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Original Research Article

Assessment of the Cardiothoracic Ratio and Its Association with Gender and Age: A Nigerian Study

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ABSTRACT

Cardiothoracic ratio (CTR) evaluation is a useful screening method used to detect cardiomegaly. It varies in different populations due to genetic, geographical and environmental factors that influence body morphology. This study aimed at assessing the CTR and determining its association with gender and age among adult Nigerians.
This retrospective cross-sectional study was conducted in the Radiology Department of a Teaching Hospital in Delta State after obtaining ethical clearance. Postero-anterior chest radiographs of 200 adults (108 males and 92 females) were used to measure the transverse cardiac diameter (TCD) and transverse thoracic diameter (TTD) in centimeters (cm). These were used to compute the CTR (TCD/TTD*100). Statistical Package for Social Sciences version 22.0 was used to analyze the data. Independent t-test and analysis of variance (ANOVA) were used to determine the differences in the measurements with regards to gender and age-groups respectively. The correlation that exists between the variables and their association with age were assessed using Pearson's correlation. P value was set at < 0.05.
The TTD and TCD were significantly larger in males than in females (p=0.001 each) while the CTR were significantly larger in females than in males (p=0.016). The TTD and CTR showed significant differences in the various age groups (p=0.002, 0.031) (p=0.195). The two diameters showed a significant positive correlation with age (0<r<0.5).
The study provides the normal mean CTR values for the studied population based on age and gender which will help clinicians in the screening for heart conditions. This will enhance early diagnosis and intervention.

Key words: cardiomegaly, thoracic diameter, cardiac diameter, chest radiographs, diagnosis, cardiothoracic ratio

INTRODUCTION

The muscular organ known as the heart is situated in the thoracic cavity's middle mediastinum. It is in charge of pumping oxygenated blood to the rest of the body and deoxygenated blood to the lungs [1]. Measuring the size of the heart is a recognized objective technique used in population studies and clinical evaluation [2]. The cardiac size is beneficial to anatomists in the assessment of sex differences and important to clinicians in the detection of cardiac anomalies such as cardiomegaly [3]. Cardiomegaly is an abnormal enlargement of the heart which may be caused by either congenital malformations or acquired diseases [4]. This enlargement may inform the presence of hypertensive, rheumatic, coronary, inflammatory and ischemic heart diseases. It may also predispose to stroke [2]. One of the main causes of death in Nigeria and other West African nations is cardiac disease [5]. Prompt diagnosis and treatment of heart disorders may be aided by early detection of cardiomegaly [7]. The most frequent method of detecting cardiomegaly is chest radiography [10]. It is helpful in determining the size of the heart and how it has changed over time [13]. Moreover, chest radiography is widely utilized since it is easy to perform, readily available and inexpensive [14]. Chest radiography is inferior to other imaging techniques for measuring the size of the heart, such as cardiac echocardiography, MRI, and computed tomography (CT) scan. These modalities can also be used to assess cardiac function [15]. However, they are limited by higher cost, poor availability and require higher technical skills [14]. Furthermore, echocardiogram is operator-dependent while CT is limited by higher radiation dose compared to radiographs hence, it may not be preferred for screening [13].

Cardiothoracic ratio (CTR) is the ratio of maximal transverse cardiac diameter to maximal transverse thoracic diameter, which can easily be measured on postero-anterior (PA) chest radiographs [4, 13]. The evaluation of CTR is a recognized method for quantifying the cardiac size and inform on the prognosis of cardiac diseases [4, 16]. It is therefore a useful screening method that can be used to detect cardiomegaly. The normal range of CTR is between 0.42 and 0.50. Values that are more than 0.5 or less than 0.42 indicate pathologic situations like cardiomegaly [5].

