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# Relationship between Blood Pressure, Blood Glucose and Body Mass Index and Coexisting Prehypertension and Prediabetes among Rural Adults in Niger Delta Region, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author AN designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors VOH and BCC managed the literature searches, analyses of the study performed the body mass index, blood pressure and blood glucose analysis and Authors FCM, OO and CO managed the experimental process and author FCM identified the pathophysiology. All authors read and approved the final manuscript.*

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## ABSTRACT

The incidence of hypertension, diabetes and overweight-obese are emerging health problems, which are increasingly prevalent globally. The objective of the study was to evaluate the prevalence and the relationship between blood pressure, blood glucose and body mass index, and the tendency of developing prehypertension and pre-diabetes in rural adults in the Niger Delta

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region. A cross-sectional, population-based descriptive design was used. A total sample of 250 subjects aged 20 years and older, that had resided continually in the order of 10 years and above, in the oil and gas extraction environments, were recruited. While body mass index was calculated using internationally accepted standard methods, blood pressure and fasting blood glucose level were recorded also by standard methods, classified and correlated. One-way ANOVA and Pearson's correlation analyses were used for comparisons between groups. Result showed that although blood pressure and blood glucose measurements increase with age, males had higher prevalence of high blood pressure and raised blood glucose compared with females ($p<0.05$). Both sexes had almost similar distribution of high body mass index which was not statistically significantly different ($p>0.05$). In total, overweight coexisted among 14% of participants with normal blood glucose, 19.6% pre-diabetes, 7.6% diabetes, 24% normotensive, 15.4% pre-hypertensive and 1.8% hypertensive. Pre-diabetes coexisted among 9.8% normotensive and pre-hypertensive respectively, while 0.2% normotensive, 5.6% pre-hypertensive, and 18.2% hypertensive had combined diabetes. About 16.4% had both combined diabetes and obesity, and hypertension and obesity. Overall, 19.5% had combined hypertension, obesity and diabetes. In total, the prevalence of obesity was 16.4%, hypertension 18.2%, and diabetes 24.0%. The prevalence of coexisting prehypertension and pre-diabetes, pre-non-communicable and main non-communicable diseases was 17.5%, 21.3%, and 23.7% respectively. Data analysis revealed positive and linear correlation and statistically significantly different ($p<0.001$) in the varying degree of complex association of blood pressure and blood glucose as well as body mass index. In conclusion, notwithstanding, this study provides baseline population based data establishing that the populations in the oil bearing communities are at high risk of developing hypertension, diabetes, and overweight-obese together with high prevalence of combination of pre-hypertension and pre-diabetes. The coexisting of significantly high prevalence of prehypertension and pre-diabetes with raised body mass index, in particular, have a more adverse effect by progression to full hypertension and diabetes. There is the need for national programme for prevention, control or delay the burden of the risk factors for non-communicable diseases for oil and gas bearing communities.

*Keywords: Body mass index; diabetes; hypertension; prediabetes; prehypertension; environmental pollution; Niger Delta; human.*

## 1. INTRODUCTION

The complex interplay in health risks and substantial increases in the non-communicable diseases - high blood pressure, raised blood glucose and overweight-obese are emerging increasingly as physiological, medical and public health importance in the 21st century. It has been estimated that high blood pressure accounts for 16.5% of global deaths, raised blood glucose 6%, and overweight-obese 5%. Indeed, according to World Health Organization, non-communicable diseases disproportionately affects the low- and middle-income countries and the current projection indicates that by 2020 the largest increases in non-communicable disease deaths will occur in Africa1. African nations' deaths from non-communicable diseases are projected to exceed the combined deaths of communicable and nutritional diseases, and maternal and perinatal deaths, as the most common causes of death by 2030 [1].

According to the data available on Western populations, social determinants and drivers of non-communicable diseases are attributable to environmental factors such as alcohol consumption, psycho-social stress, levels of physical activity and genetic factors, rapid unplanned urbanization, globalization, aging, race or ethnicity. These subsequently influence behavioural risk factors such as unhealthy lifestyles, diets, and increasingly sedentary lifestyles which show up in individuals as intermediate, metabolic or modifiable risk factors - raised blood pressure, increased blood glucose, overweight and obesity. Eventually, lead to adverse cardiovascular diseases and other complications [1,2]. In so far, there are, however, paucity of knowledge about the impact of prolonged exposure to environmental factors such as pollution-associated hazardous-chemical emissions and pathogens, emanating from oil and gas extractions, on common risk factors for non-communicable diseases.

According to World Health Organization, Nigeria, more specifically, Niger Delta, south-south geo-political region of the country, is the largest oil producers in Africa, and the most polluted region in the world [3]. As the result of the wake of industrial revolution, many tons of man-made unrelated chemicals of technological origins are produced by oil and gas explorations and exploitations and released into the environment. Oil spills and gas flares pollutants/toxins, although perceived to have resulted in ever increasing polluted air, and also contaminated water and soil [3,4], the impact of prolonged exposure on the physiological functions of the body or the seriousness of the health problems in exposed groups, are not yet understood.

