EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 7
Issue: 2
46-55
Year: 2020

HYPERTENSION AND AORTIC ROOT DIAMETER AMONGST NIGERIANS

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Article Received on 01/12/2019 **Article Revised on 21/12/2019** **Article Accepted on 11/01/2020**

ABSTRACT
Root of aorta provides linkage between the heart and the circulation, with documented reports of relationship with hypertension. The aim of this study was to use echocardiogram to evaluate the aortic root diameter in normotensive and hypertensive subjects, males and females ≥18years of age. Sixty two (62) volunteers were engaged in this research (32 males, 52%; 30 females,48%). Data were collected primarily and analysed using SPSS version 25.0. ANOVA, t-test and correlation were used to analyse the data, $p<0.05$ at 95% (confidence interval). Results showed that female hypertensives had a mean aortic diameter of 2.18cm compared to female normotensives, 1.77cm at the annulus, older female adults had higher aortic diameter at the aortic valve with a mean of 2.1cm. T-test was used to ascertain gender difference at the aortic valve, males had 2.05 ± 0.30, females had 1.84 ± 0.23, ANOVA established no significant ($p>0.05$) relationship between aortic diameters at various levels in both sexes with BMI, also aortic diameter did not increase with increasing age in males. This study recommends that cardiologists should do regular echocardiogram on their patients especially older females, and hypertensive females. In conclusion, this study provided reference values for aortic root diameter in normotensives and hypertensives in our population, it also revealed that female hypertensives have bigger aortic root diameter at annulus, older female adults also have a higher aortic root diameter at the aortic valve, males have a higher aortic root diameter at the aortic valve compared to females.

KEYWORDS: Echocardiography, Aortic root, annulus, aortic valve, normotensive, hypertensive.

INTRODUCTION
Background to the Study
Aortic root provides linkage for the heart and the circulation, its structure is complex, consisting of leaflets, which are held up by valsalva sinus and the inter-leaflet triangles.[1]

It also alludes to the outlet of the left ventricle and upper aorta.

Regurgitation of aorta means inadequacy of the aorta.[2] Enlargement in aorta, arterial hypertension are interrelated to insufficiency of the aorta.[3,4,5,6]

The World Health Organization (WHO) during the 2013 World Health day said heart carries blood to every body parts. In 2014, an estimated one billion or about (22%) populace in the world have hypertension, that is high blood pressure (WHO, 2016). Early detection and management prevent stroke, kidney damage, eye damage and even aneurysms. Cardiovascular diseases especially hypertension results in death. Aortic root dilation and arterial hypertension are two key reasons in rupture of the aorta.[6] Previous studies reported that hypertension had no effect in aortic root diameter.[7,8] Also in another related study, it was revealed that in African hypertensives, males are susceptible to dilation at aortic root compared to females.[9] In 2001, Palmieri, et. al carried out a similar research and reported that hypertensives had higher root diameter. Therefore following contrasting information on the effect of hypertension on aortic root diameter among Caucasians, there is paucity of data with respect to this research amongst Nigerians.

This study was therefore designed to compare the aortic root diameter amongst normotensive and Hypertensive subjects in a Nigerian Population.

MATERIALS AND METHODS
Sixty two (62) volunteers, Nigerians 18 years and above residing in Bayelsa State were engaged in this research

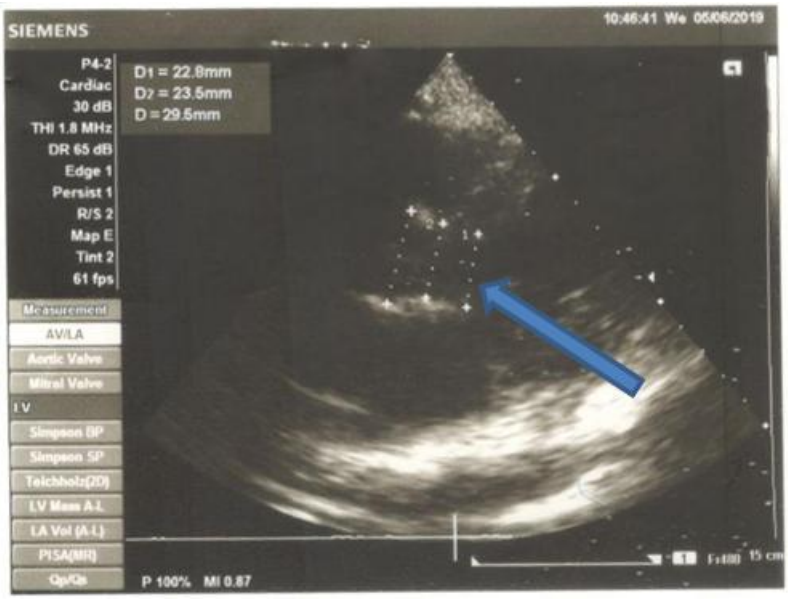
(32 males, 52%; 30 females,48%). Data were collected primarily by taking medical history, checking blood pressure, height, weight, echocardiogram performed on the individual subjects at three different locations: annulus, sinus of valsalva and aortic valve. Exclusion criteria are; diabetes mellitus, pregnancy, stroke, chronic obstructive pulmonary disease such as pulmonary tuberculosis. Blood Pressure was done by using an electronic (SilverCarePlus) Blood pressure measuring device tied round the arm between the cubital fossa and the shoulder joint and readings were recorded in millimetres mercury (mmHg), including the heart rates of the subjects recorded in beats per minute (bpm). Height and weight were done with individual subjects standing bare footed on a RGZ-160 Height and weight measuring scale, readings recorded in meter and kilogramme respectively.