Cardiothoracic ratio is affected by different factors such as age, gender, race, body posture and physique [11]. Previous research has found racial differences in the cardiothoracic ratio of different populations, with Caucasians having an upper limit of normal at 50% and people of African descent having an upper limit of normal at 55% [5, 13, 18]. Gender and age-group differences in CTR have been reported in previous studies [2, 13, 18]. Higher normal CTR of up to 0.60 has been documented in neonates and the elderly [13]. A weak positive correlation between CTR and certain anthropometric measures including Body Surface Area (BSA) and Body Mass Index has also been shown in several studies (BMI) [8, 12].

A normal heart may have a CTR of greater than 0.50. This has been associated with extracardiac causes of the apparent cardiac enlargement caused by the inability to take a deep breath during imaging. This occurs in pregnancy, ascites or abnormalities of the chest that compress the heart such as pectus excavatum and straight back syndrome [19]. Similarly, a CTR of less than 0.50 may not always point to a healthy heart. For instance, when the flow of blood from the ventricles is restricted, the ventricles' initial response is to undergo wall hypertrophy, which may not result in cardiomegaly [19].

The knowledge of normal CTR range is important in screening for heart diseases in a given population. Inaccurate CTR can delay the identification and treatment of underlying heart conditions as well as prevent early detection of cardiomegaly [17]. Furthermore, it's critical to use population-specific CTR ranges to avoid making the erroneous diagnosis of cardiomegaly, which could expose the subjects to further pointless, expensive tests and unwarranted drugs [19]. Studies on the normal cardiothoracic ratio and its association with age and gender among adults of Delta State, Nigeria are scarce. This study therefore aimed at assessing the CTR and determining its association with gender and age.

MATERIALS AND METHODS

This retrospective cross-sectional study was conducted in the Radiology Department of a Teaching Hospital in Delta State, Nigeria after obtaining the institution’s ethical clearance (HREC/PAN/2021/025/0334). Postero-anterior chest radiographs of patients who were referred to the department for imaging between 1st of January, 2016 and 31st of December, 2020 were extracted from the Picture Archiving and Communications Systems (PACS). These patients had suspicious traumatic lesions and non-traumatic pathologies such as pneumonia, heart disease and space occupying lesions. Some chest radiographs belonged to subjects who were referred for chest screening as a requirement for employment or school admission. The selection criteria for the radiographs used in this study included apparently normal postero-anterior (PA) chest radiographs of both male and female patients aged 18 years and above. However, the study excluded radiographs with incomplete skeletal maturity and gross pathological findings such as pulmonary consolidation, pleural effusion, widened mediastinum, rib fractures, and abnormal thoracic curvature. Furthermore, poor quality radiographs with artefacts, inadequate exposure, rotation of patient as well as chest radiographic views other than the PA view were also excluded.

Chest radiographs of 200 adults (108 males and 92 females) were used to assess the CTR. A digital caliper was used to measure the transverse thoracic diameter (TTD) and transverse cardiac diameter (TCD) in centimeters (cm). The TTD was defined as the maximum horizontal distance inside the rib at the widest point above the costophrenic angle (Figure 1A) [7]. The TCD was measured as the largest horizontal diameter of the heart by obtaining the maximum transverse distance between the most lateral right and left borders of the heart (Figure 1B) [22]. The CTR was calculated by dividing the TCD by the TTD and multiplying by 100 [7].

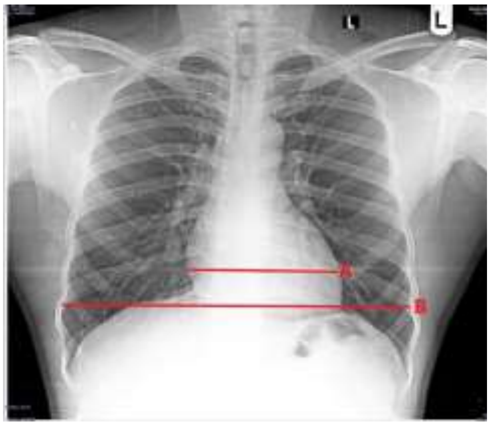

Figure 1. Posteroanterior chest radiograph showing the measurement of the transverse cardiac diameter (A) and transverse thoracic diameter (B).

