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Assessment of Cardiothoracic Ratio among Apparently Healthy Patients in Selected Diagnostic Centres/Hospitals in Benin City, Edo State

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Abstract **Original Research Article**

Introduction: The heart has the role of pumping the oxygenated blood to other parts of the body and the de-oxygenated blood to the lungs. This study assessed the cardiothoracic ratio among apparently healthy patients in selected diagnostic centres and hospitals and determined its relationship with selected demographic parameters, specifically age and gender.

Methodology: The study adopted a retrospective cross-sectional study design which involved 4,342 participants who underwent chest radiography in four diagnostic centres: University of Benin Teaching Hospital, Lily Hospital Limited, University of Benin Health Centre, and Edo Specialist Hospital. Data collected included cardiothoracic ratio which was measured from postero-anterior chest radiographs alongside age, gender. Data was summarized using descriptive statistics, and inferential statistics including Spearman's correlation, point-biserial correlation and independent samples t-test, were used to determine relationships and variations between variables at a significance level of $p < 0.05$.

Results: The results showed that females constituted majority (56.1%) of the study population, with a total average age of 33.37 ± 14.51 years. The overall average cardiothoracic ratio was 46.17 ± 4.03%, ranging from 36.1% to 58.8%. Most participants (86.7%) had normal CTR values (≤50%), while 13.3% had enlarged CTR (>50%). Comparison by gender showed that females had a fairly higher mean CTR (46.51 ± 4.27) than males (45.74 ± 3.67), and this difference was statistically significant ($t = -6.385$, $p < 0.05$), although the effect size was small ($d = -0.19$). Spearman's correlation test analysis revealed a weak but statistically significant positive relationship between cardiothoracic ratio and age ($\rho = 0.298$, $p < 0.05$). There was also a very weak but significant relationship between CTR and gender as shown by the Point-biserial correlation test ($\rho = 0.094$, $p < 0.05$).

Conclusion: The study concluded that age and gender contribute to variations in CTR among apparently healthy individuals and provides baseline values useful for clinical interpretation of chest radiographs.

Keywords: Cardiothoracic Ratio, Demographic Parameters, Gender, Chest Radiographs.

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INTRODUCTION

The heart is a muscular organ, which is located in the middle part of the thoracic cavity called the mediastinum. It has the role of pumping the oxygenated blood to other parts of the body and the de-oxygenated blood to the lungs (1). The cardiac size has a positive indicator to the anatomists as well as clinicians in evaluating sex differences and identifying cardiac deformities like cardiothoracic health with research confirms that on an average, the adult female heart is approximately 25-26% smaller in mass and volume than the male (adults) heart (2). It could signify hypertensive, rheumatic, coronary, inflammatory, and ischemic heart diseases, and predispose individuals to stroke (Longbak, Mangset and Sirisena, 2017). Heart disease is among the major causes of death in Nigeria and other West Africa countries (3). Thus, cardiomegaly can be diagnosed and treated at a pre-hypertensive stage with the help of early detection (4).

The most common method of identifying cardiomegaly is through the chest radiography (5). The reason why chest radiography is commonly used due to the ease of procedure, its ready availability, and low cost (6). Other imaging modalities such as cardiac echocardiography, MRI and CT scan are better methods than the ultrasound method in quantifying cardiac size and cardiac function. However, they are not commonly used due to their high costs, lack of availability and they require well-developed technical expertise (7). Echocardiography is dependent on the operator while CT puts an individual at a higher risk of radiation than conventional xray, and therefore, CT cannot be used as screening (8).

Cardiothoracic ratio (CTR) is the ratio of the maximal transverse cardiac diameter to the maximal transverse thoracic diameter that is assessed on the basis of postero-anterior (PA) chest radiographs (8,9). CTR is an established method of measuring the size of the heart and determining prognosis in heart diseases (9,10). It is an effective screening method of cardiomegaly. The normal value of CTR lies between 0.42 and 0.50; a value is above 0.50 or below 0.42 is a sign of pathology like in cardiomegaly (3).