BMI (Body Mass Index) – Derived using the formula weight (kg) divided by the square of the height (m^2), the unit is kg/m^2. A transthoracic echocardiogram using the M-mode and 2-D, done on the individual subjects in line with the 2005 American Society of Echocardiography (ASE) guideline which measures from leading edge to edge during diastole. A transthoracic echocardiogram was done on the individual subjects while lying down on a couch in left lateral position. This procedure involved placing a probe, ultrasonic transducer on the anterior chest wall of the subjects to get various sections in the heart. Dimensions recorded at annulus, aortic valve and sinus of valsalva. Transthoracic echocardiography (TTE) permits adequate assessment of several aortic segments of the heart. Transthoracic echocardiography is non invasive and the most widely accepted method in cardiology.[10]

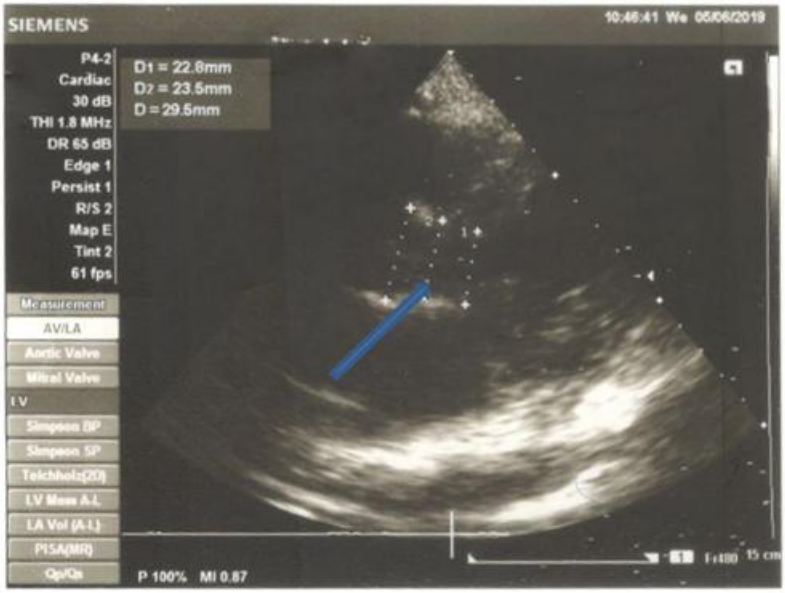
Data were analysed using SPSS version 25.0. ANOVA, t-test and correlation were used to analyse the data, $p<0.05$ at 95% (confidence interval).

Ethical clearance was gotten from the ethical review committee for human experimentation of the School of Graduate Studies, University of Port Harcourt. Furthermore a knowledgeable permission was also obtained from each subject and confidentiality of subject's identity was maintained.

