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ORIGINAL ARTICLE

RADIOGRAPHIC ASSESSMENT OF CARDIOTHORACIC RATIO IN APPARENTLY HEALTHY ADULTS IN BAHIR DAR, NORTHWEST ETHIOPIA

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ABSTRACT

Background: *Cardiothoracic ratio (CTR) is the common way for the measurement of heart size, diagnosis of heart disease, and screening of cardiomegaly. The aim of the study was to assess CTR and the factors altering its measurement.*

Materials and Methods: *Institution-based cross-sectional study was conducted among adult patients coming for a chest x-ray at Gambi Teaching General Hospital. A total of 250 adult study subjects selected by a systematic random sampling method were included in our study. The sociodemographic and radiographic data were collected using a pre-tested standardized questionnaire and measurements and analyzed using SPSS version-21. One-way ANOVA followed by Tukey post hoc test was implemented and P<0.05 was considered as statistically significant.*

Results: *The average values of CTR, transverse cardiac diameter (TCD), and transverse thoracic diameter (TTD) were 46.08 ± 3.34%, 12.53 ± 1.63 cm, and 27.05 ± 2.24 cm, respectively. The average values of male TCD and TTD were significantly greater than the mean values of female TCD and TTD (P=0.000) and the reverse holds true for the CTR. TCD and TTD values increased with age and level of monthly income. In all age groups, the CTR was less than 50%.*

Conclusion: *The CTR of females was greater than the males (P> 0.05) and compared with other African studies. Age, monthly income, and occupation of the study subjects appeared to alter the values of TCD, TTD, and CTR. Further research on the association between CTR and anthropometric measurements should be conducted.*

Keywords: *Cardiothoracic ratio, radiograph, transverse cardiac diameter, transverse thoracic diameter*

INTRODUCTION

The Cardiothoracic ratio (CTR) is measured at posteroanterior chest X-ray and is the ratio of maximal transverse cardiac diameter (TCD) to maximal transverse thoracic diameter (TTD) above the costophrenic angle measured from the inner edges of the ribs (1). The CTR is a very commonly used measure to examine the heart size and screen heart disease like cardiomegaly (2).

In developed countries, cardiovascular disease is becoming the leading cause of mortality and morbidity (3). According to a World Health Organization report, about 17.3 million people around the globe died from cardiovascular diseases (CVDs) in 2008, contributing to 30% of all global deaths (4, 5). To minimize the death rate caused by

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CVD, early investigation of a cardiac problem is very important. The chest radiograph is one of the commonest methods for diagnosis of CVD and screening of cardiac enlargement/ cardiomegaly. The standard posteroanterior(PA) view with erect position is important for screening and diagnosis of heart abnormalities. A CTR of 50% in PA views of chest radiography is generally considered to be the upper limit in adults, but in children and elderly persons CTRs may reach up to 60%.

Regardless of the precision difference, accessibility, and cost, cardiac size can be determined using various imaging modalities such as cardiac echocardiography, magnetic resonance imaging (MRI), computed tomography (CT), and chest radiography (6). The advanced imaging modalities (cardiac echocardiography, MRI, and CT) are very expensive and inaccessible to every patient but provide an accurate assessment of cardiac chamber size (7). However, radiography is affordable and accessible to every patient residing even in the countryside and useful for the assessment of cardiac size (6).

Coronary heart disease is a common cause of death in developed countries and is one of the leading causes of the disease burden in developing countries (8). One of the adverse outcomes of heart disease is cardiomegaly. Hence, relevant parameters for proper diagnosis of cardiac size will be best provided by physicians. However, until the time of this study, there is no documented information in Ethiopia. Our study therefore intends to assess TCD, TTD, and CTR and associated factors related to their measurement in normal adults.

