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Effect of GSM Phone Radiation on Human Pulse Rate (Heartbeat Rate)

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ABSTRACT

Concern about human exposure to radiofrequency (RF) is not new. The conveniences and satisfaction derived in the use of GSM mobile phone is being threatened by claims of adverse effects on human health by radiation coming from this device. This radiation belongs to the type called non-ionizing radiation the health hazard of which remains debatable. Research has not been carried out on possible effect this device might have on human health and no experimental proof, based on data obtained within Nigeria, exist to substantiate any claim. Safety standards exist for radiation from cell phone but these are not reassuring. This paper investigates any possible effect of GSM mobile phone radiation on human heart rate and then come out with conclusion based on experimental proof. Over one hundred human subjects were monitored by measuring their pulse rate under three exposure criteria. In one of the radiation tests, the phone used was put in vibration mode in order to determine subjects were not just responding to vibration. It was found out pulse rate do not change significantly when subjects were exposed to phone radiation. However, the percentage decrease recorded by people of age 40 years and above, even though barely above 1% makes it advisable that people of age 40 years and above should avoid keeping mobile phones close to the heart.

Keywords : *Phone Radiation, Human Pulse Rate, Radio Frequency*

1. INTRODUCTION

Concern about human exposure to radio frequencies (RF) is not new [1]. The development and application of devices that emit radio frequency radiation have significantly increased the quality of life throughout the world. Due to wide spread use of the Global System for Mobile Communications (GSM) mobile phones they have become indispensable as communication tools. But also, the proliferation has been accompanied by the Public's fear of potential adverse effects.

Apart from the naturally occurring cosmic microwave background radiation (CMBR) in which the human organism developed, we are being daily bombarded by the ever increasing unseen radiation being spewed out by mobile phones and their towers that straddle our residential environment. Cell phones transmit and receive electromagnetic (EM) waves, mainly at frequencies of 800-1900 MHz [2]. There is an enormous increase in the use of wireless mobile telephony throughout the world as there were more than 4.3 billion users worldwide as of July 2009 [3]. Adverse effects of these important communications tools are being reported. Sensations of burning or warmth around the ear, headache[4], disturbance of sleep, alteration of cognitive function and neural activity, are some of the effects being reported as resulting from mobile phone use. In spite of previous studies, knowledge about the adverse effect of radiofrequency and microwaves (RF/MW) radiation on human health, or the biological responses to RF/MW radiation exposure is still limited. Mobile phones are usually held in the close proximity to the human heart therefore exposure to radiation is high. Also worrisome is the fact that some people in Nigeria live virtually under GSM base stations.

And if truly any level of mobile phone radiation cause significant alteration in the condition of human heart, then we may be all pretty much on death row!

2. ABSORPTION OF RF RADIATION BY HUMAN BODY

Biological tissue is, for all practical purposes, non-magnetic with a permeability μ (H/m) close to that of free space [5]. There are three established basic coupling mechanisms through which time-varying electric and magnetic fields interact directly with living matter (UNEP/WHO/IRPA 1993): The one relevant to this study is 'absorption of energy from electromagnetic fields'. As regards absorption of energy by the human body,

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electromagnetic fields can be divided into four ranges (Durney et al. 1985). GSM phones fall within one of these ranges which are 'frequencies in the range from about 300 MHz to several GHz, at which significant local, non-uniform absorption occurs [6]. The absorption effects of RF energy by the biological body vary in magnitude with both the frequency of the applied field and the characteristics of the tissue material, which is largely based on water and ionic content [5]. The table 1 shows the penetration depth of waves of increasing frequency in typical body tissues and illustrates how high-water-content tissues such as blood and muscle and more absorptive than low-water-content tissues such as fat [5] (i.e. the more the penetration depth, the less the absorption and vise-versa).

Table 1: Penetration depth in selected biological tissues as a function of frequency

Frequency MHz	Depth of penetration (mm)			
	Blood	Muscle	Brain	Fat
150	46.0	67.1	93.7	342
915	27.8	42.1	47.2	250
2450	16.2	22.3	23.1	122
5800	6.0	7.5	7.9	40.9

(Source: Electronics & Communication journal volume13, No2. IEE 2001)

Based on the absorption level of blood and muscle as shown in the table, the human heart made up of blood and muscle could be vulnerable. The more reason proximity to the heart of radiation emitting gargets should be a concern.