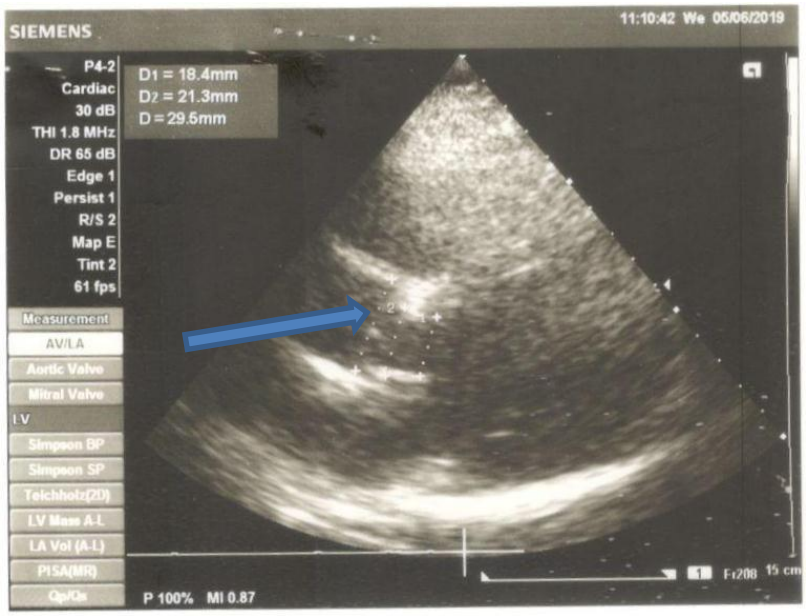
Aortic root dilatation (ARD): This was defined as: Aortic sinus index (ASi) = Aortic diameter/BSA.[11,12]
Body Surface Area (BSA): This was calculated applying the (Dubois and Dubois formula)[25]:
[BSA (m^2) = 0.007184 x height $(cm)^{0.725}$ x weight$(kg)^{0.425}$]



Film 1 shows Echocardiographic dimension of aortic root at aortic valve.



Film 2 shows Echocardiographic dimension at annulus.



Film 3 shows Echocardiographic dimension at valsalva sinus.

RESULTS AND DISCUSSION

Presentation of Data

Data was analyzed by means of statistical package for the social science (SPSS version 25.0) and Microsoft Excel 2019 enterprise edition. Results were presented in Figures 1 – 4 and Tables 1 – 8. Continuous variables were presented as Mean±SD, while categorical variables were presented as pie and bar charts. Sex differences in measured aortic root parameters, differences according to blood pressure (bp) were determined using t-test, while analysis of variance (ANOVA) was used to determine differences in aortic root parameters across different body mass index (BMI) and age categories. Correlation analysis also done to determine if any relationship exists between aortic root parameters and other variables. The confidence interval was set at 95% and $p < 0.05$ was considered significant.

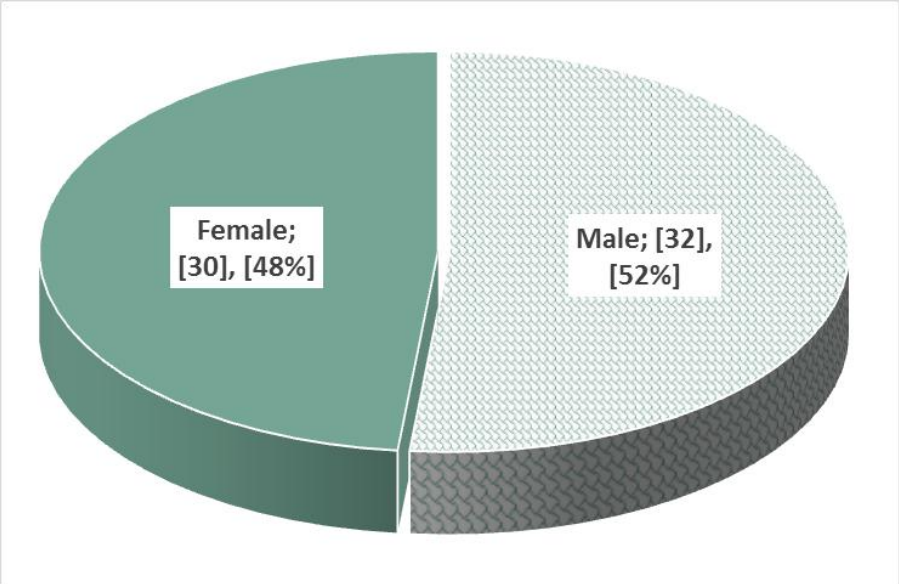


Figure 1: Distribution of the sample population by sex.

