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COMPUTED TOMOGRAPHIC DETERMINATION OF NORMAL REFERENCE VALUES FOR THORACIC AORTIC DIAMETER IN KADUNA STATE NIGERIA: A BASELINE STUDY

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ABSTRACT

Cardiovascular diseases (CVD) nowadays attract public concern as a result of its high level of mortality and morbidity. Aortic-arch dimension has a strong relationship with the dimension of the chest as well as the heart, age, gender and body surface area affect aortic size. Increase in aortic caliber may be a sign of aortic disease such as aortic aneurysm. Computed Tomography (CT) is widely used in the assessment of thoracic-aorta due to its high sensitivity, specificity and availability. The study aimed at establishing normal reference values for the thoracic-aortic diameter in Kaduna State Nigeria and to study the effects of age, gender, and anthropometric-indices on aortic diameter. A prospective study was conducted in the study population between April 2021 to August 2021. A total of 384 consented patients aged between 19-65 years that met the inclusion criteria were recruited using convenience sampling method. Patients with history of cardiovascular diseases that affect aortic size were excluded. The patients underwent chest CT scan and their aortic diameters were measured. Results were analyzed using SPSS version 22. The preset *p*-value was set at 0.05. The mean ascending-aortic-diameter, aortic-arch and descending thoracic-aorta are 36.29±5.40 mm, 31.25 ±4.99 mm, 28.79 ±4.74 mm and 32.84±4.35 mm, 28.26±4.31 mm and 25.61±4.06 mm for males and females respectively. The results of this study shows that aortic diameter of the population is in line with the findings of most of the literature reviewed. Age, weight, BMI and BSA are independent predictive factors for thoracic-aortic diameter.

Keywords: Cardiovascular diseases, Aortic diameter, Aortic aneurysm, Computed tomography

INTRODUCTION

Cardiovascular diseases (CVD) are a public concern due to its resultant high level of mortality as well as morbidity (Usman *et al.,* 2014). According to the World Health Organization (WHO), about 18 million people died of CVD annually which accounts for 31% of total global death (WHO, 2021). Low- and middle-income countries account for about three-quarter of the world's premature deaths due to CVD, and it has been projected that the mortality will overtake that of infectious disease in these countries (WHO, 2017). The premature deaths as a result of cardiovascular diseases are more common in men than women (Danhert, 2007). In Africa, CVD accounts for 38.3% of deaths arising from non-communicable diseases (Minja *et al.,* 2022).

The aorta as a central blood vessel has a clinical significance in the evaluation of cardiovascular diseases. According to McComb *et al*., (2016), aortic arch dimension has a strong relationship with the dimension of the chest as well as the heart, age, gender and body surface area. Aortic diseases contribute to the wide spectrum of arterial diseases that may be diagnosed after a long period of subclinical development (Ismail *et al.,* 2021)

Aortic aneurysm is the abnormal and significant dilatation of a segment of the aorta. It occurs when there is up to 50% permanent increase in diameter. Aortic enlargement of <50% is simply referred to as mild aortic dilatation (Masri and Cavalcante 2017). Thoracic aortic aneurysm has higher frequency of rupture when compared with abdominal aortic aneurysm (Singh, 2015). Hypertension is one of the most common risk factors for cardiovascular diseases. Its diagnosis, prevention and treatment measures are sub-optimal in the sub-Saharan Africa (Cappuccio and Millar, 2016).

Aging also affects the root of aorta by tempering its distensibility which commonly causes aortic regurgitation (Mao *et al.,* 2013). Without life threatening complications such as aortic rupture or aortic syndromes, diseases of the aorta remain asymptomatic and may not be detected on physical examination and hence, depend on medical imaging for diagnosis (Evangelista *et al.,* 2010).

The aorta may be imaged using a variety of imaging methods. This includes, plain radiography, echocardiography, computed tomography, magnetic resonance imaging and invasive catheter angiography (Holloway *et al.,* 2011).

Plain radiography provides limited information about the aortic wall and lumen, although it can identify calcification or unfolding of the aortic arch and a portion of the descending aorta. However, its sensitivity is only 47%, which is extremely poor. The ascending aorta is poorly visible on a PA x-ray of the chest because it is superimposed by the shadow of the superior mediastinum (Ngozi *et al.,* 2015).

