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Application of CUSUM Control Chart for Monitoring the Trend of Hypertension in Nigeria: Anambra Scenario

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Abstract: The study employed the cumulative sum (CUSUM) control chart in determining the trend of hypertension in Nnewi North, Anambra state, Nigeria. The objective of this study was to determine whether the process of hypertension is out of control in Anambra State from 2010-2014. Secondary source of data collection was employed in this study and the CUSUM chart analysis and descriptive statistics were the statistical tools used in this study. The findings of the study indicate that the level of hypertension is out of control in Anambra State which calls for a serious intervention program. Also, it was found that the process of hypertension was last in control in September, 2010, which implies that the shift likely occurred between September and October, 2010. Based on the findings of this study it is obvious that the rate of reported cases of hypertension is alarming. Hence, there is serious need for government and health workers to detect the assignable causes of variation and thereby educate people on how to live healthy, the foods to take and the ones to avoid.
Keywords: Hypertension, Cumulative sum chart, Health Workers, Government.

INTRODUCTION

Blood pressure (BP), sometimes called arterial blood pressure is the pressure exerted by blood in circulation on the walls of blood vessels. Blood pressure is one of the principal vital signs. When addressed without added specification "blood pressure" refers to the arterial pressure of the systemic circulation [1].

During every heartbeat, blood pressure varies between maximum (systolic) and minimum (diastolic) pressures. It is observed that the blood pressure in the circulation is principally due to the pumping action of the heart.

Blood pressure varies in healthy people as well as animals, but the variation is controlled by the nervous and endocrine systems. When blood pressure is pathologically low it is called hypotension, and when it is pathologically high it is called hypertension. The two have various causes and range from mild to severe. Hypertension (HTN) or high blood pressure (High BP) sometime referred to as arterial hypertension is a medical condition in which the blood pressure in the arteries is increased. Blood pressure is read by two measurements, namely, systolic and diastolic; they depend on whether the heart muscle is contracting (systole) or relaxed between beats (diastole). This equals the maximum and minimum pressure respectively. Normally, blood pressure at rest is between the range of 100-140mmHg systolic (top reading) and 60-90mmHg diastolic (bottom reading). The blood pressure is high when it is often at or above 140/90mmHg.

Hypertension is classified as either primary (essential) hypertension or secondary hypertension; about 90-95% of cases are categorized as "primary hypertension" which means high blood pressure with no obvious underlying medical cause [2]. The remaining 5-10% of cases (secondary hypertension) is caused by other conditions that distress the arteries, kidneys, heart or endocrine system. Hypertension strains the heart, causing hypertensive heart diseases and also coronary artery diseases if untreated. Hypertension also is a major risk factor for stroke, aneurysms of the arteries (e.g. aortic aneurysm), peripheral arterial disease and is a cause of chronic kidney disease. A reasonably high arterial blood pressure is linked to a shortened life expectancy while mild elevation isn't. However, dietary and lifestyle adjustments can enhance BP control and decrease the risk of health problems, although drug treatment is still frequently necessary in people for whom lifestyle changes are not sufficient or not effective.

The relationship between blood pressure and risk cardiovascular diseases events is continuous and consistent as well as independent of any other risk factors. Therefore, the higher the Blood Pressure, the greater the likelihood of heart attack, failure of the heart, kidney diseases, and stroke [3]. The burden of non-communicable diseases (NCDs) such as hypertension is increasing in epidemic proportions in Africa. Major target-organ complications of hypertension, such as

left ventricular hypertrophy diastolic dysfunction, congestive heart failure, ischemic heart disease, stroke, and renal failure [4] have been established by various researchers in Nigeria. Reducing the prevalence of hypertension would decrease mortality and disability in middle-aged and older persons and lead to a better quality of life. Reduction of hypertension prevalence could be achieved through risk factor prevention programs as well as using low-cost management. However, in most countries of the African region, implementation of these approaches and programs is hampered by death of data on the prevalence and control level of hypertension. Scarcity of data is sometimes understood as non-existence of the problem [3]. There is paucity of hypertension prevalence in many populations of Nigeria. Thus, burden of hypertension in these populations might be underestimated and might leave the illness undiagnosed and untreated. Uncontrolled hypertension clearly places a substantial strain on health care delivery system. Estimating the prevalence of hypertension in populations of Nigeria would be useful in efforts to control hypertension and other NCDs.