Age, gender, race, body posture and physique are some of the factors that affect CTR (11). Existing studies have determined the racial difference in CTR with the upper normal limit of 50% at Caucasians and 55% at individuals of African descent (3,8,12). Difference of gender and age in CTR also has been reported (8, 12, 13), higher normal CTR values rising up to 0.60 have been documented in the neonates and elderly (8). In a number of studies a weak positive relationship between CTR and anthropometric variables including Body Surface Area (BSA) and Body Mass Index (BMI) has been established (14,15).

Normal heart can have CTR exceeding 0.50 because of extracardiac factors that leads to apparent cardiac enlargement especially when one is not able to take a deep breath during the imaging procedure. This situation can be found in pregnancy, ascites or chest deformities including a pectus excavatum and straight back syndrome (16). Similarly, CTR of less than 0.50 may not necessarily imply healthy heart; in fact, in a situation where there is a limitation of ventricles blood flow, the ventricles may experience a wall hypertrophy without necessarily leading to cardiomegaly (16).

Assessment of the normal CTR range in apparently healthy adults subjects is vital in the screening of heart diseases among a population. The faulty measurements of CTR may cause delay in the detection and correction of underlying heart conditions and early detection of cardiomegaly (17). The population specific CTR ranges are more significant to prevent the misdiagnosis that can translate to unnecessary tests and treatments (16). Nevertheless, there is limited research in this region of Nigeria on the calculation of cardiothoracic ratio among apparently healthy local patients with relation to their demographic parameters. The objective of this study is therefore to assess CTR among

apparently healthy patients with relation to their demographic parameters.

METHODS

Ethical approval (ADM/E. 22/A/VOL.VII/1483130133) was obtained from The University of Benin Teaching Hospital Health Research Ethical Committee before the research was conducted. The research also adhered to all the relevant data protection laws.

This research was carried out at Edo Specialist Hospital, University of Benin Health Centre, Lily Hospital Limited and University of Benin Teaching Hospital all located in Benin City, Edo state, Nigeria.

The study adopted a cross-sectional and retrospective research design. The research is cross-sectional since cardiothoracic ratio (CTR) and demographic parameters were measured at one point in time among apparently healthy patients.

The target population included seemingly healthy patients who come to Edo Specialist Hospital, University of Benin Health Centre, Lily Hospital Limited and University of Benin Teaching Hospital all located in Benin City, Edo state with a request to have a routine posteroanterior (PA) chest examination during the time of the study.

Participants were recruited using a systematic random sampling technique. The selection of the eligible patients was done at a regular time until the necessary sample size is reached and the patients ought to fit the inclusion criteria.

All routine chest radiographs between March 2025 to February 2026 were used.

Total number of 4,342 radiographs were assessed

Edo Specialist Hospital =1,008

University of Benin Health Centre =1,160

Lily Hospital Limited = 1,082

University of Benin Teaching Hospital =1,092

Data for this study was collected using the following:

1. Measurement of the cardiothoracic ratio by use of normal posteroanterior (PA) chest radiographs and measuring tapes or digital measuring tools.
2. A data collection proforma was used to note down demographic data, CTR values and the demographic parameters from the archives of the centres/ hospitals

Procedure: Chest radiographs were obtained following standard radiographic protocols using a PA projection.

The cardiothoracic ratio was determined by dividing the largest transverse cardiac width by the largest internal thoracic width.

$$\text{CTR} = \frac{\text{largest transverse cardiac width}}{\text{largest internal thoracic width}}$$

Validity was ensured through the strict adherence to the standard radiographic positioning rules and measurement procedures of the CTR determination. Calibrated instruments were used to take demographic measurements to be shown as accurate and consistent.

All the chest radiographs were taken in the same radiographic system and standardized posteroanterior (PA) chest radiography protocol to reduce measurement variation. The measurements of cardiothoracic ratio (CTR) was conducted using a standardized method of measurement. To ensure even greater reliability, the researcher carried out measurements twice on the measurements at various times and then record the average value. Inter-observer reliability was evaluated where necessary by ensuring that a second qualified radiographer measures the cardiothoracic ratio independently and the degree of agreement was determined by appropriate reliability measures such as the interclass correlation coefficient (ICC). Proforma were used to take demographic measurements so as to have consistent and repeatable results.