In fact, information is limited for national survey on the prevalence of common risk factors for non-communicable diseases, especially in the Niger Delta region. Individual studies although are not representative of the whole country suggest that hypertension, overweight-obese and diabetes are prevalent in Nigeria [5-9]. It is argued below that living and working close to oil and gas extraction increases the likelihood that people will be exposed to the hazardous chemical emissions and pollutants associated with these industrial activities. Eventually, the chemically unrelated compounds can affect the health of human populations by upsetting the normal human physiological balance of the body, with concurrent exacerbation increase in diseases.

The objective of this study was to assess the prevalence of some common risk factors for non-communicable diseases, in the determinant of health status among chronically exposed individuals to oil and gas extractions in Rivers State, Niger Delta region. Still, to correlate the tendency of developing hypertension and diabetes with body mass index and coexistence of prehypertension and pre-diabetes. The findings would no doubt provide further insight into the magnitude of prevalence of hypertension, diabetes, overweight-obese together with combination of prehypertension and pre-diabetes in rural adults. Of particular interest, it would assist in the implementation of the necessary action that could provide early detection, reduction or prevention of the risk factors for non-communicable diseases. Either, it could assist in the enforcement of medical evaluation as compulsory part of promotion of health processes in the oil bearing rural communities in Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Study Sample

Samples for the study were carefully selected among adult residents in Erema and Obagi communities respectively in Ogba/Egbema/Ndoni local government area. The rural communities are located in the oil-rich Rivers State on latitude 5º13''N and 5º68''N and longitude 5º33''E and 6º42''E Western Niger Delta region, Nigeria [4]. The communities had been involuntarily subjected to the emissions of gas flaring base-stations insensitively sited near to homes and schools by Shell Petroleum Development Company (SPDC) for over 50 years. Gas and oil are flared at sea level, so the exposed groups live with the flares that roar continuously, turning night into day, and polluting the air and ground. A cross-sectional descriptive/stratified blocked randomization method and structured questionnaires with optional questions to suit local needs were employed in the study. Subjects were selected among school teachers, Clergymen, traders, civil servants, farmers, unemployed, and fishermen that had resided consistently in the rural communities in the order of 10 years and longer.

### 2.2 Data Collection

The blood pressure type, blood glucose level of the subjects and body mass index were carried out based on standard guidelines [10,11]. Two hundred and fifty subjects (85 males and 165 females) aged 20 years and older participated in the study carried out between June and December 2013. Blood glucose level of the fasting participants were performed based on the glucose –oxidase principles using the digital glucometer (ACCU-CHEK Aviva glucometer).The results were classified: low (<3.5 mmol/L), normal (3.6 – 6.0 mmol/L), pre-diabetic (6.1 – 6.9 mmol/L), diabetic (≥7.0 mmol/L). Blood pressure was measured in the sitting position using a standard manual mercury sphygmomanometer and appropriate cuff sizes. Three separate readings were taken per subject, after two minutes intervals and the lowest readings recorded and classified as: low (<90/60 mmHg), normal (91/61 - 120/80 mmHg) prehypertension (121/81–139/89 mmHg), and hypertension (≥140 mm Hg SBP and /or ≥90 mm Hg DBP). A person's body mass index was determined by calculating the ratio between the body weight in kilograms and height in meters squares ($kg/m^2$) where underweight <18.5$kg/m^2$, normal 18.5 -

24.9 kg/$m^2$, overweight 25-29.9 kg/$m^2$ or obese ≥30kg/$m^2$.

Unless otherwise stated, the research was approved by the Ethics Committee on Human Biomedical Research of the University of Port Harcourt, Nigeria and the study conforms to the Helsinki Declaration on Biomedical Research. Verbal informed consent was obtained from all participants before administration of the questionnaire and /or taking measurements. There was no conflict of interest.

### 2.3 Statistical Analysis

Analysis was carried out using Statistical Package for Social Science (SPSS) version 20.0. Data analysis were expressed as mean ± SD. Data were also subjected to both Spearman's and Pearson's correlation analysis respectively. Percentages for independent variables were calculated; $p<0.05$ was considered statistically significant.

### 2.4 Limitations

The main challenges in the report were that the subjects were community health centre based as well as limited information about the population of the communities. The small sample employed may undermine the overall generalization of the results. There are, however, no functional hospitals, both electric power supply and storage facilities, and transport difficulties to the large cities for the use of venous samples which might have affected the result of the study by not performing glucose tolerance test instead of testing fasting blood sugar. The use of glucometer may be less accurate compared with wet chemistry method. In the present study, two thirds of participants were females, which likely had an influence on the results for women while men were underrepresented, consistent with established fact that females attend medical checkups than male counterparts in Nigeria.