Regrettably, most people due to ignorance of risk factors and preventive measures of hypertension engage in unhealthy lifestyles such as excessive consumption of alcohol, sedentary lifestyle, excess consumption of sodium intake, tobacco and cigarette smoking, obesity, reduced intake of fruits and vegetables, stress and consumption of foods rich in cholesterol. These unhealthy lifestyle practices have increased the prevalence of hypertension in the world including Nigeria, which culminates into high cases of deaths. Hypertension is one of the problems affecting especially a great portion of the adult population and currently causes one in every eight deaths worldwide, making it the third leading killer disease in the world. In Nigeria, many people loss they live to hypertension. This is not an acceptable situation, considering the fact that hypertension is preventable and manageable to reduce its impact on the health and life of people in Nigeria. However, some studies have been conducted on hypertension in many parts of the world including Nigeria. The related studies were conducted among pregnant women, workers in banking industry, hypertensive patients, primary care patients, urban elderly, and in rural communities, and in different countries. This study was motivated because of the fact that there exist no study carried out in Nigeria to determine the trend of hypertension and stroke using CUSUM control chart.

The aim of this study is to determine whether the trend of hypertension in Nnewi, Anambra state is out of control. In order to achieve this aim, the following objectives were considered: to determine the observation where the process of hypertension was out of control, and to ascertain the point where the process of hypertension was last in control.

LITERATURE REVIEW

Emphasizing more on the role of knowledge, Moronkola and Okonlawon [5] posited that knowledge helps to create a change in behavior towards health. The rationale for improving health behavior knowledge among adults is derived from health behavior models, the individual's perceived risk of developing a certain condition is postulated to be essential in motivating his or her actions. Adults should be able to understand what hypertension is all about, signs and symptoms, the risk factors and preventive measures, and how it affects them in particular before it will be meaningful for them to appreciate and practice its preventive measures.

According to Klabunde [6], differences in mean blood pressure are responsible for blood flow from one location to another in the circulation. The rate of blood flow depends immensely on the resistance to flow presented by the blood vessels. Average blood pressure decreases as the circulating blood flows away from the heart through arteries and capillaries due to losses of energy to viscosity. Average or mean blood pressure reduces over the whole circulation, although most of the drop occurs along the small arteries and arterioles. Also, gravity has been identified to affects blood pressure through hydrostatic forces (e.g., during standing), breathing, valves in veins, pumping from contraction of skeletal muscles also influence blood pressure in veins. Klabunde [6] opined that blood pressure without further specification usually refers to the systemic arterial pressure measured at a person's upper arm and is a measure of the pressure in the brachial artery, the major artery in the upper arm. In humans blood pressure is normally expressed in terms of systolic pressure over diastolic pressure and is measured in millimeters of mercury (mmHg), for example 120/80.

Onuzulike [8] stated that hypertension is consistent elevation of blood pressure of above normal for a particular age. Expert Committee on Non-communicable Diseases [3] stressed that blood pressure of 120/80 mmHg is considered normal for a 30 year old person, while blood pressure of 140 mmHg is considered high for such a person. Similarly, blood pressure of 150/90 mmHg is considered normal for a 60-years old person; while blood pressure of 160/100 mmHg is high for a person of such age. Hypertension is often referred to as "the silent killer" because people who have it are often symptom-free. Ironically, despite its deadly nature, victims of hypertension rarely, if ever, are aware that they have this disease. Hypertension does not produce dizziness, headache or memory loss, unless one is experiencing a medical crisis.

Ejike *et al.* [9] estimated that about one billion adults had hypertension in the year 2010, and the number is expected to rise to 1.56 billion in the year 2025. In addition, hypertension is the commonest non-communicable disease in Nigeria with over 4.3 million Nigerians classified as being hypertensive.

RESEARCH METHODOLOGY

Study Population

The study population comprises of all the people diagnosed with hypertension in Nnamdi Azikiwe University teaching hospital, Nnewi. Hence, the total number of reported cases of hypertension at Nnamdi Azikiwe University teaching hospital, Nnewi from 2010-2014 was employed in this study.

Method of Data Collection

The method of data collection in this study was secondary data method from the records department of Nnamdi Azikiwe University teaching hospital, Nnewi.