Data was collected between February and April 2026. The demographic measurements and chest radiographs were assessed after the close of work and at weekends so that they do not disrupt the clinical workflow significantly.

The analysis was done by using Statistical

Package of the Social Sciences (SPSS), version 27. Mean, standard deviation, frequency and percentage were used to summarize CTR values and demographic parameters. The correlation between the cardiothoracic ratio and demographic parameters were evaluated by inferential statistics involving Spearman's rank correlation. The level of statistical significance used was 0.05.

RESULTS

Demographic characteristics of Respondents

Table 1 demonstrates the proportion of the participants involved in this study in the selected centres/Hospitals by Gender. In UBTH, there was a higher number of females (58.6%) than males (41.4%). Males (56.9%) were only a little more than females (43.1%) at LILY. Likewise, UBHS and ESH had reported greater rates of females (62.1% and 60.7% respectively) than males.

Figure 1 shows the overall gender distribution among the respondents and illustrates that the female gender were the bulk of the study population with a total of 56.1% and the male gender with a total of 43.9% being the minority.

Table 2 shows the age distribution of the participants in the different centres. The mean age in LILY (40.16 years) and UBHS (19.24 years) were the highest and lowest respectively. The overall average age of the participants was 33.37 years with a range of between 18 and 91 years. This implies that the population under the study was representative in terms of a large age group of seemingly healthy persons.

Table 1 Descriptive statistics of Age

Centre	Gender	Frequency	Percentage (%)
UBTH	Male	480	41.4
	Female	680	58.6
	Total	1160	100.0
LILY	Male	616	56.9
	Female	466	43.1
	Total	1082	100.0
UBHS	Male	414	37.9
	Female	678	62.1
	Total	1092	100.0
ESH	Male	396	39.3
	Female	612	60.7
	Total	1008	100.0

Assessment of Cardiothoracic Ratio (CTR)

Table 3 illustrates the average cardiothoracic ratio in the chosen centres for the study. The highest mean CTR was noted to be in ESH (47.82%), and the lowest was in UBHS (44.35%). The overall mean CTR was 46.17% with a range of 36.1% to 58.8%. These results show that mean CTR among each of centres and overall were within the clinically normal range.

Figure 2 shows the categories of the cardiothoracic ratio among the participants involved in this study. Most of the participants (86.7%) had normal CTR (≤50%), but 13.3% of the participants had enlarged CTR (>50%), respectively. This implies that the majority of the presumed healthy population of the study had normal cardiac size according to CTR calculations from the radiographic chest examination carried out of these patients.

Cardiothoracic Ratio (CTR) variations between Male and Female

Table 4 presents the average cardiothoracic ratio as per gender. The mean CTR of females (46.51%) was a little higher than in males (45.74%). This implies that there is a slight difference in cardiothoracic ratio among the two genders.

The outcome of the independent samples t-test of the CTR between male and female is shown in Table 5. The test showed a statistically significant ($t = -6.385$, $p < 0.05$) difference between the cardiothoracic ratio in both genders. Consequently, the difference between male and female participants in CTR was significantly high.

Relationship between Cardiothoracic Ratio (CTR) and Age

The Spearman's correlation analysis of CTR and age is presented in Table 6. The relationship between cardiothoracic ratio and age of the participants invloved in this study was weakly positive ($r = 0.298$, $p < 0.05$) meaning that cardiothoracic ratio is likely to increase slightly with age. This relationship between CTR and age was a statistically significant relationship.

Table 7 also supports the findings of an independent samples t-test, indicating that there is statistically significant difference ($t = -6.385$, $p < 0.05$, $d = -0.19$) in the cardiothoracic ratio between males (Mean = 45.74) and females (Mean= 46.51). This is an indication that although the females have a higher mean CTR than the males but the magnitude of the effect size is quite small. This basically suggests that there is minimal practical difference in the CTR between both genders.

Relationship between Cardiothoracic Ratio (CTR) and Gender

Table 9 displays the results of the Point-biserial correlation test and the findings are as follows: $\rho = 0.094$, $p = 0.000$; Since $p = 0.000$ is lesser than 0.05. The Point-biserial correlation test shows that there was a very weak, positive and statistically significant relationship ($\rho = 0.094$, $p<0.05$) between the Gender of participants involved in this study and their cardiothoracic ratio. This suggests that females tend to have a slightly higher cardiothoracic ratio than males.

