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Research Article

Assessment of Adiposity Status in Young Adult Nigerians Using Different Indices of Adiposity

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ABSTRACT

The increasing burden of obesity led us to investigate the levels of different adiposity indices and prevalence of excess adiposity. We recruited 200 young adults; 92 (46.0%) males and 108 (54.0%) females, aged 15-35 years. We investigated the levels of different adiposity indices and the prevalence of excess adiposity following standard anthropometric measurements needed for determination of adiposity indices. Statistical significance was fixed at $p < 0.05$. Mean values of body mass index (BMI), body adiposity index (BAI) and waist-to-height ratio (WHtR) were higher in females while waist-to-hip ratio (WHR) and waist circumference (WC) were higher in males. Based on BMI, overweight was more prevalent in males (29.0%: 29.3% vs 28.7%) while obesity was more prevalent in females (11.5%: 16.7% vs 5.4%). Additionally, the prevalence of overweight and obesity was significantly higher in females based on WC, WHR and WHtR but significantly higher in males based on BAI. Generally, mean values of adiposity indices and the prevalence of overweight and obesity increased with age. The overall high prevalence and female preponderance of excess adiposity in the population demand urgent public health action.

Keywords: *Obesity, Adiposity, Indices, Young adults*

INTRODUCTION

Obesity, a manifestation of excess adiposity is gradually attaining an epidemic status on a global scale. This is particularly significant because of its significant association with other disease conditions such as diabetes mellitus. Diabetes prevalence is known to increase with increasing severity of obesity (Nguyen *et al.,* 2011; Haluzík *et al.,* 2020) since obesity is an important modifiable risk factor associated with an increased likelihood of developing type-2 diabetes mellitus. Thus, obesity continues to pose significant public health challenge as the condition accentuates an individual's risk of mortality from cardiovascular diseases (Nguyen *et al.,* 2011).

Since 1975, the burden of obesity has nearly tripled. In 2016, the World Health Organization reported a global prevalence of 39% (39% men; 40% women) and 13% (11% men; 15% women) of overweight and obesity respectively, which corresponds to more than 1.9 billion adults with overweight and 650 million adults with obesity aged 18 years and above. The prevalence in children and adolescents also increased tremendously (World Health Organization, 2018). Obesity in children and adolescents will likely lead to obesity in adults (Di Cesare *et al.,* 2019). It is thus important to timeously consider the challenge of excess weight gain, even amongst young adults. Besides, a key focus of the global action plan on noncommunicable diseases is to halt the rise in obesity by the year 2025 (World Health

Organization, 2013). The attainment of this target in addition to protraction of the obesity status into adulthood, the difficulty in treating obesity in adulthood (Singh *et al.,* 2008), high cost and ineffectiveness of most anti-obesity therapy are strong evidences for the prioritization of strategies for the early prevention of obesity.

There is relative paucity of data on the burden of young adults with obesity in Nigerian populations. This study was therefore designed to determine the prevalence of excess adiposity in the study population using different adiposity indices.

MATERIALS AND METHODS

Participants

This cross-sectional study was carried out amongst young adults (aged 15-35 years) residing in Asaba, Delta State, Nigeria. Sample size was determined using the Vaughan's formula (Vaughan *et al.*, 1989). A total of 200 participants (92 males; 108 females) selected by convenience sampling, took part in the study. After the research protocol had been thoroughly explained to the intending participants who were apparently healthy, they were made to sign the informed consent form prior to participation. Notwithstanding, we excluded potential participants from the study on the grounds of pregnancy, drug addiction, physical disability that could impede anthropometric measurements as well as a decline of consent. The participants were stratified into four age groups; 15-20 years, 21-25 years, 26-30 years and 31-35 years.

Ethical approval and consent to participate

The study was conducted in accordance with the 1964 Declaration of Helsinki and later versions. The informed consent form, questionnaire and the study protocol was approved by Delta State Ministry of Health Research Ethics Committee, Asaba, Nigeria (HM/596/T/55). All participants were treated with anonymity and utmost confidentiality. Only participants who read, understood and signed the informed consent form were allowed to take part in the study. A parent or legal guardian of participants under 18 years of age provided informed consent with the participants informed assent.