One way of determining the RF exposure level due to phones is by measuring the device's specific absorption rate (SAR). The SAR constitutes the measures of power absorbs per unit mass, in other words, the amount of power the body absorbs. Determining SAR requires laboratory analysis and involves measuring factors such as average phone usage and the unit's distance from the body [7]. Manufacturers are required to use the specific anthropomorphic mannequin (SAM) phantom [1]. SAR is measured in watt per kilogram (W/kg) averaged over one gram of body tissue as in north America standard or over ten grams of body tissue as in European standard. SAR limits are based on whole-body exposure levels of 0.08 W/kg. Limits are less stringent for exposure to hands, wrists, feet, and ankles. Most SAR testing concerns exposure to the head. For Europe, the current limit is 2 W/kg for 10-g volume-averaged SAR. For the United States and a number of other countries, the limit is 1.6 W/kg for 1-g volume-averaged SAR [1].

3. RADIATION SOURCE AND PULSE RATE MONITORING

A dual band (900MHz, 1800MHz) Nokia1200 (Fig. 1), in receiving mode was used as radiation source. Its SAR rating is 1.15 based on 1.6W/kg averaged over one gram of body tissue or 0.81 based on 2.0W/kg averaged over ten grams of body tissue. Based on 1.6W/kg radiation rating, one of the best phones in energy emitted is Samsung Impression SGH-a877 with rating of 0.35, while one of the worst has the rating of 1.55W/kg [8]. The lower the SAR rating of a phone the better it is. Therefore using a phone with SAR rating of 1.15 represents a near worst-case scenario.

Fig. 1: Nokia 1200

Nokia1600, also of the same dual band, SAR rating 1.12 (1.6W/kg) / 0.82 (2.0W/kg), was used as transmitting phone (Fig. 2).

The SAR ratings of both the receiving and transmitting mobile phones fall within the international standard of exposure limit for public exposure which is 1.6W/kg radiation rating averaged over one gram of body tissue [1]. Hence there is no question of putting the subject under any hazard risk. Their safety is therefore guaranteed based on international standard.

Fig. 2: Nokia 1600

A 14.1 x 11.3 x 6.0cm battery powered automatic inflate/deflate arm pulse rate monitor with arm strap/cuff for arm circumference 24-36cm (Fig. 3) was used to monitor the pulse rate of the subjects. The digital display of the monitor makes reading less cumbersome. When the start button is pressed once, the unit will automatically start to inflate slowly to measure the pulse rate. During inflation, a changing measure of the cuff pressure is shown on the display. At a point, the pressure then begins to drop. When the cuff pressure has dropped to the point where the monitor can no longer detect the pulse, the subject's pulse rate will be displayed.

Fig. 3(a): Pulse rate monitor with the arm cuff **(b)** Monitor's display

Recording tool (data sheet and writing material) made it easier to organize the data.

All the above instruments were used without prejudice to subject personal health welfare.

The following activities were carried out in the pulse rate monitoring process:

The study group used as experimental subjects consisted of 102 human volunteers with age bracket ranging from 10-20years to 71-80years. The participants satisfied the following inclusion criteria: age-brackets of subjects are all within the age group of GSM phone users; arm circumference of subjects is reasonably within monitor's cuff fitting.

A battery powered automatic inflate/deflate digital display arm pulse rate monitor with arm strap/cuff which measures pulse rate was used to monitor the pulse rate of individual in the group. Each subject went through three checks under the same environmental and physical condition but different radiation exposure criteria. The normal output of a consumer mobile phone operating at GSM frequency of 900/1800MHz mobile phone was used as GSM radiation source (Fig. 1).

The three radiation exposure criteria are:

i. Pulse rate monitoring without the subject been expose to any radiation and subject fully aware of this.

ii. Pulse rate monitoring with the subject expose to radiation from a call receiving mobile phone on vibration.

iii. Pulse rate monitoring with the subject expose to radiation from a call receiving mobile phone with vibration off.

To achieve the criteria the three tests were carried out as follows:

The cuff of the monitor was wrapped around the arm above the elbow of the human subject and the pulse rate was measured while he/she was not exposed to any radiation from GSM phone.