Fifty radiographs were randomly selected and used to assess the reproducibility of the measurements. Two investigators independently measured the parameters on 25 images at different times to evaluate for inter-observer agreement. The intra-observer concordance test was assessed by a single observer who used the same methodology to measure the variables in 25 images. The same observer repeated the measurements after two months. Following the findings of the concordance tests, a single investigator thus measured all the variables in all the chest radiographs [22].

STATISTICAL ANALYSIS

Data were entered in Statistical Package for Social Sciences version 22.0 (SPSS Inc. Chicago, IL, USA) and classified according to gender, and 10 years' age-groups namely; <20, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and ≥80years. The results were summarized in means and standard deviations. Independent t-test and analysis of variance (ANOVA) were used to determine the differences in the metric variables between the gender and age groups correspondingly. The Pearson's correlation test was used to evaluate the linear correlation between variable and its relationship to age. The inter- and intra-observer variability were evaluated using the intra-class correlation coefficient (ICC). Statistically significant differences were considered when p value level was less than 0.05.

RESULTS

The gender distribution of the 200 chest radiographs analyzed comprised 108 males (54%), and 92 females (46%). These patients' age ranged from 18 to 95 years and had an average of 41.67± 15.35 years; 43.63 ± 16.20 years in males and 39.37 ± 14.03 years in females. The distribution of the radiographs based on age-groups is shown in Table 1, with majority belonging to the age-group of 20-29 years (51, 25.5%). From the inter-observer concordance test, the ICC for the TCD and TTD did not show any statistically significant differences (TCD r=0.579, p=0.146; TTD r=0.517, p=0.387). Similarly, the intra-observer variability was not statistically significant (TCD r=0.543, p=0.344; TTD r=0.560, p=0.408).

Table 1. Age Distribution of Patients

Age group (years)	Frequency	Percentage (%)
<20	4	2.0
20-29	51	25.5
30-39	47	23.5
40-49 50-59	33 39	16.4 19.5
50-59	39	19.5
60-69	18	9.0
70-79	4	2.0
≥80	4	2.0

The mean values of TTD, TCD and CTR were 27.63±2.17 cm, 12.97±1.24 cm and 46.22±3.55% respectively. The TTD and TCD were significantly larger in males than in females (p=0.001 each) while the CTR were significantly larger in females than in males (p=0.016) (Table 2).

Table 2. Gender Comparison of Parameters

	Gender	Mean	P Value
TTD (cm)	M	28.76±1.98	0.001*
	F	26.31±1.56	
TCD (cm)	M	13.37±1.26	0.001*
	F	12.49±1.03	
CTR (%)	M	45.67±3.60	0.016*
	F	46.87±3.38	

TTD-transverse thoracic diameter, TCD- transverse cardiac diameter, CTR- cardiothoracic ratio
*significant p value

The TTD and CTR showed significant differences in the various age groups (p=0.002, 0.031) (p=0.195) while TCD did not (Tables 3-5).

Table 3. Transverse thoracic diameter in different age groups

Age-groups (Years)	Mean (cm)	P Value
<20	28.01±2.68	0.002*
20-29	27.52±1.97	
30-39	27.93±2.27	
40-49	27.30±1.96	
50-59	27.71±2.56	
60-69	27.11±2.12	
70-79	28.35±1.00	
≥80	28.86±1.93	

***significant p value**

Table 4. Transverse cardiac diameter in different age groups

Age (Years)	Mean (cm)	P Value
<20	12.74±1.69	0.195
20-29	13.01±1.34	
30-39	12.93±1.12	
40-49	12.81±1.15	
50-59	12.95±1.30	
60-69	13.01±1.30	
70-79	13.61±0.46	
≥80	13.69±1.06	

Table 5. Cardiothoracic ratio in different age groups

Age (Years)	Mean (%)	P Value
<20	46.50±3.70	0.031*
20-29	46.82±2.78	
30-39	45.81±3.44	
40-49	46.12±3.77	
50-59	46.08±3.70	
60-69	47.06±3.19	
70-79	46.50±1.29	
≥80	41.25±8.92	

***significant p value**

The two diameters as well as the CTR showed a weak positive correlation with age (0<r<0.5) (Table 6). However, this association was statistically significant for only TTD and TCD (p=0.015, 0.006). The TTD and TCD showed a significant strong positive correlation with each other (r=0.598, p=0.001). The CTR showed significant weak positive (r=0.462, p=0.001) and weak negative (r=-0.234, p=0.001) association with TCD and TTD respectively (Table 6).