Ultrasound is good for the assessment of abdominal aorta due to its availability and does not use ionizing radiation. However, thoracic aorta is encased in a bony structures and air, this makes transthoracic ultrasound difficult (Hacking *et al.,* 2019). Meanwhile, echocardiography is another good imaging modality in terms of aorta and cardiac evaluation. Notwithstanding, its availability and requires high level of expertise are some of its major disadvantages.

Angiography is another good modality for aortic imaging. However, it is highly invasive, and can cause renal failure due to the large volume contrast media used (Singh *et al.,* 2015). Angiography is more commonly used in endovascular intervention (Hacking *et al.,* 2019))

Magnetic resonance imaging (MRI) is rated high as far as aortic imaging is concerned. It is relatively safe and does not require the use of ionizing radiation or large volume of iodinated contrast media. However, it is contraindicated in patient with cardiac pacemaker and those with impaired renal function (Hacking *et al.,* 2019).

Computed tomography (CT) with sensitivity up to 100% and specificity of 98-99% according to Cesare *et al* (2016), is the gold standard for imaging the thoracic aorta due to its volume rendering and reformatting ability. The accuracy, speed, reproducibility, simplicity and 3D capability has made CT to remains the mainstay in the evaluation of aorta (Hager *et al*., 2002). It is also more readily available than MRI and angiography and able to overcome the superimposition problem posed by the shadow of the superior mediastinum.

There is a relationship between increased aortic size and the risk of complications such as aortic dissection or aortic rupture. Hence accurate determination of aortic dimensions is key to effective surveillance or monitoring of progressive aortic enlargement (Davis *et al.,* 2014). Measurements of thoracic aortic diameter and wall thickness using computed tomography at different segments of the aorta was done in Caucasian populations. However, due to the dearth of data in Africa, the values documented by the Caucasians are used as a reference. Having a reference guide for aortic morphology will help in identifying many cardiovascular abnormalities before the onset of clinical symptoms. Thus, this research aimed to establish normal reference values for thoracic aortic diameter in Kaduna State.

MATERIALS AND METHOD

The study was prospective and cross-sectional 44 Nigerian Army Reference Hospital and National Ear care Center Kaduna from April 2021 to August 2021. A total of 384 candidates were recruited into the research using a convenience sampling technique. Individuals with conditions that affect the aortic size such as aortic aneurysm hypertension, congestive cardiac failure, diabetes, cigarette smoking and aortic valvular diseases were excluded in the study. The approval of the Research and Ethics Committee of Kaduna State Ministry of Health was sought and obtained prior to the commencement of data collection. The participants all signed an informed consent form after agreeing to participate in the study. All the records of the participants were kept in strict confidence. The participants were interviewed face to face by trained professional were their demographic information such as; age, gender was obtained. Their height was measured in meters (m) using a stadiometer; weight was measured in kilogram (kg) using a bathroom weighing scale. They all removed their caps, shoes and emptied their pockets before the weight was measured. Body mass index (BMI) was calculated in (kg/m2).

Blood pressure of the patients was taken before data collection. Information with regard to history of cardiovascular diseases, smoking or diabetes mellitus was collected from the patient through patients' folder and questionnaire. Data collections were performed between 8am and 4pm. The subject lie supine on the CT couch, and the median sagittal plane coincides with the center of the table. The scout images (AP and lateral) were obtained. A slice thickness of 5mm was used. Exposure factors of 140kVp, 150mA and 200ms was used for the exposure. Intravenous low-osmolar contrast media was administered based on the clinical indication of the patient. Images were acquired in craniocaudal direction with the starting location just above the lung apices, and the ending location just below the costophrenic angles in a single breath-hold. Reformatted images were obtained and analyzed.

Aortic diameter was measured as the average distance between the aortic lumens. The aortic diameters were obtained from three locations, ascending aorta, aortic arch and descending aorta. While for the distance between the adventitia and luminal boundary (tunica intima) were measured. Both measurements were obtained using an electronic caliper incorporated in the CT equipment.