With the same position maintained the test was carried out again but this time with a mobile phone in the subject's breast pocket or held against the chest in the absence of breast pocket. Holding the phone in such close proximity to the heart represent the worst-case scenario. Call is made to this phone with vibration set on and while this was going on, the pulse rate was measured.

The same procedure as the second test was repeated but with vibration set off. The duration of radiation exposure was generally in the average of 20 seconds, a typical duration for a receiving phone kept in the breast pocket to ring before a call is picked or terminated.

The three tests were carried out under the same physical and environmental conditions such as location, body position, ambient temperature and external distractions, to eliminate or minimize confounding effects on readings due to these external factors. Physical activity such as changing seats can alter pulse rate [9]. So such influencing factors were kept constant.

Fig. 4 shows the demonstration of test carried out on the subjects.

4. GRAPHS AND GRAPHICAL ANALYSIS

In order to bring about a more robust analysis, the collected data, as well as the analysis, is sectionalized into the following groups which represent sub-tables: grown-up children (age-bracket 10-20yrs), youth (age-bracket 21-30yrs), young adult (age-bracket 31-40yrs), adult (age-bracket 41-80yrs). Children below age 10 years can be considered non-phone users.

Based on the data collected through the monitoring, the following graphs were plotted.

Fig. 4: Demonstration of Test

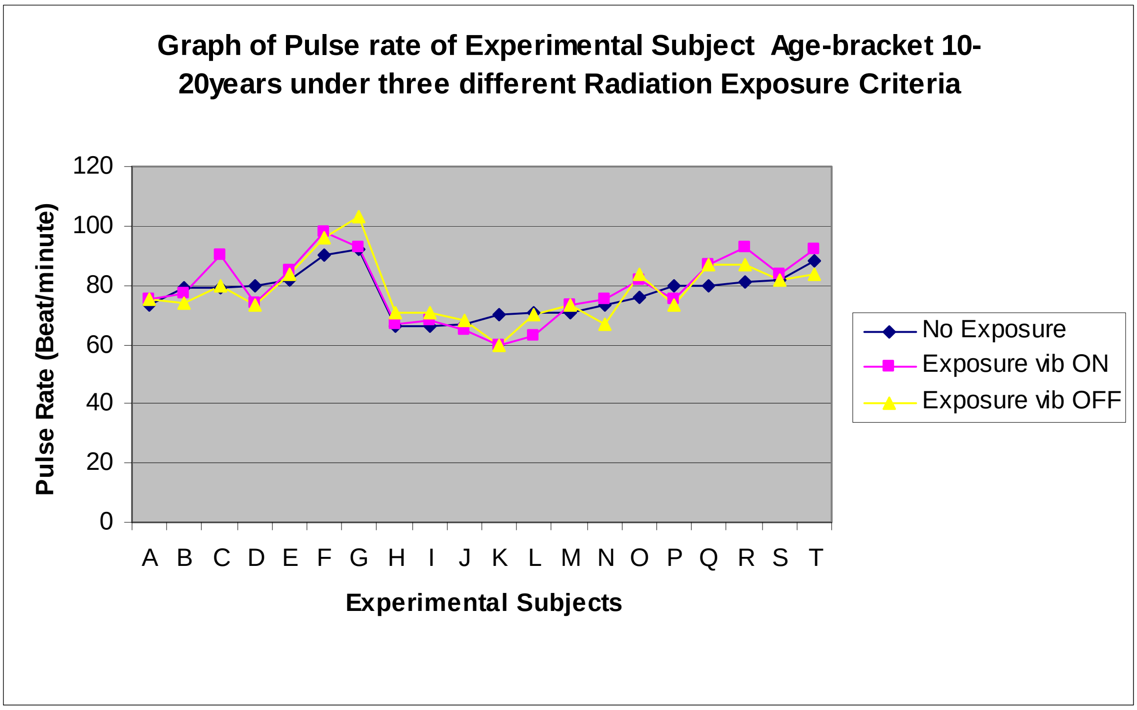

Fig. 5: Graph of pulse rate against experimental subjects of children (age-bracket 10-20yrs)