## 3. RESULTS

Two hundred and fifty (250) subjects made up 85 (34%) males with mean age 49.2±18.8 years and 165 (66%) females with mean age 40.0±16.3% years, given a ratio of male: female as 1:2, participated in the study.

### 3.1 Age and Sex Distribution of Disease Parameters

The mean values for the distribution of the disease parameters, age and sex for the population studied are depicted in Tables 1 and 2. Both sexes had increase in blood glucose and blood pressure measurements with age (Table 1). Males had significantly high prevalence of raised blood pressure (pre-hypertensive, 9.2%; hypertension 5.6%) and elevated blood glucose (pre-diabetes, 1.6%; diabetes 5%) compared to females($p<0.05$). The mean values of blood pressure-(systolic blood pressure/diastolic blood pressure (mmHg)), and blood glucose level (FBG; mmol/L) for males 126.9±16.1/79.2±12.1 and 7.8±4.8, was statistically significantly higher than that for females 119.9±16.1/73.03±12.1 and 6.1± 2.5 ($p<0.05$).

### 3.2 Body Mass Index-Overweight and Obesity

The prevalence of normal body mass index (18.5-24.9 kg/$m^2$) of the respondent was 40.4% (males 12.8%, females 27.6%) and underweight (<18.5 kg/$m^2$) was 2.0% (males 0.4% and females 1.6%). About 41.2 % (males 15.2% and females 26.0%) of the respondents were overweight (25.0-29.9% kg/$m^2$), and 16.4% (males 5.6% and females 10.8%) were obese (≥30 kg/$m^2$). The mean body mass index (BMI, kg/$m^2$) for males 26.2± 4.0 and females 26.4±4.8 fall approximately in the 25.0 – 29.9 kg/$m^2$ range defined as overweight, which were not statistically significantly different ($p>0.05$). Being overweight was slightly more prevalent in males (2.2%) as compared to females. Tables 1 and 2 depict the distribution of the prevalence of the disaese parameters compared, classified according to body mass index class, sex and age of the studied participants.

### 3.3 Blood Glucose Level-Prediabetes and Diabetes

The prevalence of normal blood glucose level (3.6 - 6.0 mmol/L) of the participants was 52.8% (males 14.8% and females 38.0%) and low blood glucose (<3.5 mmol/L) was 3.6% (males 0.4% and females 3.2%). The prevalence of prediabetes (6.1 – 6.9 mmol/L) and diabetes (≥7.0 mmol/L) were 19.6% (males 7.6%, females 12.0%) and 24.0% (males 11.2%, females 12.8%) respectively. The distribution of the association between the pathophysiological risk factors - blood glucose (FBG) and body mass Index (BMI) showed that 14% normo–glycaemics, 19.6% pre-diabetes and 7.6% diabetes had combined overweight; and 16.4% had diabetes and obesity (Fig. 1).

**Table 1. Mean value (±SD) of the disease parameters with age for the both sexes**

| | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Age (yr.)** | **Number of subjects** | **Systolic blood pressure (mmHg)** | **Diastolic blood pressure (mmHg)** | **Body mass index (kg/m$^2$)** | **Fasting blood glucose (FBG, mmol/L)** | **Number of subjects** | **Systolic blood pressure (mmHg)** | **Diastolic blood pressure (mmHg)** | **Body mass index (kg/m2)** | **Fasting blood glucose (mmol/L)** |
| 20-29 | 17 | 117.4±12.7 | 72.2±9.2 | 24.9±5.0 | 6.2±1.5 | 56 | 110.7±8.3 | 69.2±9.5 | 25.9±4.6 | 5.6±1.5 |
| 30-39 | 17 | 118.3±9.9 | 77.0±6.8 | 27.0±3.5 | 8. 6±7.4 | 33 | 114.8±12.2 | 70.0±10.2 | 26.4±4.8 | 5.5±1.7 |
| 40-49 | 07 | 119.1±9.7 | 75.0±9.6 | 27.2±3.3 | 6.6 ±1.1 | 30 | 116.3±11.4 | 72.4±9.6 | 26.7±4.3 | 6.5±2.4 |
| 50-59 | 13 | 130.5±10.3 | 82.6±9.2 | 27.6±4.2 | 9.9±5.3 | 17 | 119.7±16.2 | 74.7±11.9 | 26.3±4.2 | 6.2±2.8 |
| 60-69 | 12 | 142.0±17.2 | 87.3±7.6 | 26.3 ±3.7 | 9.7±5.9 | 20 | 140.6±22.9 | 81.0±13.8 | 27.8±6.7 | 6.8±3.9 |
| >70 | 19 | 133.7±17.4 | 81.5±10.2 | 25.2±3.4 | 6.5±2.9 | 09 | 146.7±27.8 | 81.7±15.4 | 24.7±4.5 | 8.9±4.5 |
| Overall mean | 85 | 126.9±16.1 | 79.2±9.9 | 26.2±4.0 | 7.8±4.8 | 165 | 120.0±18.7 | 73.0±12.1 | 26.4±4.8 | 6.1±2.5 |