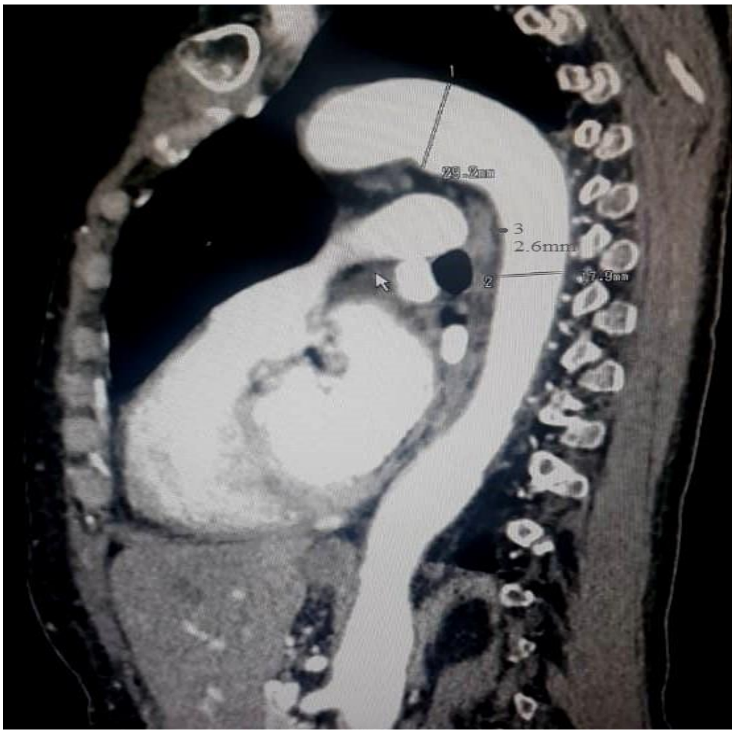

Figure 1: Segment of thoracic aorta on Computed Tomography

Statistical Analysis

All statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) Version 22.0 software. Data were analyzed using both inferential and descriptive statistics. Kolmogorov-Smirnov test was used to check the normality of the data. Mean±SD for thoracic aortic diameter was determined using descriptive statistics. Man-Witney test was used to compare the thoracic aortic diameter between males and females. Pearson's correlation was used to correlate the thoracic aortic diameter with anthropometrical indices, P-value was set at <0.05. Regression analysis was performed between age, BMI and aortic dimensions.

RESULTS AND DISCUSSION

A total of three hundred and eighty-four (384) subjects participated in the study, one hundred and eighty-eight (188) were males which represent 48.95 % and one hundred and ninety-six females (196) which represents 51.04 %. The participant's age ranges from nineteen (19) to sixty-five 65 years.

Table 1: Demographic Details of the Subjects

AGE(years)	**Males** (n=188)	**Females** (n=196)	**Total** (n=384)
18-20	5 (2.7%)	0(0%)	5(1.3%)
21-30	13(6.9%)	42(21.4%)	55(14.3)
31-40	48(25.5%)	79(40.3%)	127(33.1%)
41-50	13(6.9)	17(8.7%)	24(6.25%)
51-60	23(12.2%)	21(10.7%)	38(9.9%)
61-65	86(45.7%)	37(18.9%)	135(35.2%)
Total	188(48.95%)	196(51.04%)	384(100%)

Table 2: The Anthropometric variables of the participants

Gender	**Male (n=188)**	**Female(n=196)**	**Total(n=384)**
Anthropometric Variable	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
Age(years)	50.26± 15.26 (19.00-65.00)	42.42 ±14.17 (21.00-65.00)	46.26 ±15.21 (19.00-65.00)
Height(m)	1.64± 0.50 (1.49-1.74)	1.63 ±0.52 (1.51-1.71)	1.64 ±0.05 (1.49-1.76)
Weight(Kg)	66.11± 8.21 (51.00-95.00)	63.02 ± 8.51 (49.00-89.00)	66.68 ± 10.09 (49.00-95.00)
BMI(Kg/m^2)	24.52± 2.54 (18.70-34.89)	23.88 ±3.28 (18.60-34.48)	24.85 ±3.46 (18.6-34.89)
BSA(m^2)	1.77± 0.13 (1.49-2.05)	1.67 ±0.11 (1.45-1.99)	1.72 ±0.13 (1.45-2.05)