Anthropometric measurements

Anthropometric measurements were done by trained research assistants. To eliminate bias, participants were not allowed to do self-measurement. Weight was measured (to the nearest 0.1 kg) using a weighing scale with participants dressed in light clothing and with bare feet. Height measurement (to the nearest 0.1 cm) was done using a stadiometer with participant in an erect posture and on bare feet. Waist circumference was measured (to the nearest 0.1 cm) in a horizontal plane, midway between the lowest rib and the iliac crest using a non-stretchable measuring tape. Hip circumference was measured (to the nearest 0.1 cm) in a horizontal plane, around the pelvis at the point of maximum protrusion of the buttocks using a non-stretchable measuring tape with participant in an erect posture. From these measurements;

Waist-to-hip ratio (WHR) was calculated as:

$$WHR = \frac{Waist\ Circumference\ (cm)}{Hip\ Circumference\ (cm)}$$

Waist-to-height ratio (WHtR) was calculated as:

$$WHtR = \frac{Waist\ Circumference\ (cm)}{Height\ (cm)}$$

Body-mass-index (BMI) was calculated as:

$$BMI = \frac{Weight\ (Kg)}{Height\ (m)^2}$$

Body-adiposity-index (BAI) was calculated as:

$$BAI = \frac{Hip\ Circumference\ (cm)}{Height\ (m)^{1.5}} - 18$$

(Stefanovski *et al.,* 2011).

Definitions

Overweight and obesity were defined according to the definitions of various indices: BMI ≥ 25 kg/m^2 but < 30 kg/m^2 and BMI ≥ 30 kg/m^2, respectively (World Health Organization, 2000); BAI (21% – 26%; in males, and 33% – 39%; in females) and BAI (> 26%; in males, and > 39%; in females), respectively (Gallagher *et al.*, 2000); WC (94 cm – 102 cm; in males, and 80 cm – 88 cm; in females) and WC (> 102 cm; in males and > 88 cm; in females), respectively (Deng *et al.*, 2013); WHR ≥ 0.90 (in males) and ≥ 0.85 (in females) (Faramarzi *et al.*, 2018) and WHtR ≥ 0.5 (Mokha *et al.*, 2010).

Statistical analysis

Statistical analysis was done using Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS Inc Chicago IL). Descriptive statistics were expressed as Mean ± Standard Deviation for continuous variables and as proportions for categorical variables. Differences in adiposity indices between genders were calculated using an independent samples t-test for continuous variables and a Chi-square test for categorical variables. Differences between age groups and FINDRISC categories were calculated using a one-way analysis of variance (ANOVA) test followed by post-hoc multiple comparison test (Duncan test) for continuous variables and a Chi-square test for categorical variables. Statistical significance was fixed at $P < 0.05$.

RESULTS

Adiposity indices in participants

Females had higher mean values of BMI, BAI, HC, WHtR and FINDRISC score. There were significant differences in the mean values of BAI ($p < 0.001$), WHtR ($p < 0.05$) and FINDRISC score ($p < 0.001$) between male and female participants (Table 1).

All the adiposity indices were significantly ($p < 0.05$ and $p < 0.001$) different across the age groups. Most of the adiposity indices increased with increasing age group. In all instances, participants in the 31-35 years age group had higher mean values of adiposity indices than the lower age groups (Table 2).

Table 1. Adiposity Indices and FINDRISC Score of Participants Stratified by Gender

Parameters	Total (n = 200)	Male (n = 92)	Female (n = 108)	*P*-value
Body Mass Index (BMI) (kg/m^2)	24.85 (4.43)	24.30 (3.24)	25.32 (5.21)	0.106
Body Adiposity Index (BAI) (%)	26.77 (6.10)	24.38 (4.33)	28. 80 (6.65)	< 0.001
Waist Circumference (cm)	84.35 (11.53)	84.61 (9.12)	84.12 (13.28)	0.761
Waist-to-hip ratio (WHR)	0.86 (0.04)	0.87 (0.04)	0.86 (0.05)	0.170
Waist-to-height ratio (WHtR)	0.50 (0.07)	0.48 (0.05)	0.51 (0.08)	< 0.05

Data are means and standard deviations in parenthesis.