Figure 1: Distribution of Gender among correspondents.

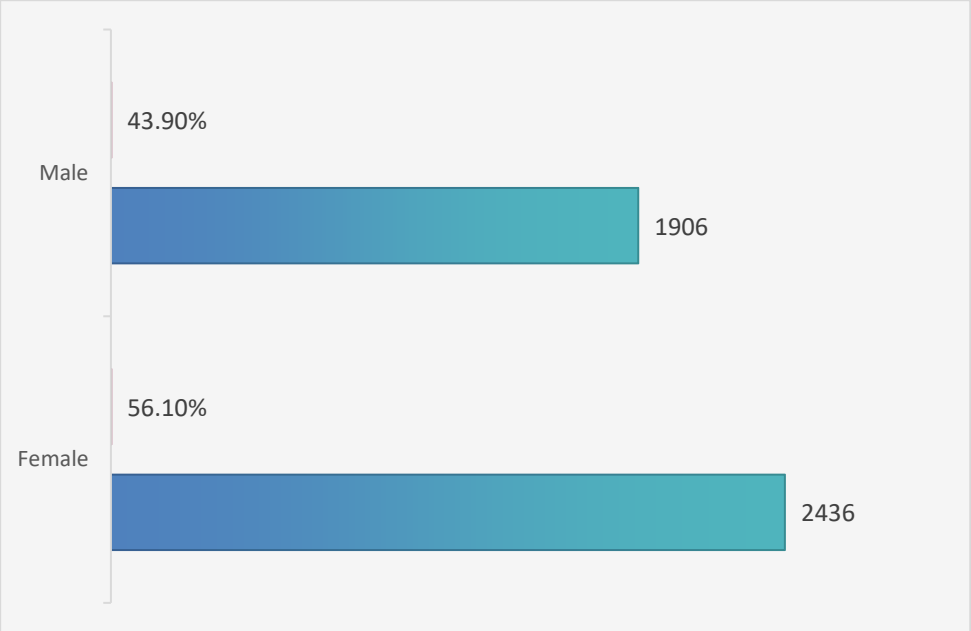


Table 2 Descriptive statistics of Age

Centre	Mean Age	Minimum age	Maximum Age
UBTH	34.76	18	78
LILY	40.16	18	91
UBHS	19.24	18	62
ESH	39.81	18	68
Overall	33.37	18	91

Table 3 Descriptive statistics of CTR

Centre	Mean CTR (%)	Minimum CTR (%)	Maximum CTR (%)
UBTH	45.42	36.1	58.7
LILY	47.29	36.4	56.0
UBHS	44.35	37.0	56.1
ESH	47.82	40.3	58.8
Overall	46.17	36.1	58.8