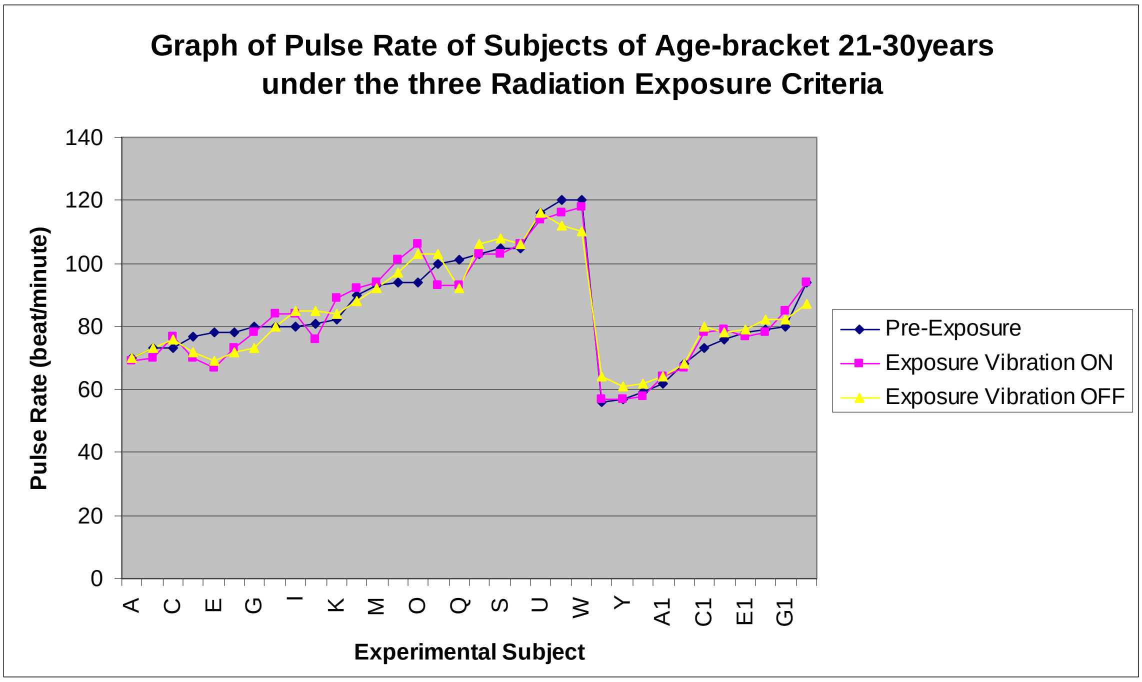

Fig. 6: Graph of pulse rate against experimental subjects of youth (age-bracket 21-30yrs)