Table 3: Aortic diameters, for different age groups in males

AGE**(years)**	**AAD(mm)**	**AArD(mm)**	**DAD(mm)**
21-30	28.44±2.88 (22.0-33.5)	23.9±2.59 (18.6-28.3)	21.8±2.37 (17.3-26.7)
31-40	33.4±2.35 (26.5-37.5)	28.52±2.63 (23.1-32.0)	25.86±2.76 (20.0-30.0)
41-50	32.1-3.6 (26.3-36.5)	27.3±3.22 (22.1-31.4)	24.8±3.2 (18.8-28.4)
51-60	33.97±4.9 (23.9-42.5)	29.8±4.57 (19.5-37.6)	26.95±4.97 (17.2-35.0)

Table 4: Aortic diameters for different age groups in females

AGE (years)	**AAD(mm)**	**AArD(mm)**	**DAD(mm)**
18-20	27.2±0.23 (26.9-27.4)	22.17±0.4 (22.1-22.2)	20.1±0.0 (20.1-20.1)
21-30	26.30±1.91 (24.5-30.6)	22.24±1.85 (19.6-25.9)	20.72±2.2 (17.00-24.6)
31-40	33.83±2.34 (27.3-39.3)	29.58±2.1 (22.6-34.1)	27.58±2 (21.8-30.1)
41-50	34.52±3.7 (28.9-39.3)	29.15±2.3 (25.2-32.1)	27.29±2.98 (22.3-30.1)
51-60	35.48±5.9 (26.4-43.5)	30.32±4.89 (22.0-37.8)	27.64±4.8 (20.3-35.6)
61-65	40.12±3.5 (26.5-45.2)	34.63±3.68 (25.0-40.3)	31.93±3.56 (22.3-38.7)

Table 5: Mean±SD of Aortic Diameter

Gender	Male (n=188)	Female(n=196)	Total(n=384)
Aortic Dimensions	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
Ascending Aortic Diameter	36.29±5.40 (24.50-45.20)	32.84±4.35 (22.0-4.31)	34.53±5.23 (22.00-45.20)
Aortic Arch Diameter	31.25 ±4.99 (19.60-40.30)	28.26 ±4.31 (18.6-37.60)	29.73 ±4.89 (18.60-40.30)
Descending Aortic Diameter	28.79 ±4.74 (17.00-38.70)	25.61 ±4.06 (17.2-35.40)	27.17 ±4.67 (17.00-38.70)

Table 6: The corresponding *p*-values of aortic diameter for males and females

Gender	**Male** (384)	**Female**(196)	***p*-value**
Aortic dimensions(mm)	Mean ± SD	Mean ± SD	
Ascending Aortic Diameter	36.29±5.40	32.84±4.35	0.00
Aortic Arch Diameter	31.25 ±4.99	28.26 ±4.31	0.00
Descending Aortic Diameter	28.79 ±4.74	25.61 ±4.06	0.00

Table 7: Correlation between aortic dimensions and anthropometric variables for males

Anthropometric Variables	Age		Height		Weight		BMI		BSA	
Aortic Dimensions	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Ascending Aortic Diameter	0.78	0.00	0.28	0.00	0.83	0.00	0.79	0.00	0.80	0.00
Aortic Arch Diameter	0.73	0.00	0.24	0.01	0.76	0.00	0.74	0.00	0.74	0.00
Descending Aortic Diameter	0.73	0.00	0.19	0.09	0.73	0.00	0.72	0.00	0.69	0.00

Table 8: Correlation between aortic dimensions and anthropometric variables for females

Anthropometric Variables	Age		Height		Weight		BMI		BSA	
Aortic Dimensions	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Ascending Aortic Diameter	0.51	0.00	0.12	0.11	0.71	0.00	0.65	0.00	0.64	0.00
Aortic Arch Diameter	0.51	0.00	0.13	0.66	0.69	0.00	0.62	0.00	0.64	0.00
Descending Aortic Diameter	0.46	0.00	0.17	0.21	0.67	0.00	0.58	0.00	0.63	0.00

Table 9: Correlation between aortic dimensions and anthropometric indices for both males and females

Anthropometric Variables	Age		Height		Weight		BMI		BSA	
Aortic Dimensions	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Ascending Aortic Diameter	0.64	0.00	0.28	0.00	0.82	0.00	0.78	0.00	0.78	0.00
Aortic Arch Diameter	0.64	0.00	0.26	0.00	0.77	0.00	0.73	0.00	0.74	0.00
Descending Aortic Diameter	0.61	0.00	0.25	0.03	0.75	0.00	0.72	0.00	0.72	0.00