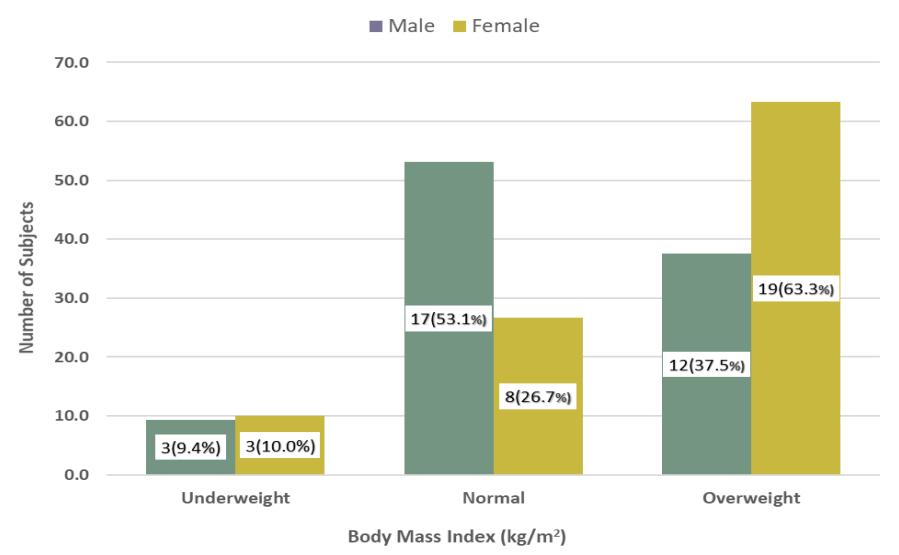


Figure 2: Distribution of the sample population by Body Mass Index.

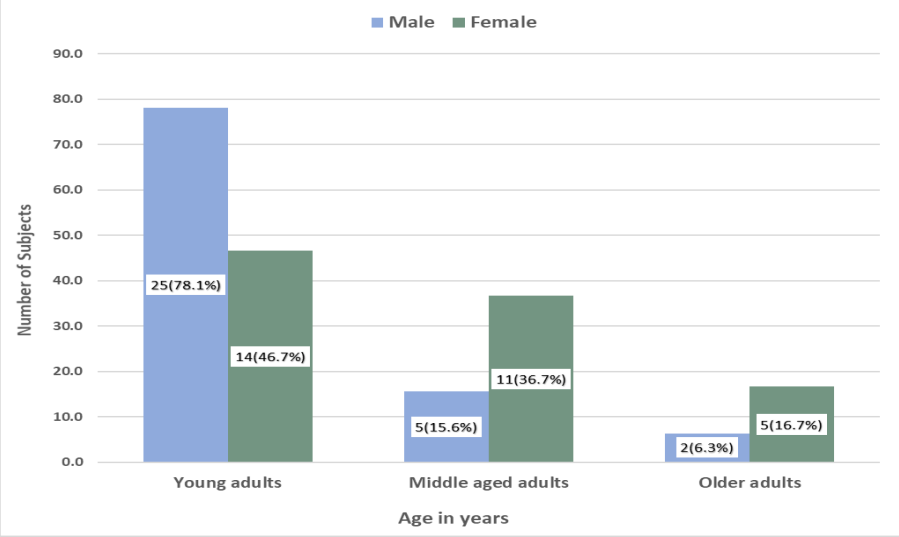


Figure 3: Distribution of the sample population by Age.

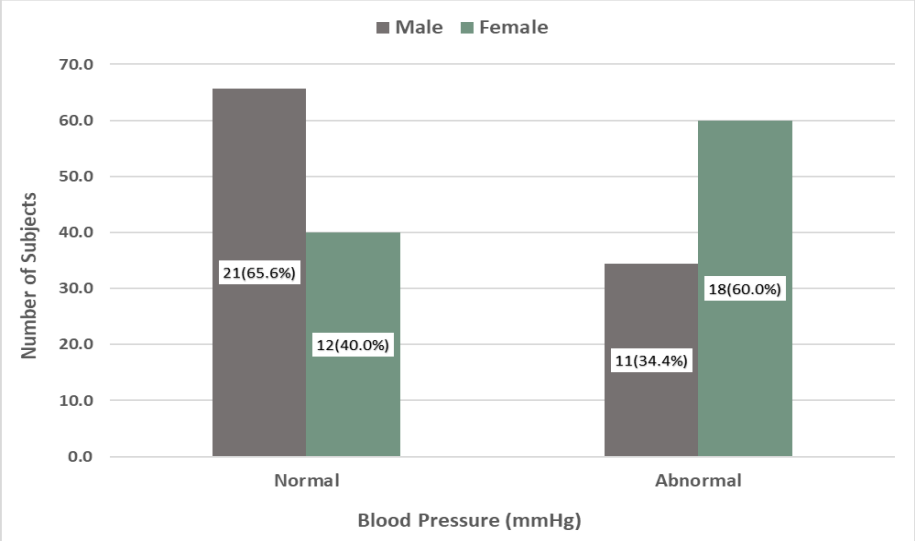


Figure 4: Distribution of the sample population by Blood Pressure.