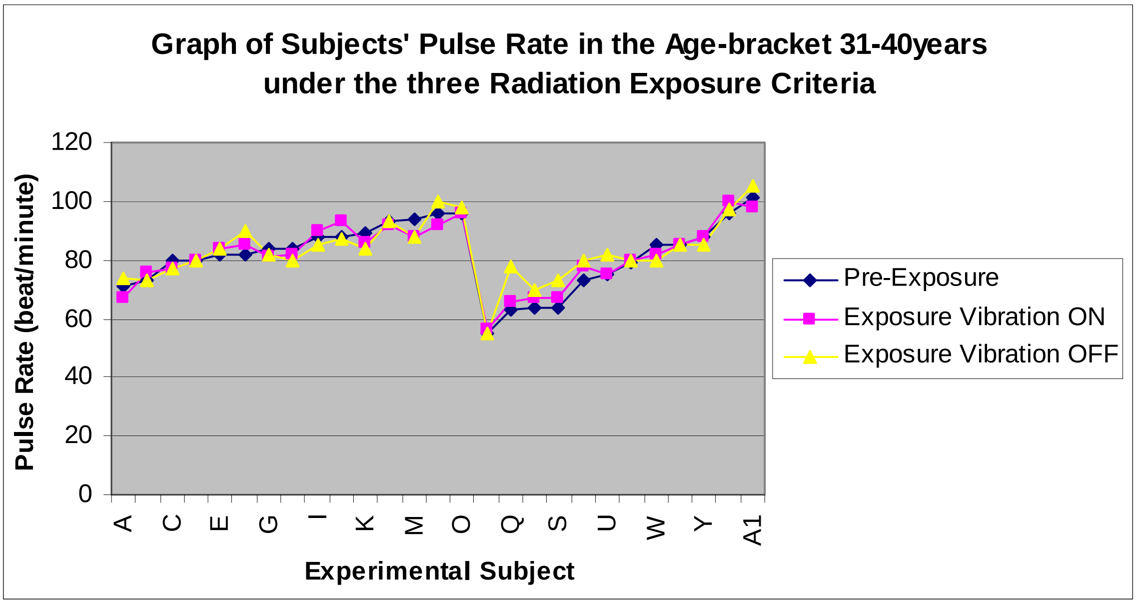

Fig. 7: Graph of pulse rate against experimental subjects of young adult (age-bracket 31-40yrs)

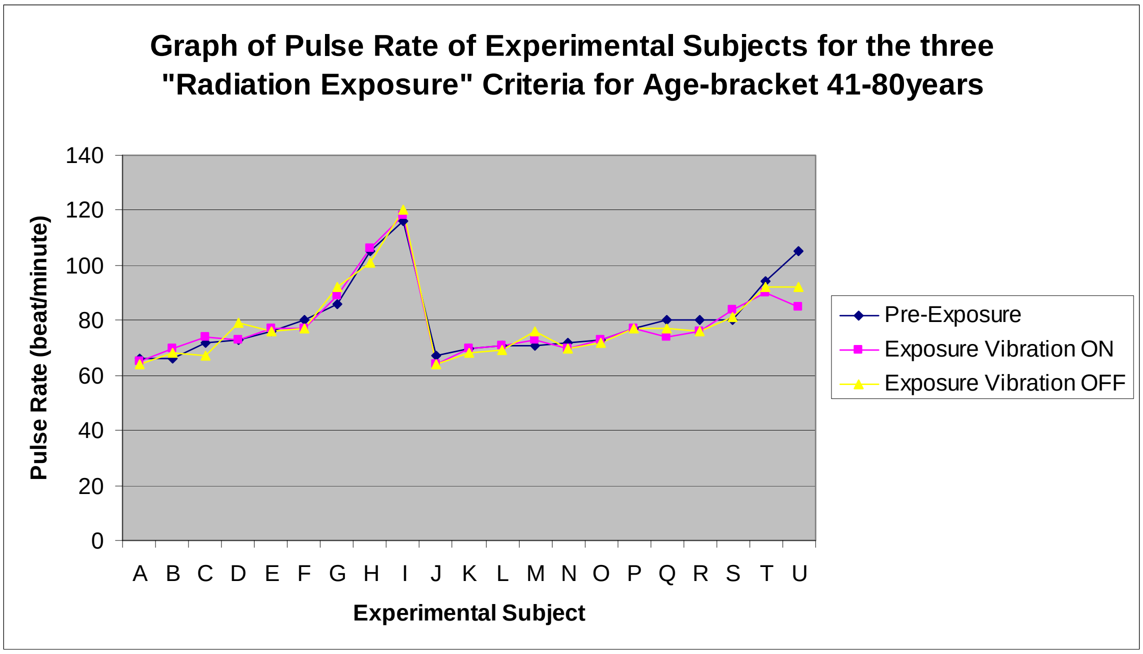

Fig. 8: Graph of pulse rate against experimental subjects of adult (age-bracket 41-80yrs)

The mean value of the whole data is desired in order to help analyze the entire data and make it less cumbersome. The mean is a value that helps summarize an entire set of numbers. In examining large collections of numbers, such as this, it is helpful to be able to present a number that provides a summary of the data. Such numbers are often called descriptive statistics. The arithmetic mean is probably the best-known descriptive statistic. The mean values of collected data sectionalized into different age groups are shown in table 2. The values were generated with the aid of Microsoft office excel 2003. Figure 9 shows the graph of the mean value of pulse rate of the four age groups under the three exposure criteria, while figure 10. is the multiple bar chart representation.