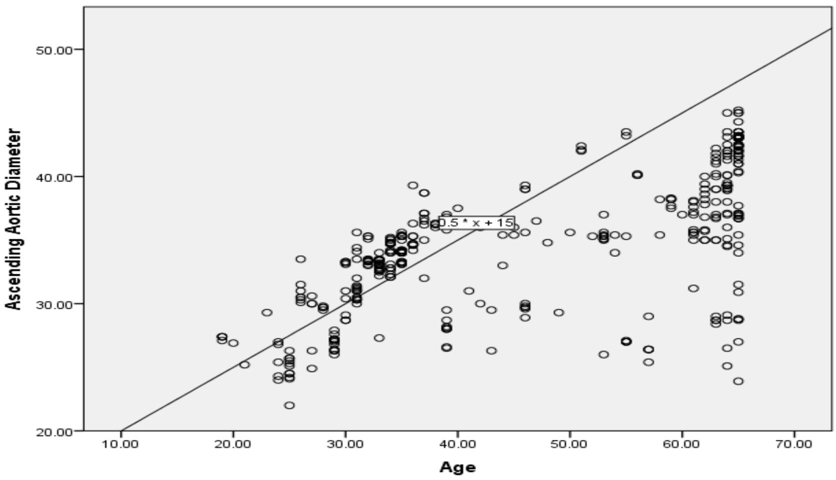

Figure 2: A regression charts between an independent variable (age in years) and dependent variable (ascending aortic diameter in mm).

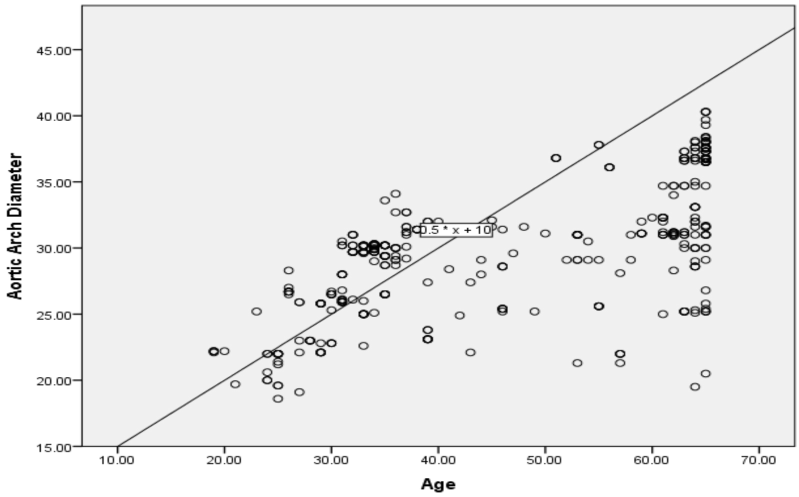

Figure 3: A regression charts between an independent variable (age) and dependent variable (aortic arch diameter).

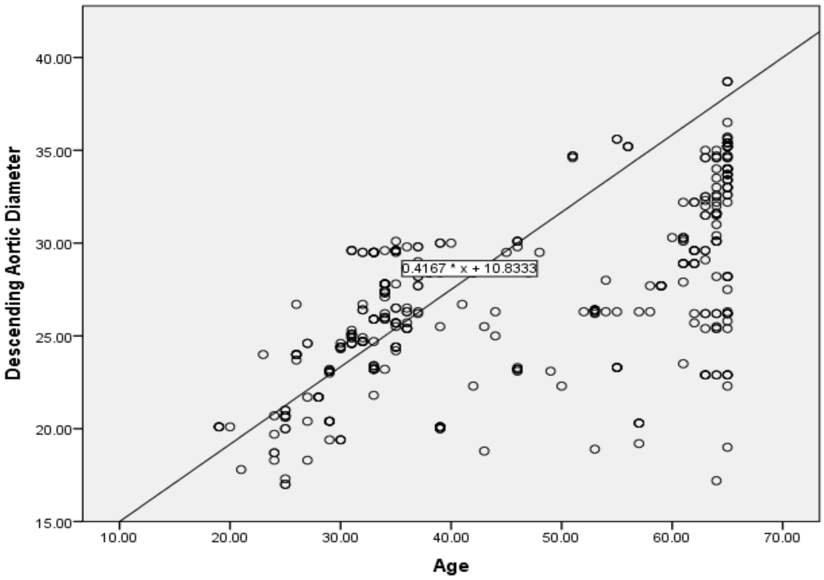

Figure 4: A regression charts between an independent variable (age) and dependent variable (descending aortic diameter).