Table 2. Adiposity Indices and FINDRISC Score of Participants Stratified by Age Group

Parameters	Total (n = 200)	15 – 20 years (n = 32)	21 – 25 years (n = 64)	26 – 30 years (n = 60)	31 – 35 years (n = 44)	*P*-value
Body Mass Index (BMI) (kg/m^2)	24.85 (4.43)	22.27 (2.60)^a	24.56 (4.18)^b	25.11 (4.13)^{bc}	26.80 (5.31)^c	< 0.001
Body Adiposity Index (BAI) (%)	26.77 (6.10)	24.43 (6.25)^a	27.47 (5.08)^b	26.08 (6.46)^{ab}	28.40 (6.39)^b	< 0.05
Waist Circumference (cm)	84.35 (11.53)	79.78 (12.75)^a	82.82 (8.70)^a	84.31 (12.33)^a	89.93 (11.28)^b	0.001
Waist-to-hip ratio (WHR)	0.86 (0.04)	0.86 (0.04)^a	0.85 (0.05)^a	0.86 (0.05)^a	0.90 (0.03)^b	< 0.001
Waist-to-height ratio (WHtR)	0.50 (0.07)	0.47 (0.07)^a	0.49 (0.05)^a	0.49 (0.07)^a	0.53 (0.07)^b	< 0.001

Data are means and standard deviations in parenthesis. $^{a\text{-}c}$Values in the same row bearing different superscripts are significantly different.

Prevalence of excess adiposity

Females in the study population had a significantly higher prevalence of overweight and obesity based on waist circumference (32.4% vs 2.2% and 32.4% vs 6.5%, respectively), waist-to-hip ratio (67.6% vs 33.7%) and waist-to-height ratio (59.3% vs 35.9%) relative to males. However, the prevalence of overweight and obesity based on body adiposity index was significantly higher in males than females (45.7% vs 13.0% and 29.3% vs 8.3%, respectively). Although males had a significantly higher prevalence of overweight based on BMI (29.3% vs 28.7%), the prevalence of obesity based on BMI was significantly higher in females (16.7% vs 5.4%) (Table 3).

The prevalence of overweight by BMI (38.3%) and overweight by waist circumference (29.7%) was significantly higher in the 26-30 years and 21-25 years age groups, respectively. However, the highest age group (31-35 years) had significantly higher prevalence of obesity by BMI (27.3%), overweight and obesity by BAI (34.1% and 34.1%, respectively), obesity by waist circumference (29.5%), overweight/obesity by waist-to-hip ratio (68.2%), waist-to-height ratio (68.2%) relative to the other age groups (Table 4).

Table 3. Prevalence of Excess Adiposity Based on Gender

Parameters	Total (n = 200)	Male (n = 92)	Female (n = 108)	*P*-value
Overweight by BMI (25-30 kg/m^2)	58 [29.0]	27 [29.3]	31 [28.7]	< 0.05
Obesity by BMI (> 30 kg/m^2)	23 [11.5]	5 [5.4]	18 [16.7]	< 0.05
Overweight by BAI	56 [28.0]	42 [45.7]	14 [13.0]	< 0.001
Obesity by BAI	36 [18.0]	27 [29.3]	9 [8.3]	< 0.001
Overweight by Waist Circumference: 94-102 cm (M); 80-88 cm (F)	37 [18.5]	2 [2.2]	35 [32.4]	< 0.001
Obesity by Waist Circumference: > 102 cm (M); > 88 cm (F)	41 [20.5]	6 [6.5]	35 [32.4]	< 0.001
Overweight/Obesity by Waist-to-hip ratio (WHR)	104 [52.0]	31 [33.7]	73 [67.6]	< 0.001
Overweight/Obesity by Waist-to-height ratio (WHtR)	97 [48.5]	33 [35.9]	64 [59.3]	0.001

Data are absolute numbers and frequencies in brackets.

