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Original Article

Comparison of Cardiothoracic Ratio between Smokers and Non-smokers Using Chest X-Ray In Tobruk City

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Abstract

Background: The cardiothoracic ratio (CTR) has been utilized as an important tool for estimating heart size. It is measured based on a chest radiograph. Smoking is a known risk factor for cardiovascular and pulmonary diseases. **Aim:** The main aim of the present study was to compare the cardiothoracic ratio (CTR) between smokers (among current and former smokers) and non-smokers using chest X-rays and to assess the prevalence of cardiomegaly in each group. It also evaluates the association between pack-years and CTR among smokers. **Methods:** A comparative cross-sectional study was conducted on 58 male participants; their age was 18-82 years, classified into smoker and non-smoker categories. Data were collected from several medical centres in Tobruk city. The CTR was measured using posteroanterior (PA) chest X-rays. Smoking history (cigarettes per day, duration, and pack-years) was recorded. Age, diabetes, and hypertension status were registered as potential confounding factors. Data were analyzed utilizing descriptive and inferential statistics; Welch's independent samples t-test was used to compare the mean CTR between smokers and non-smokers, Spearman's rank correlation to evaluate the relationship between pack-years and CTR among smokers, and multivariable linear regression to assess the independent relationship between smoking status and CTR after adjustment for age, diabetes, and hypertension. The threshold for statistical significance was chosen at $p < 0.05$. **Result:** It represented that, the mean CTR was 0.411 ± 0.031 among non-smokers and 0.434 ± 0.062 among smokers. While smokers had a higher mean CTR than non-smokers, the difference was not statistically significant (p= 0.068). No significant association was observed between pack-years and CTR among smokers (Spearman's r_s= 0.147 and p= 0.353). In the multivariable linear regression model, smoking status was not independently linked to CTR after controlling for age, diabetes, and hypertension (B= 0.0143, CI%95: -0.0182 to 0.0468, p= 0.380). The whole regression model was statistically significant ($R - squared =$ 0.182, adjusted R^2=0.120, p=0.028). **Conclusion:** Smokers demonstrated a slightly higher mean CTR than non-smokers, but the difference was not statistically significant. Additionally, pack-years were not significantly associated with CTR among smokers, and smoking status was not independently correlated with CTR after controlling for age, diabetes, and hypertension.

Key words: Chest radiography, cardiomegaly, cardiothoracic ratio, heart size.

Introduction

Chest radiography (CXR) is a major diagnostic tool used to examine the airways, pulmonary parenchyma and vessels, pleura, mediastinum, heart, and chest wall. It is one of the most common imaging methods in Western countries, accounting for 25% of the total annual diagnostic imaging procedures [1]. In the Netherlands, general practitioners order about 500,000 chest radiographs every year [1].

One of the primary advantages of CXRs is their ability to provide fast, cost-effective imaging and non-invasive visualization of the thoracic cavity [2]. Numerous respiratory diseases, including lung cancer, pneumonia, tuberculosis (TB), and chronic obstructive pulmonary disease (COPD), can be diagnosed with this imaging method [3]. CXRs have drawbacks despite their many benefits. Its reduced sensitivity in comparison to magnetic resonance imaging (MRI) or computed tomography (CT) is one significant disadvantage [3]. Despite some drawbacks of chest radiography are considered an important and effective tool for measuring the cardiothoracic ratio.

Cardiothoracic ratio (CTR) has been utilized as an important indicator of heart size on Posteroanterior (PA)

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chest radiographs [4]. This positioned decreases the magnification of the heart, giving a more realistic depiction of its actual size [5]. Even though new imaging methods have been created, it is still frequently reported today despite having been introduced more than a century ago [6]. This is most likely due to the ease of measuring and interpreting CTR using a widely accessible and reasonably priced imaging study [6]. Two measurements are used to calculate the cardiothoracic ratio:

i. The widest internal diameter of the thoracic cavity from the medial border of the ribs for example; pleura to pleura [7].

ii. The transverse diameter of the heart, which is calculated as the sum of the horizontal distances between the midline and the left and right lateral borders of the heart [7].

In adults, the normal value for the CTR is less than 50%. A value above 50% or 0.50 demonstrates as cardiomegaly [8]. Cardiomegaly is characterized by an enlarged heart and reduced contraction in the left or both ventricles [9]. There are many causes lead to cardiomegaly, such as Coronary artery disease, Hypertensive heart disease, Valvular heart diseases and Congenital heart disorders [10].

Cigarette smoking is one of the most significant preventable risk factor for heart disease, accounting about 11% of cardiovascular deaths worldwide. Approximately 1.1 billion people smoke worldwide, demonstrating the significant negative effects on public health [11]. Smoking increases the risk of coronary artery disease and sudden cardiac death in several pathological mechanisms, for example; promoting atherosclerosis, enhances blood clots formation within the arteries, leading to coronary artery spam, triggering irregular heartbeats, and reducing oxygen delivery to the heart. These consequences raise the risk of adverse cardiac events and impair cardiovascular function [12].

The main purpose of this study is to compare the cardiothoracic ratio (CTR) between smokers (among current and former smokers) and non-smokers using chest X-rays and to assess the prevalence of cardiomegaly in each group. It also evaluates the association between smoking history, including pack-years, among current and former smokers.