Figure 2: Classification of CTR

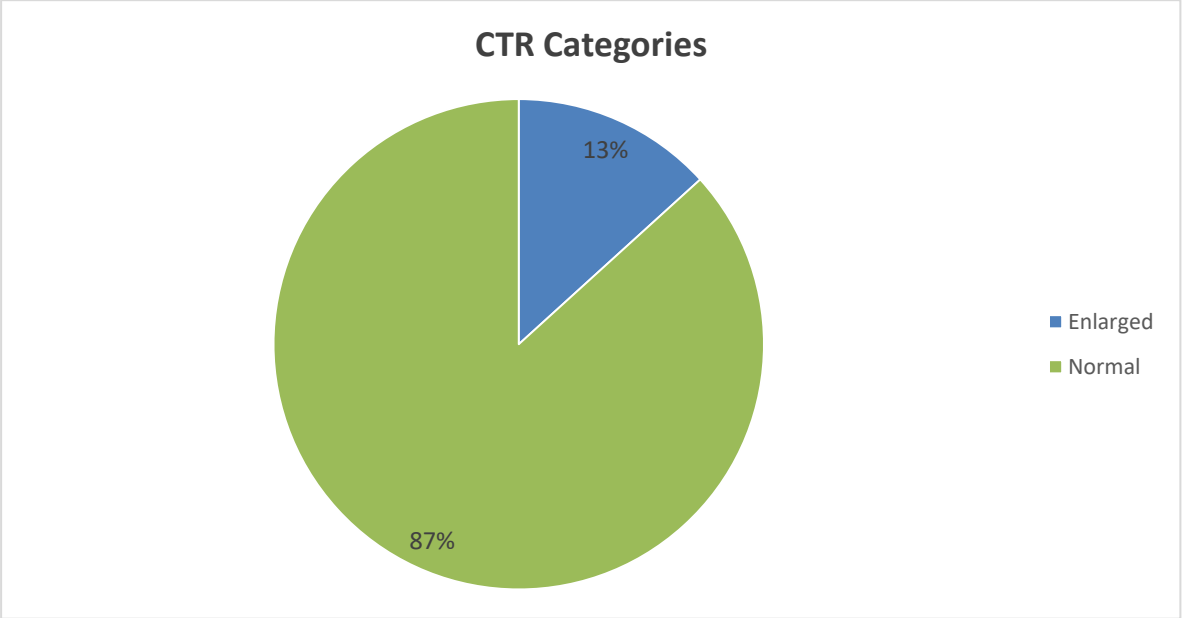


Table 4 Cardiothoracic Ratio (CTR) between genders

Gender	N	Mean CTR (%)
Male	1906	45.74
Female	2436	46.51

Table 5: Independent sample t-Test of CTR between male and female

Test	t-value	p-value	Decision
Cardiothoracic Ratio (CTR) vs Gender	-6.385	0.000	Significant difference

Table 6 Correlation between CTR and Age (Spearman's Correlation Test)

Test	rho	p-value	Interpretation
Cardiothoracic Ratio (CTR) vs Age	0.298	0.000	Weak relationship

Table 7 Relationship between CTR and Gender (Independent sample t-Test)

Test	t-value	p-value	Cohen's d	Decision
Cardiothoracic Ratio (CTR) vs Gender	-6.385	0.000	-0.19	Significant difference

Table 8 Spearman's Correlation between Cardiothoracic Ratio (CTR) and Age

Variable	rho (Spearman)	p-value	Interpretation
Cardiothoracic Ratio (CTR) vs Age	0.298	0.000	Weak relationship

Table 9 Point-biserial correlation between Cardiothoracic Ratio (CTR) and Gender

Variable	rho (Point Biserial)	p-value	Interpretation
Cardiothoracic Ratio (CTR) vs Gender	0.094	0.000	Very weak relationship

DISCUSSION

Cardiothoracic Ratio among Apparently Healthy Patients

The mean cardiothoracic ratio (CTR) of apparently healthy patients of the selected diagnostic centres and hospitals ranged from 36.1% to 58.8% and the overall mean CTR was 46.17%. Majority of the participants (86.7%) showed normal CTR value (≤50%) and 13.3% showed enlarged CTR value (>50%). It would appear from these findings that the most common finding was a normal cardiac size and that most participants did not have clinically evident cardiac enlargement.

The mean CTR in this study is similar to that reported by Ese et al. (18) with their mean CTR of 46.05% among adult Ijaw people. Likewise, for the young undergraduates of Nigeria, Longbak et al (13) found a mean CTR of 46.0%. The close similarity of these findings with our current study may be explained by the fact that all the studies were apparently healthy Nigerian populations with use of conventional chest radiographic techniques in measuring CTR. The results are also in line with that reported by

Musisi et al., (19) which was 0.46 for the median CTR of the participants who were subjected to chest radiography. The correlation between both studies supports the observation that CTR values in the range of 0.46 are typical for apparently healthy adults and could be used as a reference value for clinical judgement.

The high prevalence of normal CTR in our study was anticipated as the study placed emphasis on apparently healthy subjects without cardiovascular disease. Our study confirmed that CTR is a useful clinical parameter to screen patients that may need further cardiac assessment. The results should be treated with some caution as Simkus et al. (20) found that CTR had poor diagnostic performance when used alone especially in intermediate ranges. Thus most of the participants in this study would have a normal cardiac size due to the normal CTR; however, CTR should be used in conjunction with other clinical and imaging parameters.