**Table 2. Percent distribution of prevalence of metabolic risk factors with age and sex for the study population**

| | | Raised blood pressure (SBP/DBP, mmHg) | | High body mass index (BMI, kg/m$^2$) | | Elevated blood glucose level (FBG, mmol/L) | |
|---|---|---|---|---|---|---|---|
| **Age (years)** | **Sex** | **Pre-hypertension (121-139/81-89) %** | **Hypertension (≥140.0/≥90) %** | **Overweight (25-29.9) %** | **Obese (≥30) %** | **Pre-diabetes (6.1-6.9) %** | **Diabetes (≥7.0) %** |
| 20 -29 | Male | 4.0 | 0.4 | 1.6 | 0.8 | 2.0 | 1.2 |
| | Female | 3.2 | 0.8 | 9.3 | 2.8 | 5.6 | 2.0 |
| 30 -39 | Male | 2.4 | 0.4 | 4.0 | 1.2 | 1.6 | 2.0 |
| | Female | 2.4 | 2.4 | 6.4 | 2.0 | 1.6 | 2.0 |
| 40 -49 | Male | 1.6 | = | 2.4 | = | 1.2 | 0.8 |
| | Female | 3.6 | 3.2 | 4.0 | 2.0 | 1.6 | 3.2 |
| 50 -59 | Male | 3.6 | 3.6 | 1.2 | 2.4 | 0.4 | 3.2 |
| | Female | 2.0 | 2.8 | 2.8 | 1.6 | 1.6 | 1.2 |
| 60 -69 | Male | 2.0 | 2.0 | 2.0 | 0.8 | 0.8 | 2.4 |
| | Female | 1.6 | 7.6 | 2.8 | 2.0 | 1.6 | 2.4 |
| >70 | Male | 2.8 | 1.6 | 4.0 | 0.4 | 2.0 | 1.6 |
| | Female | 0.8 | 3.6 | 0.8 | 0.4 | = | 2.0 |
| Overall | Male | 16.4 | 16.0 | 15.2 | 5.6 | 7.6 | 11.2 |
| Mean (%) | Female | 14.4 | 20.4 | 26.0 | 10.8 | 12.0 | 12.8 |

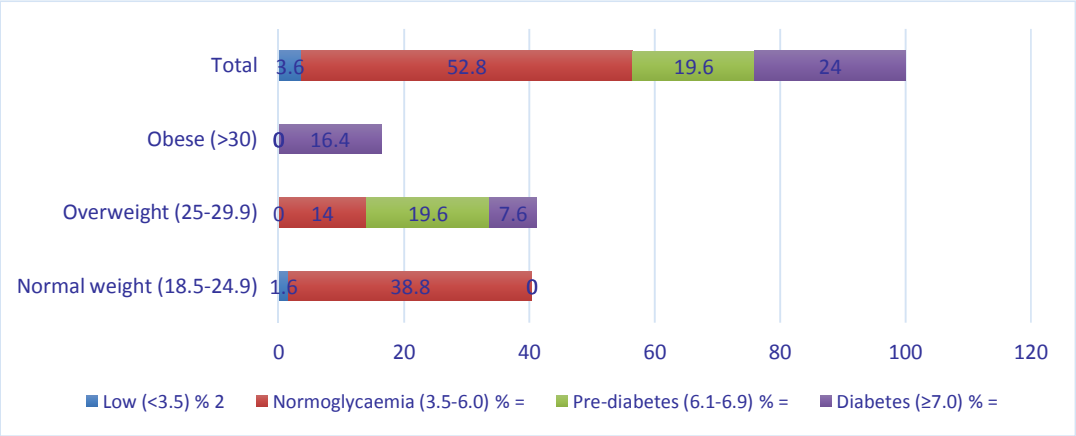


**Fig. 1. Percent distribution of blood glucose and body mass index**

### 3.4 Systolic Blood Pressure - Prehypertension and Hypertension

The prevalence of normal systolic blood pressure (91-120 mm Hg) of the respondents was 55.6% (male 13.2%, female 42.4%) and low blood pressure (< 90 mmHg) was 0.8% (males 0.4%, females 0.4%). Prehypertension (121-139 mmHg) prevalence was 24.4% (males 12.4%, females 12.0%) while the prevalence of hypertension (≥ 140 mmHg) was 19.2% (males 8.0%, females 11.2%).

The distribution of systolic blood pressure classification and body mass index revealed that 14% normotensive, 24.4% pre-hypertensive and 2.8% hypertensive had combined overweight; and 16.4% had obesity and hypertension. Whereas the relationship between systolic blood pressure and blood glucose classification showed that 19.6% pre-hypertensive are pre-diabetes, while 4.8% pre-hypertensive and 19.2% hypertensive are diabetes.