Method of Data Analysis

The cumulative sum control chart (CUSUM chart) is a sequential analysis technique developed by Page, E. S. of the University of Cambridge [7]. This type of control chart is often used for monitoring change detection and deciding when to take corrective action. A CUSUM control chart provides us with a process mean chart which has 3 lines of limits as follows:

- Center line
- Upper control limit $C_i^+ = \max\left[0, x_i - (T + K) + C_{i-1}^+\right]$
- Lower control limit $C_i^- = \max\left[0, (T - K) - x_i + C_{i-1}^-\right]$

Suppose we consider a data set with column (X_i), where n observations were drawn from a normal distribution of people with a particular case with the mean μ and standard deviation (SD). It is assumed that the sample size of $n \geq 1$ were collected, and $\overline{X}_j$ represents the average of the j^{th} sample. Suppose μ_0 is the target for the process mean, then the cumulative sum control chart is formed by plotting the quantity

$$C_i = \sum_{j=1}^{i}\left(\bar{X}j - \mu_0\right) \qquad (1)$$

against the sample number *i*. C_i is called the cumulative sum up to and including the i^{th} sample. Because they combine information from several samples.

We note that if the process remains in control at the target value μ_0, the cumulative sum defined in equation (1) is expected to be a random walk with mean zero. However, if the mean shifts upward to some value $\mu_1 > \mu_0$, say, then an upward or positive drift will develop in the cumulative sum C_i.

Conversely, if the mean shifts downward to some $\mu_1 < \mu_0$, then a downward or negative drift in C_i will develop. Therefore, if a significant trend develops in the plotted points either upward or downward, we should consider this as evidence that the process mean has shifted, and a search for some assignable cause should be performed.

The Tabular or Algorithmic CUSUM for Monitoring the Process Mean

CUSUMs may be constructed both for individual observations and for the averages of rational subgroups [7]. The case of individual observations occurs very often in practice, so that situation will be treated first.

Suppose x_i represents the i^{th} observation on the process. When the process is in control, x_i has a normal distribution with mean μ_0 and standard deviation S. It is assumed that either S is known or that a reliable estimate is available.

If the process drifts or shifts off the target value, the CUSUM will signal, and an adjustment is made manipulate the variable to bring the process back on target. Also, in some cases a signal from a CUSUM indicates the presence of an assignable cause that must be investigated. The tabular CUSUM works by accumulating derivations from μ_0 that are above target with one statistic C^+ and accumulating derivations from μ_0 that are below target with another statistic C^-. The statistics C^+ and C^- are called *one-sided upper and lower CUSUMs* respectively. They are computed as follows:

Upper control limit $C_i^+ = \max\left[0, Xi - (\mu_0 + K) + C_{i-1}^+\right]$ (2)

Lower control limit $C_i^- = \max\left[0, (\mu_0 - K) - Xi + C_{i-1}^+\right]$ (3)

Where the starting values are $C_0^+ = C_0^- = 0$

K is usually called the *reference value* (or the *allowance*, or the *slack value*), and it is often chosen about halfway between the target μ_0 and the out-of-control value of the mean μ_1 that we are interested in detecting quickly. Thus, if the shift is expressed in standard deviation units as $\mu_1 = \mu_0 + \delta$ S (or $\delta = (\mu_1 - \mu_0)/S$), then *K* is one-half the magnitude of the shift or

$$K = \frac{\delta}{2S} = \frac{(\mu_1 - \mu_0)}{2S} \quad (4)$$

Note that C_i^+ and C_i^- accumulate deviations from the target value μ_0 that are greater than *K*, with both quantities reset to zero on becoming negative. If either C_i^+ or C_i^- exceeds the *decision interval H*, the process is considered to be out of control. Montgomery [7] noted that the proper selection of K and H parameters is quite important, as it has substantial impact on the performance of the CUSUM. He suggested that the reasonable value for *H* is five times the process standard deviation S.

DATA PRESENTATION

Table-1: Distribution of Reported Cases of Hypertension and Stroke from 2010-2014

Year	Months	Hypertension
2010	January	10
	February	6
	March	10
	April	8
	May	8
	June	3
	July	4
	August	5
	September	6
	October	9
	November	7
	December	15
2011	January	10
	February	13
	March	8
	April	4
	May	5
	June	10
	July	12
	August	11
	September	5
	October	4
	November	8