METHOD

Study area and period: This study was conducted in the Gambi Teaching General Hospital (GTGH) in Bahir Dar town. Bahir Dar is located in the Northwest parts of Ethiopia, in the Amhara National Regional State at a distance of 565 km from Addis Ababa, the capital city of Ethiopia. The total population size of the town is 290,437 of which 142,068 are males and 148,369 are females. In the town there are 10 public health centers, 3 public hospitals and 2 private hospitals. Our study was conducted in GTGH from January 1 to May 30, 2020.

Study Design: An institution-based cross-sectional study was conducted to assess TCD, TTD, and CTR and the associated factors related to their measurement in normal adults presenting for chest x-ray at GTGH, Bahir Dar, Northwest Ethiopia, 2020.

Inclusion criteria: All adults (18 + years) who came to the Radiology Department were considered as a source population. The study population, however, was adult patients visiting the department for chest x-ray during the study period and fulfil the inclusion criteria (systolic and diastolic blood pressure between 100 – 120 mm Hg and 60 – 80 mm Hg, respectively).

Adult patients who had thoracic deformities, rib cage abnormality, any past and present history of cardiac or respiratory diseases, pregnancy, ascites patients, or having large cysts and tumors were excluded.

Sample Size Determination: The sample size was calculated using a single population proportion formula. This assumed a 30% prevalence from a previous study conducted in Sudan (1), 95% confidence interval, 4% margin of error and a 15% non-response rate. The final sample size was 250.

Sampling Methods: In the present study, among the 5 hospitals that are found in Bahir Dar town, GTGH was selected randomly by using the lottery

method. A systematic random sampling method was used to select individual participants. The average number of adults who came to the Radiology Department for chest x-rays in one month was 1450. Then, the Kth interval was determined by using the formula: K=N/n: 1450/250=6. The starting point of 4 was selected from 1-6 by lottery and the study participants were recruited in every fourth interval.

Data collection Tools: Under the supervision of the principal investigator, an interviewer-administered questionnaire was completed by trained nurses using the Amharic version questionnaire. The questionnaire was first developed in English and then translated into Amharic language and back to English. Consistency was checked. To evaluate the general approachability and feasibility of the questionnaires, a pretest was carried out using 10% of the sample size at the University of Gondar Comprehensive Specialized Hospital.

Data collection procedures In the present study, a digital radiograph chest x-ray machine was used. The measurement s were performed from posteroanterior (PA) views of the chest region, holding deep breath inspiration in an erect position. Radiographs were taken with focal film distance (FFD) = 72 inches; focal object distance (FOD) = 100 cm, using a grid with bucky with exposure factors adjusted at 70 – 100 kilovoltage (kV), 10 to 18 mills ampere seconds (MAs) (2).

Measurements: The TCD was obtained by summing the maximum horizontal distance from the lateral margins (right and left) of the heart border to the midline spinous process of vertebral bodies. The TTD was measured from the widest distance of the inner wall of the chest transversely to the inner point of the other side at the level of costal attachment of the diaphragm.

The CTR was derived using the formula as described elsewhere (3, 4). **CTR= (TCD/ TTD) X 100%**

Data processing and analysis: The collected data were entered into the Epi-data and transferred into SPSS version 20 for analysis. The descriptive statistics were implemented and data were presented as mean ± standard deviation. Student's t-test and ANOVA were used to compare the means of TCD, TTD and CTR between different groups and a P-value <0.05 was considered to have a significant association with the outcome variables. Levene statistics employed a P-value > 0.05 and declared homogeneity of data.

Ethical considerations: Ethical approval was obtained from Gondar University, College of Medicine and Health Science, School of Medicine Ethical Review Committee. This ethical clearance was submitted to GTGH clinical director and offered approval. Informed consent was obtained from each study participant after full explanation of the study goals and methods. Confidentiality of information including data storage, data disposal, and privacy of the respondents was maintained. The study participants had the right to withdraw from the study at any time during the study period.

RESULT

Of the 250 study participants, 57% were between the age of 21 and 40 years, 54% were male and 55% lived in an urban area. About fifty present of the study subjects had an income between 1000 and 5000 Ethiopian Birr. Besides, 44% study participants were illiterates and 42.8% were farmers (see Table 1).