Table 4. Prevalence of Excess Adiposity Based on Age Group

Parameters	Total (n = 200)	15–20 years (n = 32)	21–25 years (n = 64)	26–30 years (n = 60)	31–35 years (n = 44)	*P*-value
Overweight by BMI (25-30 kg/m^2)	58 [29.0]	6 [18.8]	19 [29.7]	23 [38.3]	10 [22.7]	< 0.05
Obesity by BMI (> 30 kg/m^2)	23 [11.5]	0 [0.0]	6 [9.4]	5 [8.3]	12 [27.3]	< 0.05
Overweight by BAI	56 [28.0]	7 [21.9]	18 [28.1]	16 [26.7]	15 [34.1]	< 0.05
Obesity by BAI	36 [18.0]	3 [9.4]	7 [10.9]	11 [18.3]	15 [34.1]	< 0.05
Overweight by Waist Circumference: 94-102 cm (M); 80-88 cm (F)	39 [19.5]	5 [15.6]	19 [29.7]	6 [10.0]	9 [20.5]	< 0.05
Obesity by Waist Circumference: > 102 cm (M); > 88 cm (F)	41 [20.5]	5 [15.6]	8 [12.5]	15 [25.0]	13 [29.5]	< 0.05
Overweight/Obesity by Waist-to-hip ratio (WHR)	104 [52.0]	20 [62.5]	28 [43.8]	26 [43.3]	30 [68.2]	< 0.05
Overweight/Obesity by Waist-to-height ratio (WHtR)	97 [48.5]	8 [25.0]	31 [48.4]	28 [46.7]	30 [68.2]	0.003

Data are absolute numbers and frequencies in brackets.

DISCUSSION

Obesity manifests as elevated levels of body fat and body weight (Ejike and Ijeh, 2012) and can be determined by indices of adiposity and body weight. Percentage body fat and fat distribution are linked to cardiovascular risk (Ijeh *et al.*, 2010). Body adiposity index gives a direct estimate of percentage body fat (Stefanovski *et al.*, 2011). BMI is a most commonly used index of body weight. The World Health Organization recommends BMI cut-off values of ≥ 25 kg/m^2 and ≥ 30 kg/m^2 in defining overweight and obesity respectively (World Health Organization, 2000). However, the use and validity of BMI as a universal measure of excess adiposity is presumably flawed by reports of BMI-metabolic-risk sub-phenotypes and the high prevalence of "metabolically obese normal weight" and "metabolically healthy obese" sub-phenotypes in Nigerian populations (Ejike and Ijeh, 2012; Ijeh *et al.*, 2010; Nnamudi *et al.*, 2020b). Although there are criticisms and limitations, some other adiposity indices such as waist circumference, waist-to-hip ratio and waist-to-height ratio are thought to be better predictors of cardiovascular risk relative to the commonly used BMI (Ejike and Ijeh, 2012; Huxley *et al.*, 2010). Irrespective of its shortcomings, BMI is still widely used because of its simplicity and remains very relevant in literature (Stefanovski *et al.*, 2011).

In this present study, we reported a 29.0% prevalence of overweight and 11.5% prevalence of obesity based on BMI definition. Although males had a slightly higher prevalence of overweight, females had a higher mean value of BMI (albeit insignificantly) and a significantly higher prevalence of obesity. Previous reports consistently follow this pattern of female preponderance of obesity and possible reasons adduced for this trend include low physical activity amongst females as well as genetic and hormonal differences between the genders (Ejike and Ijeh, 2012; Akarolo-Anthony *et al.*, 2014; Okafor *et al.*, 2014; Ogunlade and Asafa, 2015). Additionally, a tendency towards less strenuous and physically demanding activities and a low participation in sports as a result of cultural and societal restrictions has also been suggested (Nnamudi *et al.*, 2020b). The prevalence figure in the total population is similar to our previous report in a young adult Nigerian population (Nnamudi *et al.*, 2020a). Our current finding is also in agreement with the prevalence estimates of overweight and obesity in previous studies in Nigerian populations (Okafor *et al.*, 2014; Puepet *et al.*, 2002; Chukwuonye *et al.*, 2013). The high prevalence of overweight and obesity in this youthful population may be due to an urbanized obesogenic lifestyle. A low level of physical activity, a disposition to a sedentary lifestyle and the consumption of high-calorie-low-fiber fast food are common phenomena among urban dwellers of most developing nations (Christensen *et al.*, 2009; Shehu *et al.*, 2010; Agu *et al.*, 2015; Saklayen *et al.*, 2018). In Nigeria, the general misconception that individuals who are fat are living comfortably and the persistence of certain cultural practices that encourage fattening may also contribute to increasing prevalence of overweight and obesity even in the future.