	December	2
2012	January	4
	February	6
	March	9
	April	8
	May	13
	June	8
	July	10
	August	3
	September	6
	October	5
	November	6
	December	10
2013	January	8
	February	5
	March	10
	April	2
	May	13
	June	8
	July	9
	August	8
	September	10
	October	3
	November	3
	December	6
2014	January	8
	February	4
	March	3
	April	6
	May	14
	June	6
	July	4
	August	7
	September	6
	October	3
	November	9
	December	8

Source: NAUTH, 2015

DATA ANALYSIS AND RESULT

CUSUM Analysis on reported cases of Hypertension in Anambra State

Table-2: Summary of tabular CUSUM for reported cases of Hypertension

Observation(i)	x_i	$x_i - 7.5$	C_i^+	N^+	$6.5 - x_i$	C_i^-	N^-
1	10	2.5	2.5	1	-3.5	0	0
2	6	-1.5	1	2	0.5	0.5	1
3	10	2.5	3.5	3	-3.5	0	0
4	8	0.5	4	4	-1.5	0	0
5	8	0.5	4.5	5	-1.5	0	0
6	3	-4.5	0	0	3.5	3.5	1
7	4	-3.5	0	0	2.5	6	2
8	5	-2.5	0	0	1.5	7.5	3
9	6	-1.5	0	0	0.5	8	4
10	9	1.5	1.5	1	-2.5	5.5	5
11	7	0.5	2	2	-0.5	5	6
12	15	7.5	9.5	3	-8.5	0	0

13	10	2.5	12	4	-3.5	0	0
14	13	5.5	17.5	5	-6.5	0	0
15	8	0.5	18	6	-1.5	0	0
16	4	-3.5	14.5	7	2.5	2.5	1
17	5	-2.5	12	8	1.5	4	2
18	10	2.5	14.5	9	-3.5	0.5	3
19	12	4.5	19	10	-5.5	0	0
20	11	3.5	22.5	11	-4.5	0	0
21	5	-2.5	20	12	1.5	1.5	1
22	4	-3.5	16.5	13	2.5	4	2
23	8	0.5	17	14	-1.5	2.5	3
24	2	-5.5	11.5	15	4.5	7	4
25	4	-3.5	8	16	2.5	9.5	5
26	6	-1.5	6.5	17	0.5	10	6
27	9	1.5	8	18	-2.5	7.5	7
28	8	0.5	8.5	19	-1.5	6	8
29	13	5.5	14	20	-6.5	0	0
30	8	0.5	14.5	21	-1.5	0	0
31	10	2.5	17	22	-3.5	0	0
32	3	-4.5	12.5	23	3.5	3.5	1
33	6	-1.5	11	24	0.5	4	2
34	5	-2.5	8.5	25	1.5	5.5	3
35	6	-1.5	7	26	0.5	6	4
36	10	2.5	9.5	27	-3.5	2.5	5
37	8	0.5	10	28	-1.5	1	6
38	5	-2.5	7.5	29	1.5	2.5	7
39	10	2.5	10	30	-3.5	0	0
40	2	-5.5	4.5	31	4.5	4.5	1
41	13	5.5	10	32	-6.5	0	0
42	8	0.5	10.5	33	-1.5	0	0
43	9	1.5	12	34	-2.5	0	0
44	8	0.5	12.5	35	-1.5	0	0
45	10	2.5	15	36	-3.5	0	0
46	3	-4.5	10.5	37	3.5	3.5	1
47	3	-4.5	6	38	3.5	7	2
48	6	-1.5	4.5	39	0.5	7.5	3
49	8	0.5	5	40	-1.5	6	4
50	4	-3.5	1.5	41	2.5	8.5	5
51	3	-4.5	0	0	3.5	12	6
52	6	-1.5	0	0	0.5	12.5	7
53	14	6.5	6.5	1	-7.5	5	8
54	6	-1.5	5	2	0.5	5.5	9
55	4	-3.5	1.5	3	2.5	8	10
56	7	-0.5	1	4	-0.5	7.5	11
57	6	-1.5	0	0	0.5	8	12
58	3	-4.5	0	0	3.5	11.5	13
59	9	1.5	1.5	1	-2.5	9	14
60	8	0.5	2	2	-1.5	7.5	15

Using equation (2) and (3), the illustrative calculations can be obtained as: observation 1.