Table 6. Correlation between the measured parameters and age

		Age	TTD	TCD	CTR
Age	Pearson Correlation	1	.172*	.195*	.084
	Sig. (2-tailed)		.015	.006	.236
	N	200	200	200	200
TTD	Pearson Correlation	.172*	1	.598*	-.234*
	Sig. (2-tailed)	.015		.000	.001
	N	200	200	200	200
TCD	Pearson Correlation	.195**	.598*	1	.462*
	Sig. (2-tailed)	.006	.000		.000
	N	200	200	200	200
CTR	Pearson Correlation	.084	-.234*	.462*	1
	Sig. (2-tailed)	.236	.001	.000	
	N	200	200	200	200

***significant p value**

Table 7 shows the comparison of mean TCD, TTD and CTR documented in previous radiographic studies from different populations.

Table 7. Radiographic measurements and indices in different populations

Author	Country	N	TTD	TCD	CTR (%)
Gamerradin *et al.* [11]	Sudan	109	26.28±2.92cm	12.04±1.44cm	0.46±0.04
Ekedigwe *et al.* [8]	Nigeria (Jos)	100	26.97±2.13cm	12.39±1.33cm	0.46±0.04
Mensah *et al.* [13]	Ghana	1989	276.0±58.1mm	126.1±14.1mm	0.46±0.04
Longbak *et al.* [2]	Nigeria	80	26.54±2.04cm	12.23±1.06cm	0.46±0.04
Debnath *et al.* [20]	India	558	2935±224 mm	1153±20.01mm	0.39±0.03
Ali *et al.* [7]	Nigeria (Borno)	172	28.48±2.58cm	13.03±1.75cm	45.60±4.0%
Brakohiapa *et al.* [18]	Ghana	2004	28.7±2.4cm	13.5±1.4cm	47.1±3.7%
Mseuga *et al.* [19]	Nigeria (Benue)	250	23.08±0.01cm	10.56±0.02cm	45.6±0.04%
Anibor *et al.* [3]	Nigeria (Bayelsa)	200	28.26±2.37cm	12.98±1.9cm	46.05±3.63%
Current study	Nigeria	200	27.63±2.17cm	12.97±1.24cm	46.2±3.5%

DISCUSSION

The methodology used to measure TCD and TTD herein showed moderate reproducibility based on the findings from the intraobserver and interobserver concordance tests. Compared to previous Nigerian studies, the average TTD and TCD in this study were higher than the findings in Jos and Benue States and lower than TTD observed in Borno and Bayelsa States [3, 7, 8, 19]. This suggests a variation within the same geographical region which could be influenced by genetics, ethnicity and environmental factors such as climate and socioeconomic factors. These influence the physiological needs and affect the heart and lung sizes with possible effects on the thoracic size. The diameters were also lower than the findings in Ghana and India and higher than the diameters reported in Sudan [11, 18, 20]. These discrepancies could be due to genetic differences, climatic factors and variations in the sample sizes, the landmarks used and the measuring technique [3]. Mensah *et al.* [13] in Ghana documented almost similar TTD as our findings (Table 7). This perhaps was due to both studies being carried out within the same West African region [10].