Table 1: Descriptive characteristics of the subjects (Demographics).

Variables	Male [N = 32]			Female [N = 30]			Total [N = 62]		
	Mean± SD	Min	Max	Mean± SD	Min	Max	Mean± SD	Min	Max
Age (years)	29.13±11.90	18.00	67.00	39.77±15.23	18.00	70.00	34.27±14.53	18.00	70.00
Weight (kg)	69.08±13.04	48.00	110.00	72.50±20.71	45.00	124.00	70.73±17.13	45.00	124.00
Height (m)	1.70±0.08	1.50	1.97	1.59±0.05	1.50	1.70	1.65±0.09	1.50	1.97
BMI (kg/m^2)	24.09±5.34	16.75	39.44	28.64±7.85	16.90	46.29	26.29±7.00	16.75	46.29
Systolic BP (mmHg)	119.72±21.07	73.00	165.00	131.80±25.47	90.00	182.00	125.56±23.90	73.00	182.00
Diastolic BP (mmHg)	81.56±10.81	57.00	100.00	86.90±15.30	48.00	111.00	84.15±13.34	48.00	111.00
Heart rate (bpm)	81.97±24.15	55.00	167.00	85.07±14.94	43.00	121.00	83.47±20.12	43.00	167.00

***BMI** = Body Mass Index, **BP** = Blood Pressure, **Min** = Minimum, **Max** = Maximum, **SD** = Standard Deviation*

Table 2: Descriptive characteristics of Aortic root diameter at the level of aortic valve, annulus and sinus of Valsalva.

Variables	Male [N = 32]			Female [N = 30]			Total [N = 62]		
	Mean± SD	Min	Max	Mean± SD	Min	Max	Mean± SD	Min	Max
Aortic valve (cm)	2.05±0.30	1.60	3.10	1.84±0.23	1.40	2.40	1.95±0.28	1.40	3.10
Annulus (cm)	2.16±0.26	1.80	2.70	2.02±0.55	1.50	4.30	2.09±0.43	1.50	4.30
Sinus of Valsalva (cm)	2.70±0.37	1.90	3.90	2.52±0.40	1.80	3.30	2.61±0.40	1.80	3.90

***Min** = Minimum, **Max** = Maximum, **SD** = Standard Deviation*

Table 3: Subject's characteristics (Demographics) compared using t-test.

Variables	MD	S.E.M	df	t-value	p-value	Inference
Age (years)	-10.64	3.49	54.87	-3.05	**0.00***	**Significant**
Weight (kg)	-3.42	4.43	48.33	-0.77	0.44	Not Significant
Height (m)	0.11	0.02	60.00	6.15	**0.00***	**Significant**
BMI (kg/m^2)	-4.56	1.72	50.68	-2.66	**0.01***	**Significant**
Systolic BP (mmHg)	-12.08	5.92	60.00	-2.04	0.05	Not Significant
Diastolic BP (mmHg)	-5.34	3.35	60.00	-1.59	0.12	Not Significant
Heart rate (bpm)	-3.10	5.14	60.00	-0.60	0.55	Not Significant

***BMI** = Body Mass Index, **MD** = Mean Difference, **S.E.M** = Standard Error of Mean Difference*

Table 4: Sex differences in the measured parameters compared using t-test.

Variables	MD	S.E.M	df	t-value	p-value	Inference
Aortic valve (cm)	0.21	0.07	60.00	3.05	**0.00***	**Significant**
Annulus (cm)	0.14	0.11	60.00	1.29	0.20	Not Significant
Sinus of Valsalva (cm)	0.18	0.10	60.00	1.86	0.07	Not Significant

MD = *Mean Difference*, ***S.E.M*** = *Standard Error of Mean Difference*

Table 5a: Aortic root diameter compared in male normotensive and hypertensive subjects.