As presented in Figure 1, the mean TCD of male study subjects was found to be constant up to the age of 30 years and increased up to the fourth decade, gradually decreasing in advanced age through the eighth decade. In female subjects, there was an incremental increase in the measurement of TCD directly associated with advancing age. Between the age

Table 1: Socio-demographic characteristics of patients visiting GTGHl, Ethiopia, 2020

Variable		Frequency	Percentage (%)
Gender	Male	135	54.0
	Female	115	46.0
Age	<20	12	4.8
	21-30	88	35.2
	31-40	55	22.0
	41-50	40	16.0
	51-60	35	14.0
	61-70	16	6.4
	71-80	3	1.2
	>80	1	0.4
Residency	Urban	138	55.2
	Rural	112	44.8
Educational status	No attend formal education	111	44.4
	Primary education	27	10.8
	Secondary education	38	15.2
	College and above	74	29.6
Occupation	Farmer	107	42.8
	Civil servant	65	26.0
	Housewife	21	8.4
	Merchant	20	8.0
	Student	11	4.4
	Other	26	10.4
Monthly income	<1000	16	6.4
	1000-3000	67	26.8
	3001-5000	59	23.6
	5001-7000	37	14.8
	7001-9000	29	11.6
	9001-11000	27	10.8
	>11000	15	6.0

range of 71 and 80 years, the measurements of TCD were 13 cm in male and 13.6 cm in female subjects. A similar trend was observed in the general population of the study participants and values between males' and females' measured diameter.

The mean TCD of male study participants, female participants, and the general population was 13.09 ± 1.79, 95% CI 12.78, 13.39; 11.87 ± 1.10, 95% CI 11.67, 12.08 and 12.53 ± 1.63, 95% CI 12.33, 12.73, respectively.

In male subjects, TTD measurements gradually increased up to the third decade, abruptly increased from 31 to 40 years and then slightly decreased with subjects' of greater age in male subjects. A similar trend was detected in female subjects, but their TTD measurements slightly increased after the seventh decade. Female subjects had lesser diameters than the corresponding males but greater than the general population as shown in Figure 2.