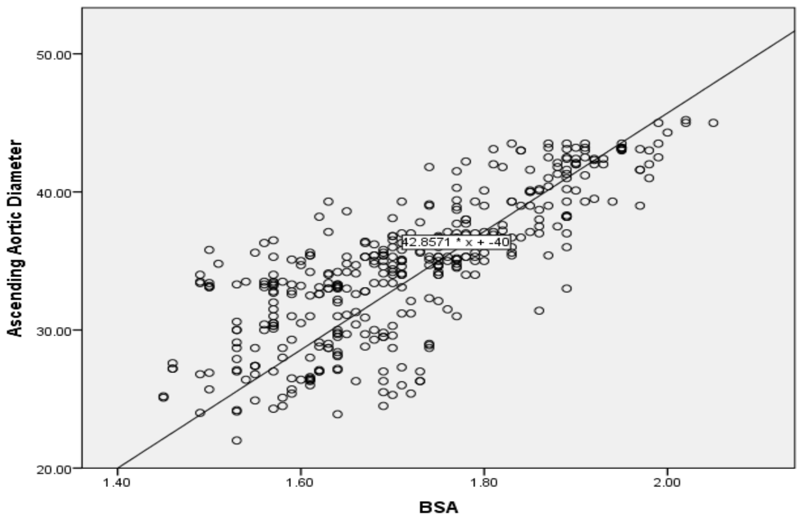

Figure 5: A regression charts between an independent variable (BSA) and dependent variable (ascending aortic diameter). The regression equation was found to be y=42.9x+(-40)

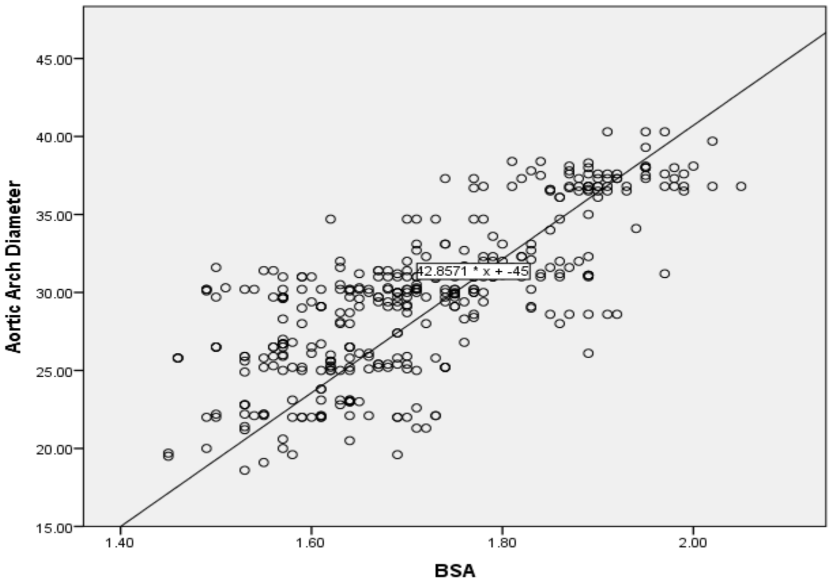

Figure 6: A regression charts between an independent variable (BSA) and dependent variable (aortic arch diameter).

