJ., Obesity and the nutrition transition in sub-Saharan Africa. Ann NY Acad Sci.2014; 1311 (1): 88-101 [PubMed] [Google Scholar]

[12] Field AE, Cook NR, Gillman MW. Weight status in childhood as a predictor of becoming overweight or hypertensive in early adulthood. Obese Res. 2005; 163-169. [PMC free article.

[13] World Health Organization. Population-based prevention strategies for childhood obesity: report of a WHO forum and technical meeting, Geneva, 15-17 December 2009, 2010 [Google Scholar].

[14] Nwaneli C. Changing trend in coronary heart disease in Nigeria. *Afrimedic J*. 2010; 1(1): 1-4. [Google Scholar].

[15] Ojikutu RK. The prevalence of cardiovascular disease in the Lagos state. *Ghana J Dev Stud* 2009; 6 (2): 41 [Google Scholar].

[16] Safaei, M., Sundararajan, E. A., Driss, M., Boulila, W., and Shapi'i, A. A systematic literature review on obesity: Understanding the causes & consequences of obesity and reviewing various machine learning approaches used to predict obesity. Computers in biology and medicine, 2021; 136:104754.

[17] Petrie J. R, Guzik T. J, Touyz R. M. Diabetes, Hypertension and Cardiovascular Disease: Clinical Insights and Vascular Mechanisms. *Can J Cardiol*. 2018 May; 34(5):575-584. Doi:10.1016/j.cjca.2017.12.005.Epub 2017 Dec 11. PMID:29459239;PMCID:PMC5953551.

[18] Salvetti A, Brogi G, Di Legge V and Bernini G. P. The Inter-Relationship between Insulin Resistance and Hypertension. Drugs, 1993; 46, 149-159. https://doi.org/10.2165/00003495-199300462-00024.

[19] Nakrani M. N, Wineland R. H, Anjum F. Physiology, Glucose Metabolism. 2023 Jul 17. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-PMID: 32809434

[20] Sapra A, Vaqar S & Bhandari P. Diabetes Mellitus. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2020

[21] Ejezie F. E & Ikekpeazu J. E. Fundamental of metabolism. 2017. 2nd edition; 3: 170.

[22] World Health Organization. Diabetes. 2023; Retrieved from https://www.who.int/news-room/fact-sheets/detail/diabetes.

[23] Hall, J. H. E. Guyton and Hall Textbook of Medical Physiology 2016; Guyton Physiology. 13th edition; Saunders.

[24] Al-Goblan A. S, Al-Alfi M. A, Khan M. Z. Mechanism linking diabetes mellitus and obesity. 2014; 7: 587–591.

[25] Cao C, Hu H, Zheng X, Zhang X, Wang Y, He Y. Association between central obesity and incident diabetes mellitus among Japanese: a retrospective cohort study using propensity score matching. 2022 Sci Rep 4; 12(1):13445.

[26] Ugwu, E., Young, E. & Nkpozi, M. Diabetes care knowledge and practice among primary care physicians in Southeast Nigeria: a cross-sectional study. BMC Fam Pract 2020; 21:128.

[27] Al-Nozha M. M, Ismail H. M, Al- Nozha I. M. Coronary artery disease and diabetes mellitus. *Journal of Taibah University Medical Sciences.* 2016; 11(4): 330-338.

[28] Tanaka, M. Improving obesity and blood pressure. Hypertension research : *official journal of the Japanese Society of Hypertension.* 2020; 43(2):79–89.

[29] Oguma, V.M; Nwose, EU.; Ulasi, LI.; Akintunde, A.A.; Chukwukelu, E.E.; Bwititi, P.T.; Richards, R.S.; Skinner, T.C.; Timothy, C.; Skinner, T.C. Cardiovascular disease risk factors in a Nigerian population with impaired fasting blood

glucose level and diabetes mellitus. BMC Public Health, 2017; 17(1), 36. http://dx.doi.org/10.1186/s12889-016-3910-3 PMID: 28061844.

[30] Cheng C, Sun JY, Zhou Y, Xie QY, Wang LY, Kong XQ, Sun W. High waist circumference is a risk factor for hypertension in normal weight or overweight individuals with normal metabolic profiles; *The Journal of Clinical Hypertension.* 2022 Jul; 24(7): 908-917.doi:10.1111/jch.14528.Epub 2022 Jun 23. PMID:35739356; PMCID: PMC9278579

[31] Akter R, Nessa A, Husain MF, Wahed F, Khatun N, Yesmin M, Nasreen S, Tajkia T. Effect of Obesity on Fasting Blood Sugar. *Mymensingh Med J*. 2017; 26(1):7-11.

[32] Chen Y, Zhang X. P,Yuan J, Cai B, Wang X, Wu X, Zhang Y, Zhang X, Yin T,Zhu X et al. Association of body mass index and age with incident diabetes in Chinese adults: a population-based cohort study. 2018.

[33] Cheekurthy A. J Predisposition of Obesity through Genetic and Non-Genetic Risk Factors. 2021.

[34] Piché M, Tchernof A, Despres JP. Obesity Phenotypes, Diabetes, and Cardiovascular Diseases.,Circulation Research. 2020 May 22;126(11): 1477-1500.doi: 10.1161/CIRCRESAHA.120.316101.Epub 2020 May 21. Erratum in: Circ Res. 2020 Jul 17;127(3): e107.PMID:32437302.

[35] Balasooriya & Liyanage. The Association between Body Weight and the Prevalence of Diabetes Mellitus. *EPRA International Journal of Multidisciplinary Research.* 2019; 5(8): 77-82.