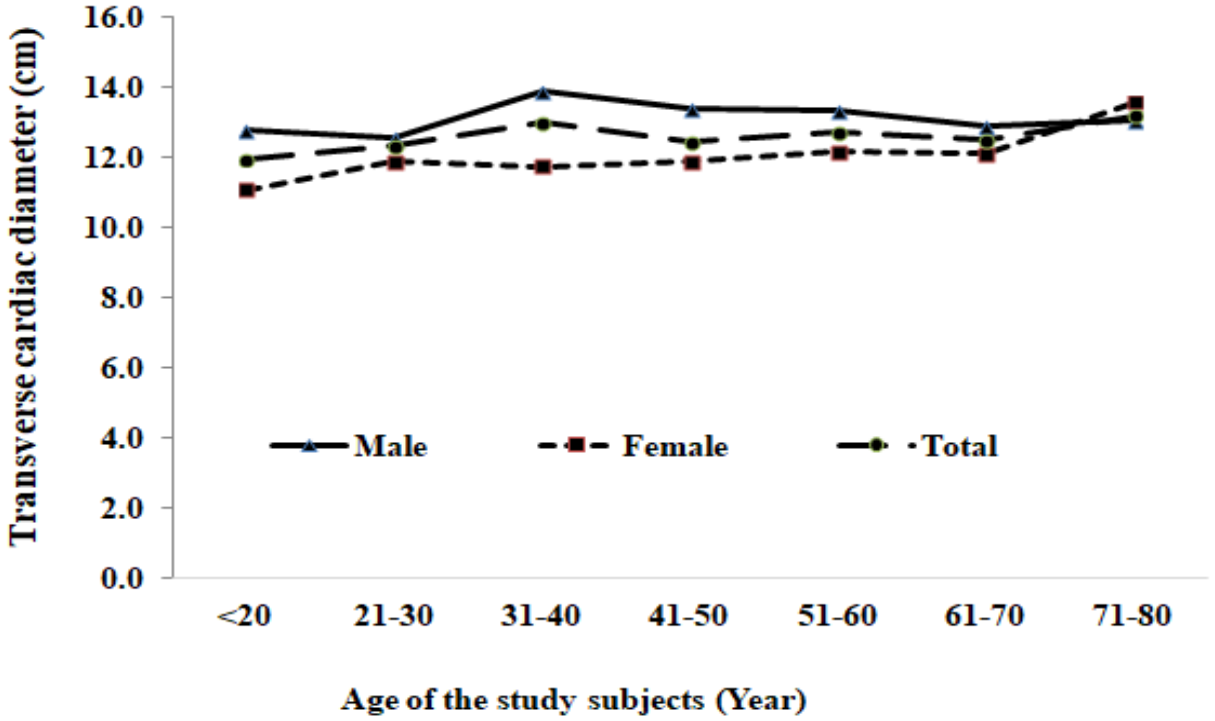

Figure 1: *Relationships between transverse cardiac diameter and age of the study subjects*

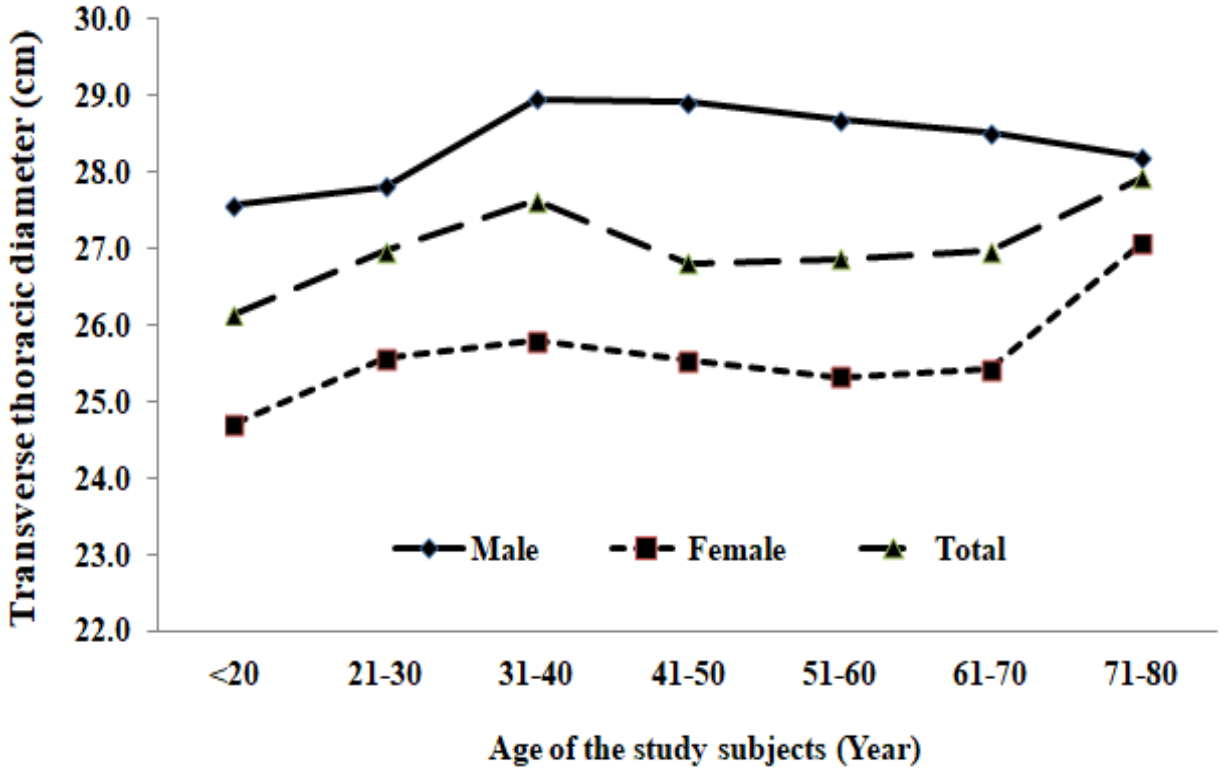

Figure 2: *Relationships between Transverse Thoracic Diameter and Age of the study subjects*