### 3.5 Diastolic Blood Pressure- Prehypertension and Hypertension

The prevalence of normal diastolic blood pressure (61-80 mm Hg) of the respondents was 60.4% (male 19.6%, female 40.8%) and low blood pressure (< 60 mmHg) was 16% (males 2.4%, females 13.6%). The prevalence of prehypertension (81-89 mmHg) was 6.4% (males 4.0%, females 2.4%) while the prevalence of hypertension (≥ 90 mmHg) was 17.2 % ( males 8.0%, females 9.2%).

When diastolic blood pressure and body mass index were compared, 34% normotensive, 6.4% pre-hypertensive and 0.8% hypertensive had combined overweight while 16.4% are both hypertensive and obese. In the distribution between diastolic blood and blood glucose, 19.6% normotensive are pre-diabetes while 0.4% normotensive, 6.4% pre-hypertensive and 17.2% hypertensive are diabetes.

### 3.6 Overall Association of Blood Pressure, Blood Glucose and Body Mass Index

Collectively, the prevalence of normal blood pressure (91-120/61-80 mm Hg) of the respondents was 58.0% (males 16.4% and females 41.6%). About 15.4% (male 8.2% and female 7.2%) are pre-hypertensive (121-139/81-89 mmHg) and 18.2% (male 8.0%; female 10.2%) of the participants are hypertensive (≥140 mm Hg SBP and /or ≥90 mm Hg DBP) (Fig. 2).

The correlation of blood pressure with either blood glucose or body mass index is depicted in Figs. 2 and 3. About 9.8% normotensive and pre-hypertensive respectively are pre-diabetes; while 0.2% normotensive,5.6% pre-hypertensive and 18.2% hypertensive are diabetes (Fig. 2). Whereas, 24% normotensive, 15.4% pre-hypertensive and 1.8% hypertensive are overweight, and 16.4% hypertensive are obese (Fig. 3). In total, the prevalence of coexisting prehypertension and pre-diabetes was 17.5%; pre- non- communicable disease (prehypertension, pre-diabetes and overweight-obese) 21.3%, and main non-communicable

disease (hypertension, diabetes and overweight-obese) 23.7% ( Fig. 4).

In total, overweight-class of body mass index (BMI, 25 - 29.9 kg/m$^2$) was significantly associated with both normal blood glucose level, normal blood pressure, diabetes, hypertension, and together with coexisting prehypertension and pre-diabetes. However, the prevalence of hypertension and diabetes did not increase with increasing body mass index (BMI ≥ 30 kg/m$^2$).

### 3.7 Association of Systolic Blood Pressure, Diastolic Blood Pressure, Blood Glucose and Body Mass Index

Overall, correlation analysis of the data showed positive and linear correlated, and statistically significantly different ($p<0.001$) in the varying complex association between blood pressure (systolic blood pressure and diastolic blood pressure) and body mass index as well as blood glucose. The association ratio - the sum of systolic blood pressure to the sum of diastolic blood pressure was established as **2:1**; diastolic blood pressure to body mass index was **3:1**; body mass index to blood glucose as **4:1**; systolic blood pressure to body mass index **5:1**; diastolic blood pressure**:** blood glucose **11:1**; while systolic blood pressure to blood glucose gave **18:1**. The varying relationships were classified relative to the recognized association between systolic blood pressure and diastolic blood pressure as: SBP: DBP, 2**:**1; DBP**:** BMI, 3**:**1; BMI**:** FBG, 4**:**1; SBP**:** BMI, 5**:**1; DBP**:** FBG, 11**:**1; SBP**:** FBG, 18**:**1.

### 3.8 Association of the Diseased Parameters

The derived association "ratio" between elevated blood pressure prevalent rate (defined as pre-hypertension and hypertension, 33.6%;) to high body mass index (defined as overweight and obese, 28.8%) was given as 1**:**1; high body index: raised blood glucose (defined as pre-diabetes and diabetes, 21.8%) was given as: 1**:**1, while elevated blood pressure to raised blood glucose as 2**:**1.

## 4. DISCUSSION

Nigeria, more specifically, the Niger delta region, is one of the top 10 most polluted regions in the world [3]. The exposed populations live with the potentially toxic chemically unrelated compounds in the polluted environment. The collected data and results for the complex interplay, and comparative study of the prevalence of common risk factors for non-communicable diseases are tabulated in Tables 1-2 and figures 1-4. The prevalence of coexisting prehypertension and pre-diabetes for the local populations in the gas and oil extraction sites are also depicted.