Other indices of adiposity follow the same trend of high prevalence of overweight and obesity as BMI, but with discrepancies. This is expected considering the disparities in cut-off values and adiposity targets. Although males had an insignificantly ($p > 0.05$) higher mean value of waist circumference relative to females, there were more females than males that attained the threshold of overweight by waist circumference. There was also a female preponderance of obesity by waist circumference. This pattern is consistent with a previous Nigerian report (Agu *et al.*, 2015). Additionally, this study reported a preponderance of females attaining the threshold values for defining overweight/obesity via waist-to-hip ratio. Considering the fact that these indices of central adiposity which diagnose

excess abdominal fat are strongly linked to a greater risk of cardiometabolic diseases, specifically myocardial infarction in females relative to males (Klein *et al.*, 2007; Peters *et al.*, 2018; Nnamudi *et al.*, 2020a), the risk of future heart attack may be higher in these young females. In addition to the general tendency of weight gain amongst females in Nigeria due to reasons earlier mentioned, the lower cut-off values established for females may have also contributed to the female preponderance as it is easier for females to attain this lower threshold. A female preponderance of waist-to-height ratio ≥ 0.5 was reported in this present study. It has been reported that waist-to-height ratio ≥ 0.5 outperforms other indices of adiposity in determining risk susceptibility and higher values correlate with increasing risk of developing diabetes (Xu *et al.*, 2013; Son *et al.*, 2016).

The discrepancy in the prevalence of excess adiposity based on BMI and BAI standards observed in this study is worth mentioning. More females were obese (16.7% vs 5.4%) based on BMI standards whereas more males were obese (29.3% vs 8.3%) based on BAI standards. A possible reason for the discrepancy is the lower obesity cut-off established for males (> 33%) relative to females (> 39%). Thus, it is easier for males to attain the threshold values of obesity than females. Additionally, it is quite possible that in spite of having a lower prevalence of excess body weight, the males in the study population had a higher distribution of excess body fat. Therefore, a possible consequence of the discrepancy in the BMI and BAI prevalence rates is the fact that it supports already established evidence that weight gain cannot be exactly equated with body fat (Ejike and Ijeh, 2012). For instance, it is possible to be obese by weight without accompanying excess body fat and the corresponding metabolic consequences of excess body fat and vice versa. This forms the basis for the "metabolically healthy normal weight" and "metabolically obese normal weight" sub-phenotypes prevalent in adult and young adult Nigerian populations, respectively (Ijeh *et al.*, 2010; Nnamudi *et al.*, 2020b).

The age-group-dependent increase in adiposity indices is worth mentioning. Beyond the increased risk of obesity, previous reports suggest that increasing age is a risk factor for diabetes mellitus and its complications (Kalyani *et al.*, 2017; Omar *et al.*, 2019).

CONCLUSION

This study reported a high prevalence of overweight and obesity based on different indices of adiposity. Generally, there was a female preponderance of excess adiposity in the population. Adiposity indices increased with increasing age. Our findings can be generalized for an urban Nigerian setting. Urgent public health action is therefore recommended to mitigate the burden and health implications of future rise in the prevalence of people with obesity in this population.

Limitation and strength

This study is limited by the sampling of a specific age group which may limit the generalizability of the study findings. Despite the small population size, the apathy exhibited by some young Nigerian adults towards health research makes this modest attempt good enough. Additionally, the recruitment of these young adults appear relatively novel.

AUTHORS' CONTRIBUTIONS

ACN was responsible for acquisition, analysis and interpretation of data. NEJO and III contributed to the conception, design and supervision of the study. ACN wrote the initial draft of the manuscript. ACN, NEJO and III did critical revision of the manuscript. All authors read and approved the final version of the revised manuscript.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

Agu, U., Agu, M. C., & Nnaji, G. A. (2015). Assessment of risk of developing diabetes mellitus among local government employees in Onitsha, south-eastern Nigeria. *Epidemiology Reports 3*(4), 1-6.