Table 2: Mean pulse rate (expectation value) of the four age bracket groups

	Pulse rate (beat/minute)		
Age-bracket (year)	Pre-Exposure	Exposure Vibration ON	Exposure Vibration OFF
10 to 20	77.3	78.8	78.1
21 to 30	84.56	84.41	84.68
31 to 40	81.78	81.89	83.15
41 to 80	80	78.86	78.95

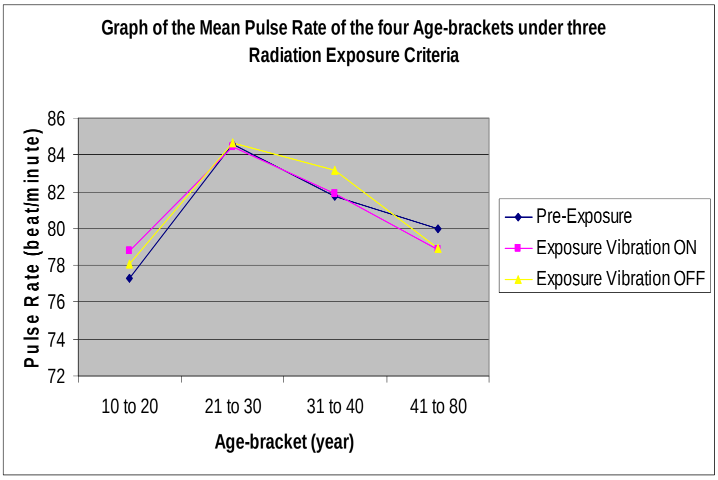

Fig. 9: Graph of mean pulse rate against group age-bracket

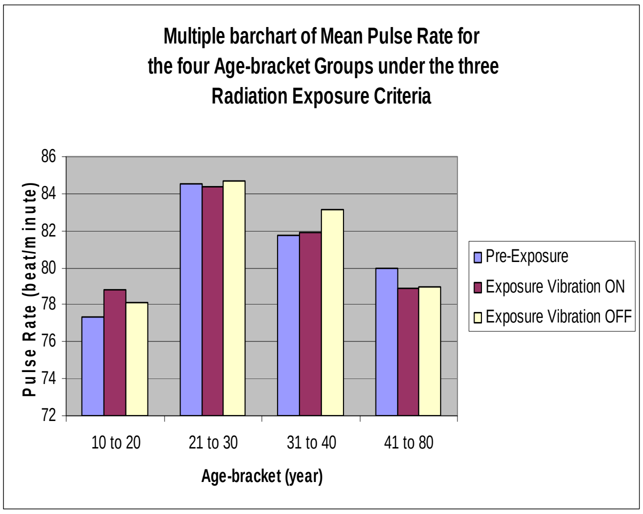

Fig. 10: Multiple bar chart of mean pulse rate against group age-bracket

It is interesting to note that the graph of each section display a general unique characteristic pattern. The graph of the pulse rate when the subjects were exposed to radiation both in the vibration ON and OFF mode simply looped around the graph of resting pulse rate subjects when subjects are not exposed to radiation source. For the age group 10-20yrs, the graphs of the pulse with radiation exposure were basically looping around the resting pulse rate with virtually the same trend as the latter (fig. 5). Slightly significant deviation occurred only with Subjects K and R. Also Subject C showed response to vibration only. The sharp descent noticed in all the graphs is the transition from female Subjects to male Subjects.

In figure 6, the same trend of looping round the resting pulse rate was observed. All the pulse rate values in the three graphs fall within the same range with the exception of only Subjects E and O having slight decrease and increase respectively when exposed to radiation from phone in vibration and non-vibration mode. Vibration does not seem to affect their pulse rate.

The graphs of all the three radiation criteria in figure 7. for young adult are invariably uniform. Only Subject Q showed a marked increase in pulse rate when exposed to radiation from phone in non-vibration mode. This however is not so pronounced in other Subjects in the same group.

For the adult group in figure 8, the graph of the three radiation criteria are basically the same. The pattern or the trend is uniform. The only exception being Subject U which experience drop in pulse rate when exposed to radiation. The drop is more pronounced when the phone is in vibration mode.