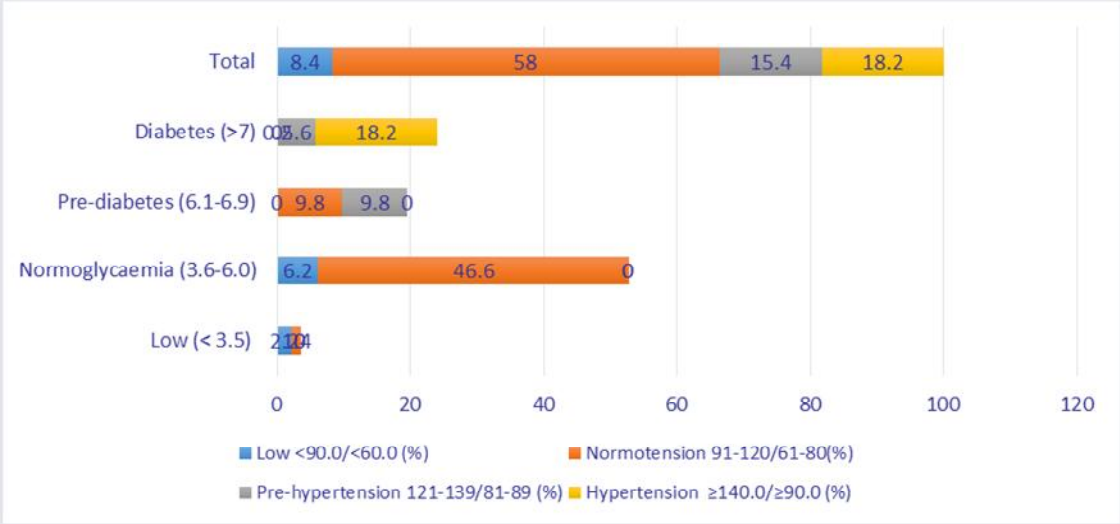


**Fig. 2. Percent distribution of blood pressure and blood glucose**

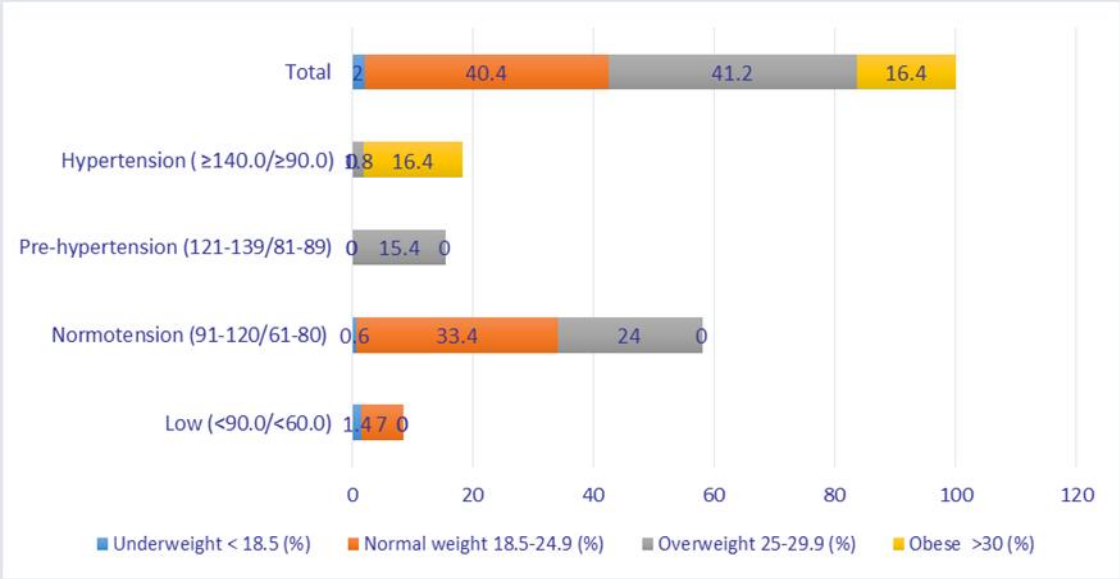


**Fig. 3. Percent distribution of blood pressure and body mass index**

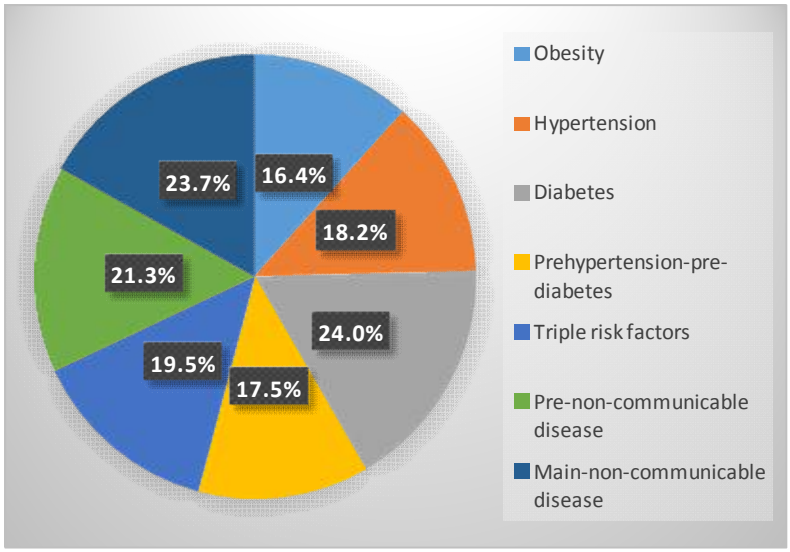


**Fig. 4. Summary of percent prevalence of metabolic risk factors**

In total, mean value (±SD) of blood pressure defined as systolic blood pressure/diastolic blood pressure (mm Hg), blood glucose (mmol/L) and body mass index (kg/m$^2$) for the participants were 122.2±18.1/75.1±11.8, 6.6±3.6 and 26.3±4.6 respectively. The prevalence of obesity, hypertension, diabetes, and coexisting prehypertension and pre-diabetes was 16.4%, 18.2%, 24.0% and 17.5% respectively. The triple risk factors- obesity, diabetes and hypertension were present in 19.5% of the respondents. The prevalent rate of coexisting prehypertension and pre-diabetes during this study was higher than the reported rate of 11.2± 6% for Americans, which suggests risk of displayed adversely altered cardiovascular events[2]. Meanwhile, the prevalence of pre-non-communicable and main non-communicable diseases was 21.3% and 23.7% respectively. The later, however, was much lower than the prevalent value of 32.8% reported in the studies at Uyo [7] also in the south-south geo-political region of Nigeria.

The present study demonstrated that overweight-class of body mass index (25-29.9 kg/m$^2$) was significantly associated with normal and/or above normal blood glucose level and blood pressure. This however, is consistent with the generalization that not everyone who has diabetes is overweight or obese, and not everyone who is overweight or obese will develop diabetes. However, the independent significant and varying degree of complex association of body weight and blood pressure as well as blood glucose show that all three are intricately connected to each other. As such, prolonged exposure to potentially toxic chemically unrelated compounds in the environment, can generate increased risk of developing high prevalence of common risk factors for non-communicable diseases. Given the relative high prevalence of some modifiable risk factors for non-communicable diseases from this survey, the study hypothesize the likelihood that Nigerians, in particular, in the Niger Delta region, obviously have entered unprecedented epidemic of hypertension, diabetes and overweight-obese, which still no attention aimed toward prevention.

No doubt, a number of factors had been attributed to the development of non-communicable diseases including genetic and epigenetic factors. This also includes individual behaviours such as physical activity, sedentary lifestyle, Western-type lifestyle associated with caloric intake. Included also are sociocultural factors, economic and policy environment [9, 12-14].