Akarolo-Anthony, S. N., Willett, W. C., Spiegelman, D., & Adebamowo, C. A. (2014). Obesity epidemic has emerged among Nigerians. *BMC Public Health*, *14*(1), 1-9.

Christensen, D. L., Friis, H., Mwaniki, D. L., Kilonzo, B., Tetens, I., Boit, M. K., Omondi, B., Kaduka, L., & Borch-Johnsen, K. (2009). Prevalence of glucose intolerance and associated risk factors in rural and urban populations of different ethnic groups in

Kenya. *Diabetes Research and Clinical Practice*, *84*(3), 303-310.

Chukwuonye, I. I., Chuku, A., John, C., Ohagwu, K. A., Imoh, M. E., Isa, S. E., Ogah, o. S., & Oviasu, E. (2013). Prevalence of overweight and obesity in adult Nigerians–a systematic review. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *6*, 43-47.

Deng, W. W., Wang, J., Liu, M. M., Wang, D., Zhao, Y., Liu, Y. Q., Wang, H., & Dong, G. H. (2013). Body mass index compared with abdominal obesity indicators in relation to prehypertension and hypertension in adults: the CHPSNE study. *American Journal of Hypertension*, *26*(1), 58-67.

Di Cesare, M., Sorić, M., Bovet, P., Miranda, J. J., Bhutta, Z., Stevens, G. A., Laxmaiah, A., Kengne, A. P., & Bentham, J. (2019). The epidemiological burden of obesity in childhood: a worldwide epidemic requiring urgent action. *BMC Medicine*, *17*, 1-20.

Ejike, C. E., & Ijeh, I. I. (2012). Obesity in young-adult Nigerians: variations in prevalence determined by anthropometry and bioelectrical impedance analysis, and the development of % body fat prediction equations. *International Archives of Medicine*, *5*(1), 1-7.

Faramarzi, E., Ostadrahimi, A., Nikniaz, Z., Jafarabadi, M. A., Fakhari, A., & Somi, M. (2018). Determination of the best anthropometric index of obesity for prediction of prehypertension and hypertension in a large population-based-study; the azar-cohort. *Iranian Red Crescent Medical Journal*, *20*(3), e59911.

Gallagher, D., Heymsfield, S. B., Heo, M., Jebb, S. A., Murgatroyd, P. R., & Sakamoto, Y. (2000). Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *The American Journal of Clinical Nutrition*, *72*(3), 694-701.

Haluzík, M., Hrádková, V., Kudláčková, M., & Jakubíková, I. (2020). Obesity treatment in patients both with and without diabetes: current options and perspectives. *Casopis Lekaru Ceskych*, *159*(3-4), 136-140.

Huxley, R., Mendis, S., Zheleznyakov, E., Reddy, S., & Chan, J. (2010). Body mass index, waist circumference and waist: hip ratio as predictors of cardiovascular risk—a review of the literature. *European Journal of Clinical Nutrition*, *64*(1), 16-22.

Ijeh, I. I., Okorie, U., & Ejike, C. E. C. C. (2010). Obesity, metabolic syndrome and BMI-metabolic-risk sub-phenotypes: a study of an adult Nigerian population. *Journal of Medicine and Medical Sciences*, *1*(6), 254-260.

Kalyani, R. R., Golden, S. H., & Cefalu, W. T. (2017). Diabetes and aging: unique considerations and goals of care. *Diabetes Care*, *40*(4), 440-443.

Klein, S., Allison, D. B., Heymsfield, S. B., Kelley, D. E., Leibel, R. L., Nonas, C., & Kahn, R. (2007). Waist circumference and cardiometabolic risk: a consensus statement from shaping America's health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *The American Journal of Clinical Nutrition*, *85*(5), 1197-1202.

Mokha, J. S., Srinivasan, S. R., DasMahapatra, P., Fernandez, C., Chen, W., Xu, J., & Berenson, G. S. (2010). Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolic risk profile among normal weight and overweight/obese children: The Bogalusa heart study. *BMC Pediatrics*, *10*, 1-7.