The equations for $C_1^+ = \max\left[0, x_1 - 7.5 + C_0^+\right]$

and

$$C_1^- = \max\left[0, 6.5 - x_1 + C_0^-\right]$$

Since k = 0.5 and $\mu_0 = 7$. Now $x_1 = 10$, so since $C_0^+ = C_0^- = 0$,

$$C_1^+ = \max\left[0, 7.5 - 10 + 0\right] = 2.5$$

and

$$C_1^- = \max\left[0, 6.5 - 10 + 0\right] = 0$$

For observation 2.

$$C_2^+ = \max\left[0, x_2 - 7.5 + C_1^+\right] = \max\left[0, x_2 - 7.5 + 0\right]$$

and

$$C_2^- = \max\left[0, 6.5 - x_2 + C_1^-\right] = \max\left[0, 6.5 - x_2 + 0\right]$$

Since $x_2 = 6$, we obtain

$$C_2^+ = \max\left[0, 6 - 7.5 + 0\right] = 0$$

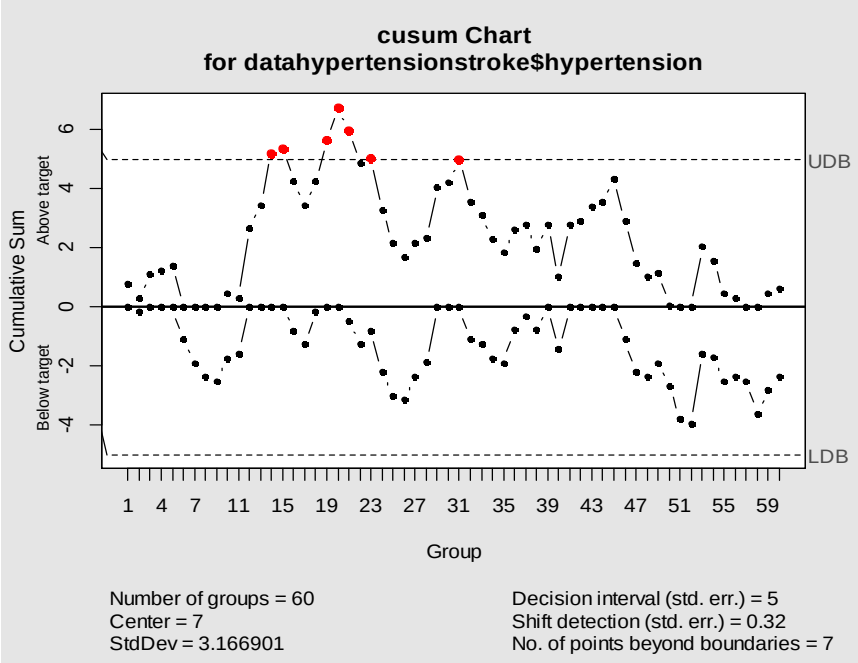

Fig-1: CUSUM Chart Analysis of Reported of Hypertension in Nnewi North, Anambra State, Nigeria

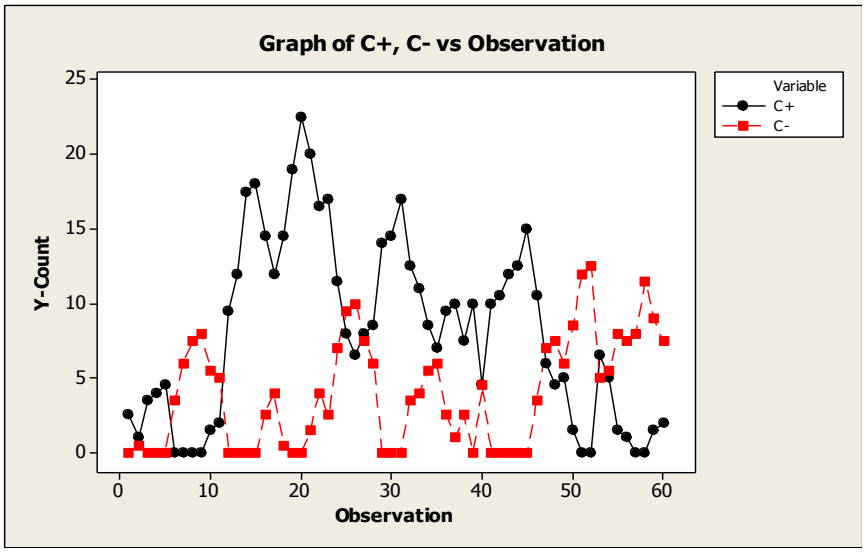

Fig-2: Distribution of the Upper and Lower Limit of Reported of Hypertension in Nnewi North, Anambra State, Nigeria