Variations in CTR between Male and Female Participants

The findings of our study corroborates the study of Ahama et al. (21) conducted at University of Benin Teaching Hospital which revealed that females had higher mean CTR value although males had a larger cardiac and thoracic diameter. Like this, Ominde, Enakpoya and Ikubor (22) observed that females had significantly higher CTR values than males in Delta State, Nigeria. Additional noteworthy findings from the study by Ese et al (18) included the significantly higher CTR values for females than for males.

This greater CTR for females is perhaps due to the differences in anatomy and physiology between males and females. As thoracic dimensions are smaller in females, within normal range of the cardiac dimensions, it may be possible to have relatively higher CTR in females than males. These differences may also be due to hormonal influences and/or differences in body composition.

The results, however, differ from the observation by Okoseimiema and Agi (23) which observed higher CTR among males of a population in Port Harcourt. This difference could be attributed to the differences in the characteristics of the samples, geographic location, ethnic population, age distribution, and the different techniques in the measurement of radiography used in various studies. Although statistical significance was observed in the current study, the effect size was very small indicating there was very little difference between males and females when it comes to the actual levels of CTR. Gender does seem to have an impact on CTR measurements, but this difference may not be clinically significant in everyday clinical use.

Evaluation of the selected Demographic Parameters of the Study

The results in our study indicated that mean age of the subjects was 33.37 years ranging from 18 to 91 years. The age range of the subjects was large and would reflect all age groups, thus giving a representative sample of age-related changes in cardiothoracic ratio. The older age group distribution was a notable feature of this study since age has been noted to have an impact on cardiovascular anatomy and physiology. Structural and functional changes can develop in the cardiovascular system as people get older, which could result in a change in cardiac dimensions and thus the cardiothoracic ratio.

This discovery is consistent with the study conducted by Ahama et al. (21) which showed that age is a crucial demographic variable in determining the CTR values of adults in Nigeria. Likewise, Ominde et al. (22) reported that there was a significant variation in CTR among different age groups, indicating the variability in cardiac sizes with age-related physiological changes.

The age distribution seen in our present study is also a reason for the high level of age-related results reported later on the correlation analysis. In contrast to studies that only sampled children and young people with a narrow age window, like Angmorterh et al. (24) who sampled a mean age group of about 19.6 years, our present study sampled a broad age range that increased the chances of age-related trends being identified in CTR.

Relationship between CTR and Selected Demographic Parameters

The results of our study also corroborates the result obtained by Ahama et al. (21) that there were age related differences in CTR of adults. It also corroborates with the findings made by Ominde et al., (22) which indicated that considerable age related differences were observed in CTR values and positive correlation between age and thoracic measurements. The change in CTR with age may be due to cardiovascular changes that occur with age; which include gradual cardiac remodeling, thoracic elasticity decrease, and changes in the chest wall anatomy which may affect cardiac and thoracic dimensions. The results, however, contradict those of Angmorterh et al. (24) who did not find any significant relationship between age and CTR for university students. The difference could be attributed to the difference in population of the studies. The age range of the participants (18–91 years) in our present study was wider than that of Angmorterh et al. (24) who involved a relatively young and homogenous population with limited age variability. Diverse age groups give a larger window to see physiological changes with age that impact on CTR.

Likewise, the results are inconsistent with the study of Chia et al. (25) which found that age had a negative correlation with CTR among Nigerian children. This disagreement is to be anticipated because children grow and bring about a thoracic expansion that may decrease CTR values as a function of age, while adults have other physiological changes related to ageing.

The point-biserial correlation analysis also showed a statistically significant, but very small positive correlation between gender and CTR ($\rho = 0.094$ with $p < 0.05$), meaning that females resulted in slightly higher CTR values than males. This finding is in agreement with the outcome of the independent samples t-test and also corroborates the findings of previous studies by Ahama et al. (21), Ominde et al. (22) and Ese et al. (18) which reported higher CTR values among females.

The statistical significance of these relationships was noted, but the correlation values were low. This indicates that age and gender is only a minor factor in affecting CTRs and that other factors also play a part in this. Other parameters like body habitus, thoracic dimensions, genetic factors, and cardiovascular status can also be important factors in determining the values of cardiothoracic ratio.