There are an estimate of 371 million people with diabetes in the world and around 90% of these are type 2 diabetes. By 2030, there would be some 550 million with this condition. Diabetes and its complications, including heart disease and also increase in the likelihood of kidney failure, blindness, impotence, and amputation, is the fourth or fifth leading cause of death among the most high income countries. Diabetes thus is now changing into an epidemic in low and middle income countries [15]. Diabetes prevalence in this study was slightly higher in males than females as obtained in Caucasian populations. The prevalence, however, was much higher than the global estimate of 10% (WHO, 2011)[16,17] and 12.7% among the participants at Uyo [7] in the Niger Delta region and the Africa region prevalence of 4.9% [18]. Diabetes prevalence as high as 23.4% had been reported for the high socio-economic class oil industrial workers and 16% for the low socio-economic class non-oil company workers in Port Harcourt [18].

This study also shows that pre-diabetes prevalence was 9.8% and 43.6% of the population have high blood glucose level, evidently, Nigerians in the Niger Delta are at high risk for diabetes. According to the Centre for Disease Control and Prevention, each year, about 6 percent of people with pre-diabetes develop type 2 diabetes. Unless lifestyle changes are made, about 15 to 30 percent pre-diabetes will develop diabetes within five years [19].

Our correlation ratio analysis revealed that the association between body mass index (BMI: FBG; 4:1) and blood glucose was about a 1 to 4-fold, collaborating with previous reports [13], which indicates that excess weight was strongly related to increase risk of diabetes. Furthermore, our analysis also showed that high body weight (BMI > 25 kg/m$^2$) and raised blood glucose (FBG > 6.1 mmol/L) were directly proportional linked by approximately a 1:1-fold. The varying degree of complex and strong relationships between blood glucose and body mass index, indeed may underscore the underlying complex mechanisms about the pathophysiology of diabetes-obesity in humans, and the development of serious health issues like blindness, heart stroke, kidney failure, cancers and other associated complications. Notwithstanding, the intimate link between obesity and diabetes had long been recognized but the molecules responsible for such associations are unclear. Nevertheless, a number of proposed mechanisms linking obesity with diabetes had been put forward [20,21]. Aside, the correlation ratio analysis revealed also that systolic blood pressure (SBP: FBG; 18:1) and diastolic blood pressure (DBP: FBG; 11:1) are intricately connected with blood glucose by approximately 11 to 18 – fold. Further, the association of elevated blood pressure (prehypertension and hypertension) and raised blood glucose (pre-diabetes and diabetes) was about 1 to 2 – fold. Similarly, the complex association of blood pressure and blood glucose may also underscore the underlying complex mechanisms about the pathophysiology of hypertension-diabetes.