The mean TTD of the general population was 27.05 ± 2.24, 95% CI 26.77, 27.33. It was 25.52 ± 1.58, 95% CI 25.23, 25.82 in female subjects and 28.35 ± 1.86, 95% CI 28.03, 28.67 in male study participants.

Regardless of irregularities in the calculated values of CTR until the fifth decade, there was a progressive increase in the value of CTR in advanced age (eighth decades) of female subjects. By contrast, CTD ratios were relatively constant in male subjects and lower than the corresponding females. The mean CTR of male subjects was 45.79 ± 3.55%, 95% CI 45.18%, 46.39%. In female subjects and the general population, the mean CTR was found to be 46.42 ± 3.16%, 95% CI 45.85%, 47.01% and 46.08 ± 3.34%, 95% CI 45.66%, 46.50%, respectively.

A one- way ANOVA for TCD: As it is presented in Tables 2 and 3, there was a statistically significant difference in TCD measurements between males and females ($F(1, 248) = 40$, $P<0.001$). A statistically significant difference was also detected among the different forms of occupation of the study participants ($F(5, 244) = 5.03$) $P< 0.0001$). A Tukey post hoc test showed that civil servants ($P< 0.01$) and merchants ($P< 0.05$) had significantly greater TCD measurements compared with farmers.

A one way ANOVA revealed a statistically significant difference between groups with differing educational levels ($F(3, 246) = 3.462$, $P<0.05$). A Tukey post hoc test clearly demonstrated significant difference in the mean TCD of illiterates (M= 12.19, Std = 1.19) and those attending college and above (M= 12.88, Std = 1.54), $P< 0.05$. Additional factors include monthly income, which had a statistically significant influence on TCD ($F(6, 243) = 5.22$, $P< 0.005$). The urban or rural residency of the study participants also had a statistically significant effect on TCD values ($P< 0.001$). However, the marital status of the study participants did not reveal a statistically significant difference in the mean values of TCD ($F(3, 246) = 0.267$, $P> 0.05$), see Table 2 and 3.

A one- way ANOVA for TTD: A one- way ANOVA demonstrated a statistically significant difference in the mean measurements of TTD of male and female study participants ($F(1,248) = 40$, $P< 0.001$). Nonetheless, the mean value of TTD was not significantly affected by the age of study participants (see, Table 2 and 3).

In the present study, there was a statistically significant difference of TTD among different educational levels ($F(3, 246) = 9.91$, $P< 0.001$). Further, the Tukey post hoc test revealed a significant difference between study subjects attending college and above with illiterates ($P< 0.001$) and those attending secondary education ($P< 0.05$) as compared to illiterates. Our finding also indicated a significant difference between the categories of occupation ($F(5, 244) = 9.22$, $P< 0.0001$) in the values of TTD (see, Table 2 and 3). Post hoc test shown greater TTD values in civil servants (28.25 ± 2.22 cm) as compared to farmers (26.4 ± 2.06 cm, $P< 0.001$), housewives (25.80 ± 1.36 cm, $P< 0.001$), and students (26.27 ± 2.38 cm, $P< 0.05$). The monthly income of study participants had a significant effect on the mean values of TTD ($F(6, 243) = 6.82$, $P< 0.005$). TTD values of study subjects having a monthly income of more than 11,000 Ethiopian Birr differed significantly with income of less than 1000 ($P< 0.005$), 1000 – 3000 ($P< 0.005$), and 3001 - 5000 Ethiopia Birr (see, Table 2 and 3).