Figure 9. represents the graph of the entire data for the four groups combined, using the mean value. The multiple bar charts in figure 10. also stand for this representation. It is interesting to note that in all, young adult and adult groups, 31-40years and 41-80years respectively, showed a general tendency to the exceptions in their groups. The age-bracket 31 to 40 years experienced increase in pulse rate when exposed to from phone in non-vibration mode as did Subject Q in this group. Also age-bracket 41 to 80 years experienced decrease in pulse rate when exposed to radiation from phone in both vibration and non-vibration mode as did Subject U in that group.

5. GENERAL ANALYSIS BASED ON PERCENTAGE DIFFERENCE

The heart of any measurement process is deciding whether the quantity being measured is greater than, equal to, or less than some reference value. Therefore after graphically analyzing the result, it is a desired goal to be able to determine the variation, in numerical quantity, of each group pulse rate when it is exposed to mobile phone radiation. To achieve this, the data was further analyzed based on percentage difference (increase or decrease) in comparison to the resting pulse rate which served as the reference value. At any time, the actual numerical value increase or decrease in pulse rate of an individual within the age groups covered by my experiment can then be easily determined. The calculation was based on the expectation values given in table 2.

The expectation value is just the limit, as the number of measurements increases to infinity, of the average value, defined in the usual way as the sum of the results divided by their number. This expectation value in other word is the mean, and since it is regarded to be the best indication of central tendency, it is applied here to the different age groups in the calculation of the percentages.

Defining Ct as percentage difference (the % increase or decrease) to be the ratio of the discrepancy between the true value and the experimental value of the pulse rate to the true value, hence;

$$Ct = (Xt - Xe)/Xt \times 100 \qquad \text{……………………….1}$$

Where (Xt - Xe) is the discrepancy, Xt is the mean value of resting pulse rate taking as the true value, Xe is the mean value of pulse rate under real exposure and it is considered here as the experimental value. Xe will be written as X_{evon} for vibration ON and X_{evof} for vibration OFF. Therefore Ct is given as:

$$Ct_{evon} = (Xt - X_{evon})/Xt \times 100 \qquad \text{…………………………………..2}$$

And

$$Ct_{evof} = (Xt - X_{evof})/Xt \times 100 \qquad \text{………………………………...3}$$

Based on equations 2 and 3 table 3 was generated using manual calculation.

Table 3: Percentage difference in Subject's Pulse Rate under Exposure to GSM Phone Radiation

	Pulse rate (beat/minute)			Percentage difference (%)	
Age-bracket(years)	Xt	X_{evon}	X_{evof}	Ct_{evon}	Ct_{evof}
10-20	77.3	78.8	78.1	1.94	1.03
21-30	84.56	84.41	84.68	-0.18	0.14
31-40	81.78	81.89	83.15	0.13	1.68
41-80	80	78.86	78.95	-1.42	-1.31

The negative values show percentage difference. It is worth stating and quite interesting that at this level, variation in pulse rate (numerical value!) of any individual within the age of 10 to 80 years exposed to phone radiation while taking call can be easily determined.

The variation in pulse rate, after exposure to radiation is given by the following equations:

$$Pd_{evon} = (Ct_{evon}/100) \times Po \quad \ldots\ldots 4.4$$

And

$$Pd_{evof} = (Ct_{evof}/100) \times Po \quad \ldots\ldots 4.5$$

Where Pd_{evon} and Pd_{evof} are variation in pulse rate when subject is exposed to radiation with in phone in vibration and no-vibration mode respectively, Po is the pulse rate with no exposure to radiation and Ct_{evon} and Ct_{evof} are as defined earlier. If equations 4.4 and 4.5 are applied to age group 41 to 80 years, a person in that age group with resting pulse rate of 80beat/minute will have his pulse rate reduced by 1.136bpm and 1.048bpm if exposed to phone radiation within the time considered here.

6. CONCLUSIONS

The objective of the research work was achieved. The data collected is the first ever on effect of GSM phone radiation on human health, especially in connection with human heart, anywhere in Nigeria. In the analysis carried out, the elderly ones, basically of age 40 years and above, showed a slight decrease of about 1.4% in pulse rate after exposure. Even though this just barely above 1%, it is advisable that this age group should avoid keeping phone anywhere close to their heart as this may further put stress on their ageing hearts. Overall, variation in pulse rate after Subjects have been exposed to mobile phone radiation is not significant as to call for serious concern.

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