Variables	BP (mmHg)	Descriptive Statistics			T-test			
		N	Mean	SD	df	t-value	p-value	Inference
Aortic valve (cm)	Normotensives	21	2.03	0.35	30.00	-0.35	0.73	Not Sig
	Hypertensives	11	2.07	0.18				
Annulus (cm)	Normotensives	21	2.12	0.27	30.00	-0.97	0.34	Not Sig
	Hypertensives	11	2.22	0.24				
Sinus of Valsalva (cm)	Normotensives	21	2.69	0.33	30.00	-0.29	0.77	Not Sig
	Hypertensives	11	2.73	0.46				

BP = *Blood Pressure*, ***SD*** = *Standard Deviation*, ***Sig*** = *Significant*

Table 5b: Aortic root diameter compared in female normotensive and hypertensive subjects.

Variables	BP (mmHg)	Descriptive statistics			T-test			
		N	Mean	SD	df	t-value	p-value	Inference
Aortic valve (cm)	Normotensives	12	1.77	0.17	28.00	-1.46	0.15	Not Sig
	Hypertensives	18	1.89	0.25				
Annulus (cm)	Normotensives	12	1.77	0.21	28.00	-2.16	**0.04***	**Sig**
	Hypertensives	18	2.18	0.64				
Sinus of Valsalva (cm)	Normotensives	12	2.38	0.36	28.00	-1.62	0.12	Not Sig
	Hypertensives	18	2.61	0.41				

BP = *Blood Pressure*, ***SD*** = *Standard Deviation*, ***Sig*** = *Significant*

Table 6a: Aortic root diameter compared in male subjects by Age.

Variables	Age (years)	Descriptive statistics			ANOVA			
		N	Mean	SD	df	F-value	p-value	Inference
Aortic valve (cm)	Young adults	25	2.05	0.32	2.00	0.13	0.88	Not Sig
	Middle aged adults	5	2.08	0.23				
	Older adults	2	1.95	0.35				
Annulus (cm)	Young adults	25	2.15	0.27	2.00	0.31	0.74	Not Sig
	Middle aged adults	5	2.22	0.19				
	Older adults	2	2.05	0.35				
Sinus of Valsalva (cm)	Young adults	25	2.68	0.40	2.00	0.21	0.81	Not Sig
	Middle aged adults	5	2.80	0.32				
	Older adults	2	2.65	0.21				

SD = *Standard Deviation*, ***Sig*** = *Significant*

Table 6b: Aortic root diameter compared in female subjects by Age.

Variables	Age (years)	Descriptive statistics			ANOVA			
		N	Mean	SD	df	F-value	P-value	Inference
Aortic valve (cm)	Young adults	14	1.74	0.20	2	6.10	**0.01***	**Sig**
	Middle aged adults	11	1.85	0.10				
	Older adults	5	2.10	0.32				
Annulus (cm)	Young adults	14	1.98	0.69	2	0.25	0.78	Not Sig
	Middle aged adults	11	1.99	0.46				
	Older adults	5	2.18	0.29				
Sinus of Valsalva (cm)	Young adults	14	2.45	0.34	2	2.09	0.14	Not Sig
	Middle aged adults	11	2.45	0.45				
	Older adults	5	2.84	0.36				

SD = *Standard Deviation*, ***Sig*** = *Significant*

Table 7a: Aortic root diameter compared in male subjects by Body Mass Index.

Variables	BMI (kg/m^2)	N	Mean	SD	ANOVA			
					df	F-value	p-value	Inference
Aortic valve (cm)	Underweight	3	2.20	0.10	2	0.91	0.41	Not Sig
	Normal	17	2.08	0.36				
	Overweight	12	1.97	0.22				
Annulus (cm)	Underweight	3	2.10	0.20	2	0.08	0.93	Not Sig
	Normal	17	2.16	0.28				
	Overweight	12	2.17	0.26				
Sinus of Valsalva (cm)	Underweight	3	2.70	0.00	2	0.00	1.00	Not Sig
	Normal	17	2.69	0.37				
	Overweight	12	2.71	0.43				

SD = *Standard Deviation,* ***Sig*** = *Significant*

Table 7b: Aortic root diameter compared in female subjects by Body Mass Index.

Variables	BMI (kg/m^2)	Descriptive statistics			ANOVA			
		N	Mean	SD	df	F-value	P-value	Inference
Aortic valve (cm)	Underweight	3	1.93	0.25	2	0.27	0.77	Not Sig
	Normal	8	1.83	0.25				
	Overweight	19	1.83	0.22				
Annulus (cm)	Underweight	3	1.73	0.21	2	0.53	0.59	Not Sig
	Normal	8	2.13	0.91				
	Overweight	19	2.02	0.38				
Sinus of Valsalva (cm)	Underweight	3	2.53	0.32	2	1.30	0.29	Not Sig
	Normal	8	2.33	0.30				
	Overweight	19	2.59	0.44				

SD = *Standard Deviation,* ***Sig*** = *Significant*

Table 8: Reference values for the diameter of aortic root parameters in Normotensive and Hypertensive Subjects.