The average CTR in this study was 46.2±3.5% and this was almost similar to Nigerian studies by Longbak *et al.* [2], Anibor *et al.* [3] and Ekedigwe *et al.* [8]. On the contrary, other Nigerian studies by Ali *et al.* [7] and Mseuga *et al.* [19] reported lower CTR compared to our findings. The CTR documented in Sudan and Ghana was akin to the CTR herein [11, 13]. However, another Ghanaian study reported higher average CTR. (18) The Indian population assessed by Debnath *et al.* [20] had lower CTR (39%) while Dimopoulos *et al.* [16] in the United Kingdom documented a higher mean CTR of 52.0% (Table 7). This variation of CTR in different studies could be ascribed to genetic differences that contribute to population variations [3]. Additionally, the differences in geographical, climatic and environmental factors contribute to these discrepancies. Variation in CTR may also be caused by the differences in sample size, inclusion criteria, and sample composition in terms of gender or age distribution, and healthy verses subjects with heart conditions [21]. For instance, Dimopoulos *et al.* [16] observed a higher CTR on chest radiographs of adult patients with congenital heart diseases than in radiographs of healthy controls. Halilu *et al.* **[10]** similarly documented these findings in the comparison of CTR on radiographs of hypertensive patients to those of normal control subjects.

The CTR was significantly greater in females than in males, which is consistent with the findings of Ali *et al.* [7], Gamerradin *et al.* [11], Brakohiapa *et al.* [18], and Debnath *et al.* [20]. This can be as a result of females having a lower TTD than males. In contrast, males had considerably greater CTR than females, according to Alghamadi *et al.* [6], Ekedigwe *et al.* [8], and Mseuga *et al.* [19]. The distinct genetic and physiological elements in either gender is presumably what contribute to these gender disparities in the diameters and CTR [11].

The larger male morphology (body size) and their higher levels of physical activities could be responsible for the significantly larger TCD in males [11].

The TTD and CTR differed significantly across age groups, whereas the TTD and TCD showed a significant positive correlation with age. Gammeradin *et al*. [11] and Longbak *et al*. [2] also found a positive association between diameters (TTD and TCD) and age. Longbak *et al*. [2] found no significant relationship between CTR and age, which is consistent with our findings. In contrast, Gammeraddin *et al*. [11] and Brakohiapa *et al*. [18] found that CTR increased with age. The increase in cardiothoracic ratio (CTR) with age may be explained by the contraction of thoracic diameter rather than an increase in cardiac diameter, especially in women [12].

TTD and CTR had a significant negative correlation, which was consistent with Longbak *et al*. [2]. This is primarily due to the formula used to calculate CTR, which is based on its inverse relationship with TTD. In accordance with the findings of Ekedigwe *et al*. [8] and Longbak *et al*. [2], TCD and CTR had a significant positive association. According to Halilu *et al*. [10], the loss of elasticity of great vessels increases the vascular resistance hence, the need for higher cardiac muscle force to ensure effective cardiac output. This subsequently causes enlargement of the ventricles and hypertrophy of the ventricular muscles which largely contribute to the increase in the TCD. The CTR therefore increases due to its direct association with TCD. Furthermore, we report a significant strong positive correlation between TTD and TCD, consistent with Longbak *et al*. [2].

The correlation between CTR and BMI in both males and females was shown to be weakly positive, according to studies by Ekedigwe *et al*. [8] and Emegoakor and Ukoha [12]. The relationship between CTR and BMI was not compared in the current study. Nevertheless, the fact that there is little correlation between CTR and BMI and that CTR is less influenced by body habitus than BMI supports the claim that CTR is a better predictor of cardiac enlargement [13].

CONCLUSION

The study provides the normal mean CTR values for the studied population based on age and gender which will help clinicians in the screening for heart conditions. This will enhance early diagnosis and intervention.

LIMITATIONS

The study covered only patients from 18 years and above, and did not involve younger age groups. The sample size in the study was small due to the study's retrospective nature in a single center.

RECOMMENDATION

A larger multicenter study can be conducted to obtain the normal CTR range in the different states or ethnic groups in Nigeria. Furthermore, CTR values for the pediatric age-group can also be investigated.

Declaration by Authors

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