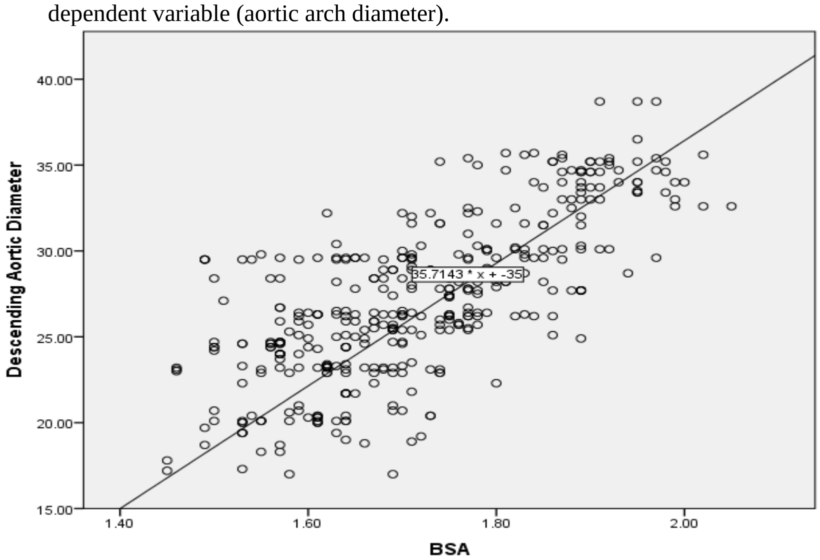

Figure 7: A regression charts between an independent variable (BSA) and dependent variable (descending aortic diameter).

Discussion

Three hundred and eighty-four (384) subjects participated in the study; this comprise of one hundred and eighty-eight (188) males and one hundred and ninety-six females (196). The ages of the participants ranged from 19 years to 65 years for both male and female subjects. The mean of age of the participants are; 46.26 ±15.21 (years);50.26± 15.26 (years) for males and 42.42±14.17 (years) for female subjects as shown in table 1. This is similar to the findings of the studies conducted by Hager *et al.*, (2002) that reported the mean age±SD of 50.5±15.2 (years) for males and 49.6±19.1 (years) for females. It also agrees with the findings of Lee *et al.,* (2013) who reported 50.8±16.9 (years) and 50.9±16.6(years) as mean ±SD age of males and females respectively. However, values of mean age reported by Davis *et al.,* (2014), disagrees with that of the current study. He reported the mean age of 36±13 (years) for males and 38±12 (years) for female participants.

Table 2 shows the mean height of the participants was 1.64±0.01m; 1.64±0.50m and 1.63±0.52m. Higher values of height were reported by Hager *et al.,* (2002) in which the mean ± SD height was found to be 1.75±7.3m and 1.65±6.6m for males and females respectively. Also, Lee *et al.,* (2013) reported higher mean ± SD values for of the height of 168.1±6.0. The average weight of the participants was 66.68±10.09kg; 66.11±8.21kg and 63.02±8.51kg for males and female participants respectively. Lower mean weight of 57.39±8.15kg was recorded by Koju *et al.,* (2018) in a Nepalese Population. Participants' body mass index (BMI) and body surface area (BSA) were 24.52±2.54kg/m^2 and 1.72±0.1m$^{2;}$ mean BMI values for males are 24.11±8..21kg/m^2 and 23.88±3.28kg/m^2 for females, while the BSA was 1.77±0.1m^{2}and 1.67±0.1 m^2 for males and females respectively.

Table 5 shows the mean value of aortic diameter as; 34.53±5.23mm, 29.73±4.89mm for aortic arch, 27.17±4.67mm for descending thoracic aortic diameter. The mean ascending aortic diameter, aortic arch and descending thoracic aorta for males is 36.29±5.40mm, 31.25 ±4.99mm and 28.79 ±4.74mm respectively. While for females is 32.84±4.35mm, 28.26±4.31mm and 25.61±4.06mm for ascending aortic diameter, aortic arch and descending thoracic aortic diameter respectively. These values for the thoracic aortic diameter are in agreement with researches conducted by McComb *et al*., (2016) where he reported that the mean ascending aortic diameter in men was 37mm while it measures 34.5mm in women. The descending thoracic aortic diameter measure 28.2mm and 25.4mm in men and women respectively. The agreement between these findings and that of the current study may be due to the similar study design used. Furthermore, Lee *et al.*, (2013) study showed that age and gender were major determinants of ascending aortic diameters in asymptomatic Korean adults. They found that men had slightly larger aortic diameters than women ($P<0.05$). Lower values for ascending aortic arch and the descending thoracic aorta were reported by Koju *et al.,* (2018) in research conducted in a Nepalese population. He reported the mean values of the ascending aorta as 28.8±0.38mm for ascending aorta, 26.2mm for proximal aortic arch, 24.7±0.28mm for distal transverse arch and 22.0mm±0.31mm for descending aorta. The disagreement may be attributed to the lower mean age 46.05±15.12 years, weight 57.39±8.15kg and BMI 24.8±4.19kg/m^2 of the participants. Also, the current research is in disagreement with aortic dimension values reported by Lee *et al.,* (2013) of a Japanese population. He reported the ascending aorta as 28.8±mm for ascending aorta, 25.4 mm for aortic arch and 23.6mm for descending aorta. This disparity between these studies and the current study might be because of lower mean weight (60.9±11.4kg), age (50.6±16.7 years) and higher mean height (1.68m) of the participants.