A one- way ANOVA for CTR: However, as it is presented in Table 2 and 3, we could not find variables of the present study which significantly affected the measurement of CTR as demonstrated in one-way ANOVA ($P> 0.05$). Besides, the Tukey post hoc test indicated non-significant differences between the different categories of the variables ($P> 0.05$). However, the Levene statistics for homogeneity revealed uniform data distribution ($P> 0.05$).

Table 2: Frequency Table of TCR, TTD and CTR of study participants, May, 2020

Variables		N	TCD Mean (STD)	TCD 95% CI LB	TCD 95% CI UB	TTD Mean (STD)	TTD 95% CI LB	TTD 95% CI UB	CTR Mean (STD)	CTR 95% CI LB	CTR 95% CI UB
	Male	135	13.09 (1.79)	12.78	13.39	28.35 (1.86)	28.03	28.67	0.458 (0.036)	0.452	0.464
Gender	Female	115	11.87 (1.11)	11.67	12.08	25.52 (1.58)	25.23	25.82	0.464 (0.032)	0.458	0.47
	<20	12	11.93 (1.35)	11.07	12.79	26.13 (1.89)	24.93	27.33	0.45 (0.038)	0.426	0.474
	21-30	88	12.3 (1.16)	12.05	12.54	26.97 (2.14)	26.52	27.42	0.457 (0.036)	0.449	0.464
	31-40	55	12.98 (2.53)	12.29	13.66	27.63 (2.38)	26.99	28.27	0.46 (0.034)	0.45	0.469
	41-50	40	12.43 (1.38)	11.98	12.87	26.81 (2.44)	26.03	27.59	0.462 (0.029)	0.453	0.471
	51-60	35	12.69 (1.23)	12.27	13.11	26.86 (2.17)	26.12	27.61	0.473 (0.033)	0.462	0.484
	61-70	16	12.49 (1.15)	11.88	13.1	26.97 (2.01)	25.9	28.05	0.464 (0.028)	0.448	0.479
Age	71-80	4	13.17 (1.74)	10.39	15.95	27.92 (2.12)	24.54	31.3	0.471 (0.044)	0.402	0.541
	Farmer	107	12.1 (1.16)	11.88	12.33	26.41 (2.06)	26.01	26.8	0.458 (0.033)	0.452	0.465
	Civil servant	65	13.11 (1.55)	12.72	13.49	28.25 (2.23)	27.69	28.8	0.464 (0.037)	0.455	0.473
	Housewife	21	12.25 (1.22)	11.69	12.8	25.8 (1.36)	25.19	26.42	0.475 (0.034)	0.46	0.49
	Marchant	20	13.33 (3.36)	11.76	14.9	27.14 (2.23)	26.1	28.19	0.465 (0.023)	0.455	0.476
	Student	11	11.86 (1.35)	10.96	12.77	26.27 (2.38)	24.67	27.87	0.444 (0.025)	0.427	0.46
Occupation	Other	26	12.74 (1.27)	12.23	13.26	27.96 (1.91)	27.19	28.74	0.456 (0.037)	0.441	0.471
	<1000	16	11.65 (1.33)	10.94	12.36	25.73 (1.87)	24.73	26.72	0.45 (0.034)	0.432	0.468
	1000-3000	67	11.96 (1.14)	11.68	12.24	26.29 (2.01)	25.8	26.78	0.455 (0.033)	0.447	0.463
	3001-5000	59	12.35 (1.23)	12.03	12.67	26.92 (2.11)	26.37	27.47	0.459 (0.035)	0.45	0.468
	5001-7000	37	12.94 (2.59)	12.08	13.81	27.02 (1.89)	26.39	27.66	0.463 (0.032)	0.452	0.474
	7001-9000	29	13.02 (1.87)	12.31	13.73	27.67 (2.86)	26.58	28.76	0.47 (0.04)	0.455	0.486
Month	9001-11000	27	13.35 (1.09)	12.92	13.78	28.39 (1.73)	27.71	29.08	0.471 (0.031)	0.458	0.483
Income	>11000	15	13.26 (1.05)	12.68	13.85	28.8 (2.06)	27.66	29.95	0.461 (0.027)	0.446	0.476
	Urban	138	12.91 (1.84)	12.6	13.22	27.61 (2.24)	27.23	27.99	0.463(0.034)	0.458	0.469
Residency	Rural	112	12.06 (1.17)	11.84	12.28	26.36 (2.03)	25.98	26.74	0.458 (0.033)	0.451	0.464
	Illiterate	111	12.19 (1.19)	11.9639	12.4099	26.36 (2.05)	25.98	26.75	0.462 (0.03)	0.456	0.468
Education	Primary	27	12.94 (3.06)	11.7341	14.1519	27.18 (2.26)	26.28	28.07	0.458 (0.038)	0.443	0.473
status	Secondary	38	12.56 (1.31)	12.1274	12.9874	26.92 (1.97)	26.28	27.57	0.464 (0.033)	0.453	0.475
	College and above	74	12.89 (1.54)	12.5232	13.2373	28.1 (2.26)	27.57	28.62	0.458 (.038)	0.45	0.467