Parameter	Male		Female	
	Normotensive	Hypertensive	Normotensive	Hypertensive
Aortic valve (cm)	1.33-2.73	1.70-2.44	1.42-2.12	1.39-2.39
Annulus (cm)	1.58-2.66	1.73-2.71	1.34-2.20	0.89-3.47
Sinus of Valsalva (cm)	2.03-3.35	1.79-3.67	1.65-3.11	1.78-3.44

4.2 Data Analysis

Data was presented in figures (1 – 4) and table (1 – 8).

Figure 1 shows the sample population by sex (male and female) subjects, 52% (32) and 48% (30) respectively.

Figure 2 shows sample population by BMI, 9.4% (3) males were underweight, 10% (3) females were underweight. Normal males and females were 53.1% (17) and 26.7% (8) respectively. Also overweight (males and females) were 37.5% (12) and 63.3% (19) respectively.

Figure 3 shows sample population by age. This study showed that 78.1% (25) males and 46.7% (14) females were young adults, 15.6% (5) males and 36.7% (11) females were middle aged adults. Also 6.3% (2) males and 16.7% (5) females were older adults.

Figure 4 shows the sample distribution by Blood Pressure. This study showed that 65.6% (21) males and 40% (12) females had normal pressures whereas 34.4% (11) males and 60% (18) females had abnormal blood pressures.

Table 1 shows the descriptive characteristics of the subjects demographics, the mean age (years) for males and females are 29.13±11.90 and 39.77±15.23, (the females have the higher mean value), weight (kg) for males 69.08±13.04 and females 72.50±20.71, (females have a higher mean), height (m) for males 1.70±0.08, females 1.59±0.05, (males have a higher mean), BMI (kg/m^2) 24.09±5.34, for males, females 28.64±7.85 (females have a higher mean), systolic BP (mmHg) for males 119.72±21.07, females 131.80±25.47 (females have a higher mean), diastolic BP (mmHg) for males 81.56±10.81, females 86.90±15.30 (females have a higher mean) heart rate for males 81.97±24.15, females 85.07±14.94 (females have a higher mean value) and waist circumference (cm) for males 83.10±14.72, females 95.77±20.55.

Table 2 shows descriptive characteristics of Aortic root diameter at aortic valve, annulus and sinus of valsalva, (males 2.05±0.30, females 1.84±0.23), (males 2.16±0.26, females 2.02±0.55), (males 2.70±0.37 and females is 2.52±0.40) respectively. It was noticed as shown in table 4.2, that males had a higher values at aortic valve, annulus and sinus of valsalva.

Table 3 shows the subject's characteristics (demographics) compared using t-test. The mean difference for age is -10.64, therefore there is significant difference ($p<0.05$) in the age of the individuals (the females are older). The mean difference for the weight of individuals is -3.42, there is no significant difference ($p>0.05$). The mean difference for height is 0.11, there is significant difference ($p<0.05$). The mean difference for BMI is -4.56, there is significant difference ($p<0.05$). The mean difference for systolic BP is -12.08, no significant difference. The mean difference for diastolic BP is -5.34, no significant difference. The mean difference for heart rate is -3.10, no significant difference ($p>0.05$) and the mean difference for waist circumference is -12.66, there is significant difference ($p<0,05$).

Table 4. It was observed in this study as shown in table 4.4 that males had a wider [aortic root diameter] with a mean value of 0.21 which is significant ($p<0.05$). The mean difference at the annulus is 0.14, no significant difference ($p>0.05$) and at the valsalva sinus is 0.18, no significant difference ($p>0.05$).

Table 5a shows the aortic root diameter compared in male normotensive and hypertensive (subjects). There were no significant differences ($p>0.05$) in the aortic root diameter measured at various levels between male normotensive and hypertensive subjects.

Table 5b shows the aortic root diameter compared in female normotensive and hypertensive subjects. There were no significant differences ($p>0.05$) in the aortic root diameter at various levels between female normotensive and hypertensive subjects. But there is a significant difference ($p<0.05$) in the aortic root diameter at the level of the annulus between female normotensive and hypertensive subjects. The female hypertensive had higher diameter.

Table 6a shows the aortic root diameter compared in male subjects by Age. There were no significant differences ($p>0.05$) as regards age at various points measured.