This study shows that, the mean±standard deviation of the aortic diameters is not close to the upper limit of normal as reported by most literatures. This implies that; the study subjects are at lower risk of being affected with pathological conditions associated with increased aortic wall diameter.

Additionally, a statistically significant difference (p=0.00) in the ascending aortic diameter, aortic arch diameter, and descending aortic diameter between males and females was detected in this study. This implies that reference values for males could not apply to females in clinical practice. Research by Wolak *et al.,* (2008), Mao *et al.,* (2013), McComb *et al.,* (2016), and Ismail *et al.,* (2021) is consistent with this. The influence of sex steroid hormone on blood arteries may be related to the gender variation in aortic dimension. Men in this region of the world tend to be more physically active than women, which could be another factor contributing to the disparity.

The link between age and aorta diameter is depicted in Figures 2, 3, and 4. The results of this study indicate that aortic diameter and age have a significant positive association. This holds true for both genders. The maximum values of thoracic aortic diameter are found in older age groups, and it increases with age. These results are consistent with those published by Rogers *et al.,* (2013), Lee *et al.,* (2013), McComb *et al.,* (2013), Mao *et al.,* (2013), Cesare *et al.,* (2016), and Ismail *et al.,* (2021).

Furthermore, findings from this study show that there is a weak positive correlation between height and thoracic aortic diameter. This is true for all genders. However, weaker positive correlation was observed in female participants as shown in table 8. This is contrary to the findings of the research conducted by Lee *et al*.,(2013) where larger aortic diameter are associated with increase in height.

Table 9 shows a strong positive correlation between aortic diameter with weight. These findings correspond with the researches conducted by; McComb *et al*., (2013), Lee *et al.,* (2013) Mao *et al*.,(2013), Wolak *et al.,* (2008), Cesare *et al*., (2016) and Rogers *et al.,* (2013). On other hand, (Koju and Joshi 2018) found a weak positive correlation (r=0.29, *p*=0.78) and a weak negative correlation (r=-0.54, *p*=0.59) between the height, ascending aortic diameter and descending aortic diameter respectively.

According to Rodrigues *et al.,* (2012), one of the factors that predicts cardiovascular death is obesity. It might be the root cause of pathologic or physiological alterations in the cardiovascular system. The results of the current investigation showed a significant positive connection between BMI and thoracic aortic diameter. This is consistent with study results published by Wolak *et al*., (2008), Rodrigues *et al.,* (2012), Lee *et al.,* (2013), Mao *et al*.,(2013), Cesare *et al*., (2016) and Rogers *et al.,* (2013). On the other hand, Hager et al.'s (2002) study found that age and gender had an impact but that weight, height, or body surface area had no effect. Moreover, (Koju and Joshi 2018) contradicts this finding in a cohort of Nepalese people, demonstrating that there is no statistically significant correlation (r=-0.12, p=0.25) between BMI and thoracic aortic diameter. A smaller sample size (less than 100) and the potential impact of ethnic differences may be the root cause of the dispute.

Aortic size is a function of body size as observed by Pearce *et al*., (1993). From the study, BSA also shows a strong positive correlation with thoracic aortic diameter. This is in line with the findings of McComb *et al.,* (2016), where aortic diameter at all level increases with increase in BSA.

CONCLUSION

The purpose of this study was to determine the normal values of computed tomography for thoracic aortic diameter in the state of Kaduna. The technique is non-invasive and yields crucial data about the dimensions of the vessel. The population's aortic diameter, according to the study's findings, is consistent with what the majority of the examined literature found. Weight, BMI, and BSA are independent predictors of thoracic aortic diameter, according to the results. This quantification technique will support the distinction between pathological and normal values, tracking therapeutic response, and facilitating subject comparisons.

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