In general, the results of this study indicate that the demographic factors, especially age and gender had an effect on cardiothoracic ratio as suggested by the available literature. Therefore, these should be taken into account for the analysis of chest radiographs and to define reference values for clinical use.

CONCLUSION

CTR is significantly different between males and females and females have higher mean values. There was also statistically significant correlation between CTR and age, which means that radiographic cardiac proportions are affected by demographic features. Although CTR is a handy, easy, and economical screening parameter to cardiomegaly, it cannot be employed alone since it has been known to be limited to diagnosis. Instead, it is to be understood in conjunction with clinical discoveries and where possible, sophisticated imaging techniques.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

DATA AVAILABILITY

The data sets generated and analysed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

Ugwuanyi D. C. supervised the study design and data analysis, approved the final version for submission.

Okeh E. O. conceived the study, collected, analysed the data, drafted and critically reviewed the manuscript.

REFERENCES

1. Shirazu, I., Sackey, T. A., & Tiburu, E. K. (2019). Determination of Standard Reference Cardiothoracic Ratio and the Relationship with Body Parameters as A Patients Health Indicator for Clinical Application. Int J Sci Res Sci Eng Technol, 6(5), 318-226.
2. Ominde, B. S., Enakpoya, P., Ikubor, J., & Ovovwero, O. (2021). Assessment of the Cardiothoracic Ratio and Its Association with Gender and Age: A Nigerian Study.
3. Truszkiewicz, K., Macek, P., Poręba, M., Poręba, R., & Gać, P. (2022). Radiological cardiothoracic ratio as a potential marker of left ventricular hypertrophy assessed by echocardiography. Radiology Research and Practice, 2022(1), 4931945.
4. Ali, A. M., Gangrang, A. S., Abubakar, A., & Abubakar, U. (2019). Radiographic assessment of cardiothoracic ratio in apparently healthy adults in Maiduguri. *Hamdan Medical Journal, 12(4), 204-207*.
5. Halilu, S., Aiyekomogbon, J., Igashi, J., Ahmed, H., & Aliyu, Y. (2017). Cardiothoracic ratio on chest radiographs as a predictor of hypertensive heart disease among adults with systemic hypertension. Archives of International Surgery, 7(3), 82-82.
6. Centurión, O. A., Scavenius, K., Miño, L., & Sequeira, O. R. (2017). Evaluating cardiomegaly by radiological cardiothoracic ratio as compared to conventional echocardiography. J Cardiol Curr Res, 9(2), 00319.
7. Chon, S. B., Oh, W. S., Cho, J. H., Kim, S. S., & Lee, S. J. (2011). Calculation of the cardiothoracic ratio from portable anteroposterior chest radiography. *Journal of Korean medical science, 26(11), 1446-1453*.
8. Mensah, Y. B., Mensah, K., Asiamah, S., Gbadamosi, H., Idun, E. A., Brakohiapa, W., & Oddoye, A. (2015). Establishing the cardiothoracic ratio using chest radiographs in an Indigenous Ghanaian population: a simple tool for cardiomegaly screening. *Ghana medical journal*, 49(3), 159-164.
9. Gupte, T., Niljikar, M., Gawali, M., Kulkarni, V., Kharat, A., & Pant, A. (2021, August). Deep learning models for calculation of cardiothoracic ratio from chest radiographs for assisted diagnosis of cardiomegaly. In 2021 International conference on artificial intelligence, big data, computing and data communication systems (icABCD) (pp. 1-6). IEEE.
10. Dimopoulos, K., Giannakoulas, G., Bendayan, I., Liodakis, E., Petraco, R., Diller, G. P., ... & Gatzoulis, M. A. (2013). Cardiothoracic ratio from postero-anterior chest radiographs: a simple, reproducible and independent marker of disease severity and outcome in adults with congenital heart disease. *International journal of cardiology, 166(2), 453-457*.
11. Gameraddin, M. (2014). Evaluation of cardiothoracic ratio of normal subjects in Al Madinah Al Munawwara using chest radiographs. La Pensee.
12. Brakohiapa, E. K., Botwe, B. O., & Sarkodie, B. D. (2021). Gender and age differences in Cardiac size parameters of Ghanaian adults: can one parameter fit all?