Table 3: Comparing of the mean values of TCR, TTD and CTR using One-Way ANOVA of study participants, May, 2020

				TCD		**TTD**		**CTR**	
				ANOVA					
Variables		Source of Variation	df	F	P-value	F	P-value	F	P-value
	Male	Between Groups	1	40	0.000	40	0.000	2.26	0.134
Gender	Female	Within Groups	248						
	<20	Between Groups	6	1.47	0.190	1.19	0.311	1.284	0.265
	21-30	Within Groups	243						
	31-40								
	41-50								
	51-60								
	61-70								
Age	71-80								
	Farmer	Between Groups	5	5.03	0.000	9.22	0.000	1.749	0.124
	Civil servant	Within Groups	244						
	Housewife								
	Marchant								
	Student								
Occupation	Other								
	<1000	Between Groups	6	5.22	0.000	6.56	0.000	1.369	0.228
	1000-3000	Within Groups	243						
	3001-5000								
	5001-7000								
	7001-9000								
Month	9001-11000								
Income	>11000								
	Urban	Between Groups	1	18.02	0.000	21	0.000	1.767	0.185
Residency	Rural	Within Groups	248						
	Illiterate	Between Groups	3	3.462	0.017	9.91	0.000	0.352	0.788
Education	Primary	Within Groups	246						
status	Secondary								
	College and above								

DISCUSSION

The main findings of our study is that the TCD and TTD were consistently greater in men conversely, CTR was greater in women. The TCD and TTD measurements were progressively increased with age; however, CTR had irregularities. Illiterate study subjects had smaller TCD and TTD values compared to those attending at least college. Interestingly, the TCD, TTD and CTR progressively increased with rising income.

Studies conducted on Caucasians, Asians and people of African descent reported progressive increase in TCD values with age (5-9). Similarly, our study clearly indicated an increase TCD value with advancement age. This may be due to increased vascular resistance or loss of elasticity of the greater vessels as age advanced; subsequently, may resulted in increased cardiac ventricular muscle thickness (5).
The study done in Nigeria reported that males TCD (12.85cm) and TTD (29.84cm) were significantly higher than females TCD (11.86cm) and TTD (26.68cm) ($P<0.05$) (10). According to a prospective study conducted in Nigeria, Maiduguri, males TCD and TTD were 13.71 cm and 30.39 cm, respectively and significantly higher than female TCD (12.47cm) and TTD (27.02cm) ($P=0.000$) (3). Study from Jos North Central Nigeria also reported males TCD (12.86cm) and TTD (27.88cm) and female TCD (11.7cm) and TTD (25.65cm) (11). A retrospective study conducted in Saudi Arabia on 109 study subjects reported that in male the mean TCD was 12.151 and TTD was 26.996; however, in females the TCD and TTD was 11.869 and 25.1674 ($P<0.05$), respectively (2). Similarly, in the present study, the mean values of TCD (13.09 ± 1.79 cm) and TTD (28.35 ± 1.86 cm) of males had statistically significant difference compared to females TCD (11.87 ± 1.11 cm) and TTD (25.52 ± 1.58 cm) ($P=0.000$). This may be due to the morphological or body size difference, level of physical activity difference and hormonal variation between males and females.