About 33.6% of the respondents who have high blood pressure were also overweight-obese. People in overweight-class of body mass index were also predominantly pre-hypertensive. High body mass index coexisted with hypertension and high frequency of hypertension and

prehypertension in agreement with previous report [22]. Analysis of our results revealed that systolic blood pressure (SBP: BMI; 5:1) and diastolic blood pressure (DBP: BMI; 3:1) are approximately a 3 to 5- fold intimately linked with body mass index. More so, overweight-obese was intricately connected with high blood pressure by approximately a 1 to 1 –fold. This further underscores the assertion that obesity is an important risk factor for the development of hypertension [23].

The high hypertension prevalence observed in this study, however, was at abeyance with the generalization that those in the urban settings rather than rural are more prone to hypertension. Such high prevalence in the urban setting had been attributed largely to Westernization-type of lifestyles of over-nutrition. Hypertension prevalence during this study was much higher than the prevalent rate of 14.2% among the participants at Uyo [7] also in the Niger Delta region, and 12.9% among rural dwellers in Kuje area council, Kuseki, near Abuja [24]. The prevalence, however, was lower than the African region at 46%, while the lowest prevalence at 35% found in the Americans. High-income countries had been associated with a lower prevalence of hypertension - 35% than other groups at 46% [25].

Although hypertension prevalence was slightly higher in males than females, there was no cross-over effect as reported for the Americans [25]. The prevalence of hypertension (high blood pressure) being highest among men than women until age 45. From ages 45 -54 and 55 -64, the percentage of men and women are similar, there after a much higher percentage of women than men have high blood pressure [25]. A similar age-sex related-hypertension crossover has been reported for Eritreans [26].

Pre-hypertension prevalence was 15.4% and 30.8% of the participants are pre-hypertensive indicating that the populations in the Niger Delta region are at a high risk of developing hypertension, the starting path of most complications including cardiovascular disease and kidney disease [27]. The high prevalence of the proportion between hypertension and prehypertension concurs with previous studies [28]. However, the prevalent rate for rural Niger Delta Nigerians are significantly lower than that for the rural Indians [28].

In this study, the percentage of overweight participants was 41.2% and obese participants were 16.4%. Obesity prevalence during this study was higher than the prevalent rate of 8.1% for the residents of Maiduguri, Nigeria [29], 13.9% among the dwellers of Sokoto metropolis, Nigeria [30], but lower than 25% reported in the studies at Uyo, Nigeria [7]. The subjects in this study have a high body mass index which either was normal or above normal. The preponderance of high body mass index may not be attributable to certain traditional rites of sedentary life and caloric abundance [12], or that the subjects came from affluent strata of the population, but to some yet unidentified environmental-associated–pollutants/toxins-induced changes in physio-biochemistry of the body [8,31]. Indeed, the high prevalence of overweight-obese may be fueled by prolonged exposure to potentially toxic chemically unrelated compounds in the body, which probably increase silent inflammation, which increases insulin resistance [32]. This simply implies that chronically exposed individuals to pollutants from oil and gas extractions are at high risk of developing overweight-obese. This may predispose in causing hypertension, diabetes and coronary-heart-disease in such individuals. Further studies, however, are needed to fully understand this. Interestingly, in this study, the health risks were not detected by sufferers in contrast to the situation in the United State of America were about 81.5% know of it [26].

This study again establishes the ratio of the relationship between blood pressure (systolic blood pressure and diastolic blood pressure), blood glucose or body mass index. The varying relationships were classified relative to the recognized association between systolic blood pressure and diastolic blood pressure as: SBP: DBP, 2:1; DBP: BMI, 3:1; BMI: FBG, 4:1; SBP: BMI, 5:1; DBP: FBG, 11:1; SBP: FBG, 18:1. *(In our unpublished work, the relationship in early pregnancy was as: SBP: DBP, 2:1; DBP: BMI, 3:1; SBP: BMI, 4:1; BMI: FBG, 5:1; DBP: FBG, 13:1; SBP: FBG, 22:1).* There was a shift in the relationship: *BMI: FBG and SBP: BMI* between the two populations. Hitherto, the findings of this study may probably contribute to our understanding of the complex relationships and mechanisms of action between diabetes, overweight-obese and hypertension. It thus may open new possibilities for the management and prevention of these conditions, which are becoming increasingly prevent globally. Nevertheless, since this study came from a small population with similar socio-economic background, the findings appear to be highly

significant and call for concern. Large study populations are needed for further studies.

## 5. CONCLUSION

In conclusion, notwithstanding, this study provides baseline population based data establishing that the populations in the oil bearing communities are at high risk of developing hypertension, diabetes, and overweight-obese. The study shows that there is also strong association between tendencies for developing prehypertension and pre-diabetes which showed positive correlation with high body mass index. It is hoped that this study could assist in professional support for health care programmes that would eventually reduce and prevent risk factors of non-communicable diseases in the Niger Delta region.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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