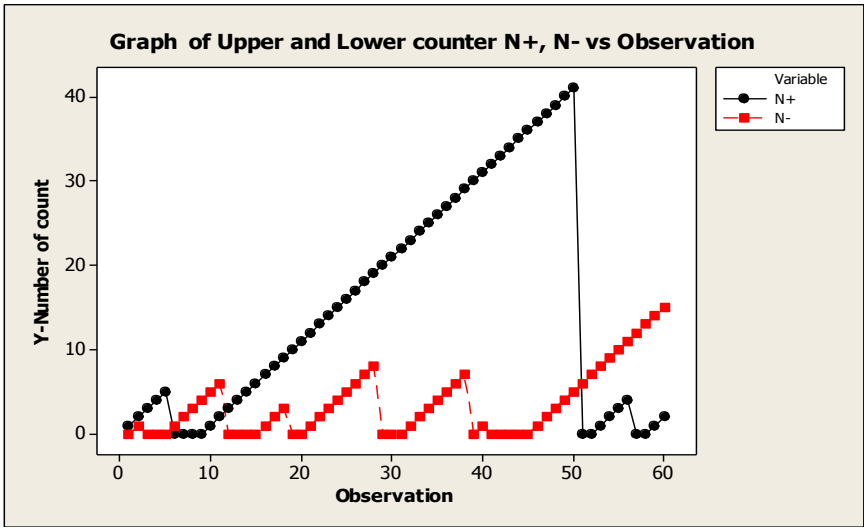

Fig-3: Distribution of the Upper and Lower counter of Reported of Hypertension in Nnewi North, Anambra State, Nigeria

The quantities N^+ and N^- indicates the number of consecutive periods that the CUSUM C_i^+ or C_i^- have been non zero.

The CUSUM calculations in table 2 and figure shows that the upper-side CUSUM at observation 14 is C_{14}^+ = 17.5, since this is the first observation at which C_i^+ is greater than H = 16, therefore we conclude that the level of hypertension is out of control as was observed in figure 1. This tabular CUSUM also indicates when the shift probably occurred.

The counter N^+ records the number of consecutive observations since the upper-side CUSUM C_i^+ rose above the value of zero. Since N^+ = 5 at the observation 14, we would conclude that the process was last in control at observation 14 – 5 = 9, so the shift likely occurred between observation 9 and 10.

CONCLUSION

This study monitored the trend of hypertension in Anambra State. Hypertension involves the persistent raised levels of blood pressure in which the systolic pressure is 140 mmHg and diastolic above 90 mmHg. The findings of the study indicate that the level of hypertension is out of control in Anambra State which calls for a serious intervention program. Also, it was found that the process of hypertension was last in control in September, 2010, which implies that the shift likely occurred between September and October, 2010. Based on the findings of this study it is obvious that the rate of reported cases of hypertension is alarming. Hence, there is serious need for government and health workers to detect the assignable causes of variation and thereby educate people on how to live healthy, the foods to take and the ones to avoid.

REFERENCES

1. Caro C, Pedley TJ, Schroter RC, Seed WA. Flow in pipes and around objects. The Mechanics of the Circulation. 1978:44-78.
2. Agrawal VK, Bhalwar R, Basannar DR. Prevalence and determinants of hypertension in a rural community. Medical Journal Armed Forces India. 2008 Jan 1;64(1):21-5.
3. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, Jones DW, Materson BJ, Oparil S, Wright JT, Roccella EJ. Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. hypertension. 2003 Dec 1;42(6):1206-52.
4. Akinkugbe OO. Current epidemiology of hypertension in Nigeria. Archives of Ibadan Medicine. 2000;1(1):3-5.
5. Moronkola OA, Okanlawon FA. Fundamentals of public and community health education. Ibadan Royal People. 2003.
6. Klabunde RE. Cardiovascular Physiology Concepts. Micheal Alderman, Oxford University Press. 2005.
7. Montgomery DC. Introduction to statistical quality control. John Wiley & Sons (New York); 2009.
8. Onuzulike NM. Issues in health. Owerri: Megasoft Publishers. 2006.
9. Ejike CC, Ezeanyika LU, Ugwu CE. Variations in the prevalence point of prehypertension in a Nigeria school–going adolescent population living in Auchi, Nigeria. BMC Pediatrics. 2010;10(13):1471-2431.