Consistently, various studies from Saudi Arabia (2); Nigeria, Ilorin University of Teaching Hospital (10); Nigeria, Jos University Teaching Hospital (11); indigenous Ghanaians (12); London study conducted among the three ethnic groups (Africa dissent) (7) and Nigeria, Maidugari (3) reported the mean value of CTR as 0.46. Similarly, in the present study the mean value of CTR of total population was 0.46. However, our finding contradicted with the studies conducted in Sudanese population CTR (0.43) (1); Nigeria, CTR (0.44, 0.451), respectively (13, 14); London the study conducted among three ethnic groups (Asia CTR= 0.44 and Caucasian CTR=0.43) (7). This may be due to racial, environment or body structure differences.

In the present study, the mean values of TCD and TTD were significantly increased with the escalation of monthly income. The heart of obese individuals is overburdened with workload and presumably leads to hypertrophy of the cardiac muscles and increase in heart size (10). According to the study published in Global Food Security Journal in 2019, obesity is one of the major health concerns of the 21st century and is frequently associated with economic development. On average, obesity rates increase with income (15). However, those physically active once like farmers and students will not be exposed to obesity compared with civil servants subsequent to cardiac problem. This was observed in the present study, in such a way that, the TCD, TTD and CTR were smaller in farmers and students compared to corresponding civil servants.

According to the study done in Nigeria, Maidugari , the mean CTR of healthy adult male was 0.451 and females 0.4571 (3). Besides, in Jos University Teaching Hospital, Nigeria male young adults had mean CTR of 0.462 and female had 0.457 (11); Indigenous Ghana-

ians male and female had mean value of CTR 0.452 and 0.467, respectively (12). Interestingly, in our study, the mean value of CRT in male was 0.4579 and 0.4651 in females (P>0.05). The higher CTR value of females may be due smaller TTD than males, which is natural body habitus.

Our study indicated irregularities in the values of CTR until the fifth decade, then a progressive increase in advanced age (in the eighth decade) of female subjects. However, in male subjects there was a slight decrease in CTR during the 3rd and 6th decades, then an increase during the 7th that was lower than the corresponding females. Generally, it was less than 50% in all ages. Studies conducted elsewhere reported that TCD and TTD gradually increase with age up to the fourth decades (12, 14), which may contribute for the progressive increase in CTR of advanced aged subjects. In contrast, studies indicated that the value of CTR increased in age up to the fourth decades and then decreased accordingly (3). This discrepancy may be due to methodological or genetic variation.

CONCLUSION

In our study, the mean CTR, TCD and TTD of adults were 0.46, 12.46cm and 27.05cm, respectively. There was no significant difference between male and female CTR but ratios were slightly greater in females. However, TCD and TTD of males were significantly greater than females. Age, monthly income and occupation of the study subjects have statistically significant association with TCD, TTD and CTR. We recommend further study on the impact of body habitus (Weight, height, Body mass index, Body surface area, waist circumference, Hip circumference, waist-to-hip ratio).

Limitation of the study: The study may not be representative because most of the time private hospitals are too expensive and not affordable.

Abbreviations: CT, Computed tomography; CTR, Cardiothoracic ratio; CVD, Cardiovascular disease; FFD; Film focus distance; MRI, Magnetic resonance imaging; PA, Postero-anterior; TCD, Transverse cardiac diameters, TS, Thoracic size; TTD, Transverse thoracic diameter.

Data Sharing Statements: All data and materials of this study are available and can be accessed with a reasonable request from the corresponding author using the email address: "abemuche@gmail.com"

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