Nguyen, N. T., Nguyen, X. M. T., Lane, J., & Wang, P. (2011). Relationship between obesity and diabetes in a US adult population: Findings from the National Health and Nutrition Examination Survey, 1999–2006. *Obesity Surgery*, *21*, 351-355.

Nnamudi, A. C., Orhue, N. E. J., & Ijeh, I. I. (2020a). Assessment of the levels of cardiovascular risk markers in hyperglycemic young Nigerian adults. *European Journal of Biology and Biotechnology*, *1*(3), 1-7.

Nnamudi, A. C., Orhue, N. E. J., Ijeh, I. I., Etim, O. E., & Eke-Ogaranya, I. N. (2020b). Obesity, metabolic abnormalities, metabolic syndrome and BMI-metabolic-risk sub-phenotypes among young adult Nigerians. *Haya Saudi Journal of Life Science*, *5*(6), 90-97.

Ogunlade, O., & Asafa, M. A. (2015). Pattern and prevalence of underweight, overweight and obesity among young adult Nigerians. *American Journal of Biomedical and Life Sciences*, *3*(2), 12-15.

Okafor, C. I., Gezawa, I. D., Sabir, A. A., Raimi, T. H., & Enang, O. (2014). Obesity, overweight, and underweight among urban Nigerians. *Nigerian Journal of Clinical Practice*, *17*(6), 743-749.

Omar, S. M., Musa, I. R., ElSouli, A., & Adam, I. (2019). Prevalence, risk factors, and glycaemic control of type 2 diabetes mellitus in eastern Sudan: a community-based study. *Therapeutic advances in Endocrinology and Metabolism*, *10*, 2042018819860071.

Peters, S. A. E., Bots, S. H., & Woodward, M. (2018). Sex differences in the association between measures of general and central adiposity and the risk of myocardial infarction: results from the UK Biobank. *Journal of the American Heart Association*, *7*(5), e008507.

Puepet, F. H., Zoakah, A. I., & Chuhwak, E. K. (2002). Prevalence of overweight and obesity among urban Nigeria adults in Jos. *Highland Medical Research Journal*, *1*(1), 13-16.

Saklayen, M. G. (2018). The global epidemic of the metabolic syndrome. *Current Hypertension Reports*, *20*(2), 1-8.

Shehu, R. A., Abdullahi, A. A., & Adekeye, D. S. (2010). Sedentary lifestyle and wellness in Kaduna state, Nigeria. *Studies on Ethno-Medicine*, *4*(1), 15-19.

Singh, A. S., Mulder, C., Twisk, J. W. R., Van Mechelen, W., & Chinapaw, M. J. M. (2008). Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obesity Reviews*, *9*(5), 474-488.

Son, Y. J., Kim, J., Park, H. J., Park, S. E., Park, C. Y., Lee, W. Y., Oh, K. W., Park, S. W., & Rhee, E. J. (2016). Association of waist-height ratio with diabetes risk: a 4-year longitudinal retrospective study. *Endocrinology and Metabolism*, *31*(1), 127-133.

Stefanovski, D., Buchanan, T. A., Sumner, A. E., Reynolds, J. C., Sebring, N. G., Xiang, A. H., & Watanabe, R. M.

(2011). A better index of body adiposity. *Obesity*, *19*(5), 1083-1089.

Vaughan, J. P., Morrow, R. H., & World Health Organization. (1989). *Manual of epidemiology for district health management*. World Health Organization, Geneva, Switzerland. p. 126–128.

World Health Organization (2018). Obesity and Overweight. World Health Organization, Geneva, Switzerland.

World Health Organization. (2000). Obesity: preventing and managing the global epidemic: report of a WHO consultation. *WHO Technical Report Series,* 894, 1–253.

World Health Organization. (2013). *Global action plan for the prevention and control of noncommunicable diseases 2013-2020*. World Health Organization, Geneva, Switzerland.

Xu, Z., Qi, X., Dahl, A. K., & Xu, W. (2013). Waist-to-height ratio is the best indicator for undiagnosed Type 2 diabetes. *Diabetic Medicine*, *30*(6), e201-e207.