Table 6b shows the aortic root diameter compared in female subjects by Age. There were no significant differences ($p>0.05$) with respect to age at the annulus and sinus of valsalva, but there was a significant difference ($p<0.05$) at the aortic valve in older adults, they had higher diameters.

Table 7a shows the aortic root diameter compared in male subjects by BMI. There were no significant differences ($p>0.05$) as regards BMI at various levels.

Table 7b shows the aortic root diameter compared in female subjects by Body Mass Index. There were no significant differences ($p>0.05$) with respect to BMI measured at the various levels.

Table 8: show reference values gotten from this research for the diameter of aortic root parameters in Normotensive and Hypertensive Nigerian subjects.

Blood Pressure

In a bid to compare the aortic root diameter amongst normotensive and hypertensive individuals, this study did not find any significant difference at the various levels in male normotensive and hypertensive subjects, but there was an increase in aortic root diameter in female hypertensives compared to female normotensives at the annulus.

This could possibly be that aortic aneurysms are caused by atherosclerosis occuring when cholesterol and fat build up within the arteries, hypertension is a risk factor. Atherosclerosis enhances the breakdown of collagen and elastin, two proteins that provide structural support and elasticity to the aortic wall. Over time, it cause weakness and damage to the aortic wall. Therefore, (high blood pressure) through the aorta makes the wall of the aorta to enlarge and bulge.[13] However no differences was observed at the aortic valve and sinus of valsalva in female normotensives and hypertensives. On the contrary it was reported that aortic root diameter at valsalva sinus did not differ between hypertensive and normotensive individuals when they compared aortic root diameter between persons with hypertension and normotensive subjects.[7] Another similar research on non-hypertensives showed that aortic root diameter was not related to occurrence of hypertension.[8] Also another related study, revealed that in African hypertensives, males are susceptible to dilation at aortic root compared to females.[9] Moreso, similar research reported hypertensives had higher root diameter.[14]

Age differences

In a bid to found out the consequence of age on aortic root diameter, three age groups were set up; young adults (18-35) years, middle aged adults (36-55) years, older adults (>55) years. In this study, there was no significant effect of age on aortic root diameter of males. This is in disagreement to similar work that found out that aortic root is larger in men.[12] Another researchers measured aortic root diameter at the sinuses of Valsalva with transthoracic echocardiography and reported a rise in aortic root diameter with increasing age at an overall average rate of 25 per decade in men ($r = 0.25$, $P < 0.0001$) and 3% per decade in women ($r = 0.30$, $P < 0.0001$).[15] Similar work also found increase in aortic root dimension in older persons.[16] Also it was

postulated that because aortic distensibility decreases with age, the aortic diameter increases.[17] It was also reported that aortic root dimensions increase gradually and smoothly with age in subjects of both sexes.[18] However from this study, older female adults had higher parameters (at the aortic valve). This is not in conformity with Framingham Heart Study, that reported a 2.4-mm decrease in the female dimension.[19]

Other researchers in similar research also showed an age related increase in aortic root size.[20]

Sex differences

This study found out that aortic root diameter was larger in males at the aortic valve, and it is in agreement with similar studies done by other researchers. Therefore there is sexual dimorphism. This is possibly because of the defensive role of estrogen in aneurysm of the abdominal aorta, while male testosterone has been demonstrated to highly promote angiotensin two induced abdominal aortic aneurysm.[21] It was also reported that aortic root diameter was higher in males.[15] Another study reported smaller aortic root in women compared to men.[19] In a related study, it was discovered that females had smaller aortic root parameters when compared to males at sinus of valsalva and at annulus, this is slightly in contrast to the findings of this study, in this study there were no significant differences as regards sex at the annulus and sinus of valsalva.[19,22,23]

BMI (Body Mass Index)

No significant difference (no relationship) in BMI of the male and female subjects used in this study as regards aortic root diameter at the various levels. This is not in line with previous studies done.[24] Related study also showed that BMI is only correlated with aortic annulus and not sinus of valsava.[19]

CONCLUSIONS

This study established the fact that female hypertensives have a bigger aortic root diameter at the annulus, older female adults also have a higher aortic root diameter at the aortic valve.

Also we found out that males had a higher aortic root diameter at the aortic valve.

ACKNOWLEDGEMENTS

The authors sincerely appreciate all those who volunteered subjects for this research and also thank members of staff of Silhouette Radiodiagnostic Consultants, Yenagoa, Bayelsa State, Nigeria for their support in terms of manpower and space for this study.

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