Part two. *Ethiopian Journal of Health Sciences, 31(3).*

13. Longbak, N. S., Mangset, W. E., & Sirisena, U. A. I. (2017). Determination of cardiothoracic ratio (CTR) of normal fresh undergraduate students of University of Jos using plain chest radiographs. Int Res J Pure & Appl Physics, 5(2), 29-36.
14. Ekedigwe, J. E., Pam, S. D., Binitie, P. O., Sirisena, A. U., Hameed, M., & Adegbe, E. O. (2014). Cardiothoracic ratio and body mass index in normal young adult Nigerians. *Journal of Medicine in the Tropics, 16(2), 47-51.*
15. Emegoakor, A. C., & Ukoha, U. (2018). Relationship between cardiothoracic ratio and some selected anthropometric parameters in relation to gender in an adult Nigerian population. *International Journal of Basic, Applied and Innovative Research, 7(3), 83-91.*
16. Msuega, C. D., Mohammad, H., Terkimbi, A. I., Aliyu, A., Aondoaseer, U. A., & Msuega, C. D. (2021). Establishing the cardiothoracic ratio of non-hypertensive patients using posteroanterior (PA) chest radiographs in an indigenous Nigerian population. J Med Sci Clin. Res, 9, 1-9.
17. Brakohiapa, E. K. K., Botwe, B. O., Sarkodie, B. D., Ofori, E. K., & Coleman, J. (2017). Radiographic determination of cardiomegaly using cardiothoracic ratio and transverse cardiac diameter: Can one size fit all? Part one. *The Pan African Medical Journal, 27, 201.*
18. Ese, A., Efe, A., & Charles, E. (2021). Radiographic Determination of Cardiothoracic Ratio and Cardiac Size in the Ijaw Ethnic Group of Nigeria. *International Medical Journal, 28(04).*
19. Musisi, A., Nakatudde, R., Namuwonge, O., Babirye, D., Kintu, I., Olweny, F., Malumba, R., Nakalanzi, V., & Mubuuke, A. G. (2024). Cardiothoracic Ratio (CTR) Among Patients Presenting for Chest X-ray in Radiology Department at Mulago National Referral Hospital: A Patients' Health Indicator for Clinical Application.
20. Simkus, P., Gutierrez Gimeno, M., Banisauskaite, A., Noreikaite, J., McCreavy, D., Penha, D., & Arzanauskaite, M. (2021). Limitations of cardiothoracic ratio derived from chest radiographs to predict real heart size: Comparison with magnetic resonance imaging. Insights into Imaging, 12(1), 158.
21. Ahama, E. E., Igabari, J. N., Ehebha, E. S., & Abarugo, G. P. (2023). Radiographic Assessment of Cardiothoracic Ratio among Patients of University of Benin Teaching Hospital. 6(6).
22. Ominde,S. B., Enakpoya, P., & Ikubor, J. (2023). Assessment of the Cardiothoracic Ratio and Its Association with Gender and Age: A Nigerian Study. *Galore International Journal of Health Sciences and Research, 8(2), 16–22.*
23. Okoseimiema, S. C., & Agi, C. E. (2023). Cardiothoracic Ratio, Vertical Height, Transverse Dimension of the Trachea of Nigerians Resident Port Harcourt, Rivers State, Nigeria. *Scholars International Journal of Anatomy and Physiology, 6(2), 7–11.*
24. Angmorterh, S. K., Van De Venter, R., Alesu-Dordzi, E., Alidu, H., Aboagye, S., Ogundiran, O., Agyemang, P. N., Angaag, N. A., Amoussou-Gohoungo, M. M., Inusah, A., & Dzefi-Tettey, K. (2024). Microcardia and cardiomegaly screening using postero-anterior chest X-ray (PA CXR) across university students in Ghana – a retrospective study. BMC Medical Imaging, 24(1), 351.
25. Chia, M. D., Mohammad, H., Annongu, T. I., Abah, O. R., Abdallah, R., Abdullahi, A., Ugande, A. A., & Iorpagher, K. P. (2022). Radiographic assessment of the cardiothoracic ratio in the pediatric age group at a tertiary institution in North-Central Nigeria. *Calabar Journal of Health Sciences, 6, 65–71.*