Material and Method

Study design and participants:

This research was structured as a comparative cross-sectional study aimed at assessing the CTR, involving 58 patients who had posteroanterior (PA) chest radiographs between October and the end of December 2025. The participants were categorised into smokers (current and former smokers) and non-smokers. Data were gathered from different places in Tobruk city, such as Tobruk Medical Center, Omar Al-Mukhtar Al-Qarawi Hospital, and various private clinics, including Al-Haya Clinic. Participants aged between 18 and 82 years with high-quality chest X-ray images were involved.

Radiographic measures:

The cardiothoracic ratio is determined by dividing the maximum transverse cardiac diameter by the maximum internal transverse diameter of the thoracic cage.

The cardiac diameter is assessed by adding the largest horizontal distances from the midline to both the right and left borders of the heart. The thoracic diameter is measured as the internal distance between the inner rib margins on the right and left sides at the chest's widest point, as illustrated in figure (1). The cardiothoracic ratio (CTR) is computed using this formula:

$$CTR = \frac{A+B}{C}$$

Where: (A) Extending from the left border of the heart to the midline.

(B) Extending from the right border of the heart to the midline.

(C) Indicates the greatest internal transverse diameter of the rib cage, measured between the inner edges of the right and left ribs at the chest's widest point.

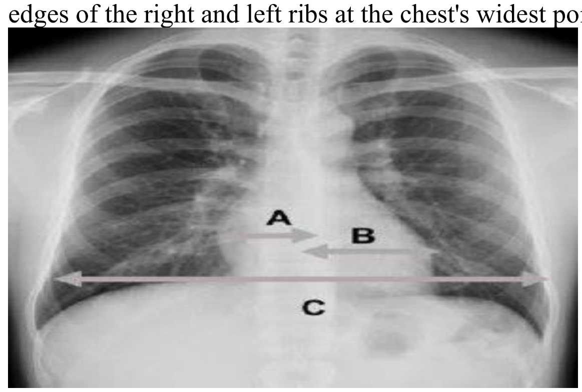

Figure 1 : Shows the method of calculating the CTR on a chest X-ray by measuring cardiac width (a+b) and thoracic width (c).

Radiographic technique:

Chest radiographs were acquired utilizing the conventional posteroanterior (PA) view to assess the CTR in both smokers and non-smokers. All chest radiograph examinations were obtained with the patient during full inspiration and in an erect position to ensure accurate visualization of the heart.

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Images were obtained utilizing Computed Radiography (CR) and Digital Radiography (DR) systems. Standardized exposure settings were implemented in accordance with institutional chest X-ray protocols to guarantee sufficient image quality while reducing the radiation dose to patients. A source-to-image receptor distance (SID) of roughly 180cm was maintained to minimize the magnification of the heart. The central ray was aimed perpendicular to the image receptor and was centred at the level of the 7th thoracic vertebra (T7).

Data Collection:

Data were gathered utilizing a structured questionnaire and a chest X-ray evaluation for every participant. The information collected involved demographic and clinical details, including participant ID, age, and the enrollment date. Furthermore, participants were categorized based on their smoking history into three groups: never smokers, current smokers, and former smokers. For those identified as former and current smokers, further information was collected, such as the length of time spent smoking, the average number of cigarettes consumed daily, and their pack-year history. Additionally, for former smokers, the duration since they quit smoking was also noted.

Clinical data concerning comorbidities were gathered, which included breathlessness, chronic cough, chest pain, hypertension, diabetes mellitus and other associated conditions. Additionally, radiographic data were acquired from chest X-ray images. Subsequently, the CTR was computed for each participant utilizing standard measurement techniques.

Statistical analysis:

All data were gathered and assessed manually for each participant. The findings were summarised utilising basic descriptive statistics, for example, means, standard deviation, and percentages. Data for all participants were entered into Microsoft Excel for statistical analysis. Data were entered into Microsoft Excel and analyzed statistically. An independent-samples t-test (Welch's t-test) was utilized to compare the mean CTR between smokers and non-smokers, Spearman's correlation was used to evaluate the association between pack-years and CTR among smokers, and multivariable linear regression was performed to adjust for age, diabetes, and hypertension.

Ethical considerations:

This research was carried out in accordance with ethical standards. All participant information was handled with confidentiality and anonymized. No identifying details were utilized in this study.

Inclusion Criteria:

Individuals aged 18 years and older. A standard (PA) chest radiography was performed on all participants, and possess high-quality radiographs that demonstrated adequate inspiration, suitable exposure, and correct positioning.

Exclusion Criteria:

Any images of PA chest X-ray with low quality (for instance, insufficient inspiration or rotation). Participants diagnosed with congenital heart diseases or significant thoracic deformities, along with incomplete clinical or radiographic information.

Results

Distribution of age groups among Participants :

This study included a total of 58 participants. The largest age groupings were those between the ages of 18 and 29 and those between the ages of 40 and 49 years, with 12 participants, or 20.68% of the total. Next, the age group of 30 to 39 years old had 9 participants (15.51%). There were eight participants (13.79%) in the 50–59 age group.

The age group of 60 to 69 years old had 10 participants, or 17.24%, while the age group of 70 to 82 years old had just 7 participants, or 12.07%, as seen in Figure 2.

These findings are clearly shown in the bar chart, which displays a broad age range among all categories. Overall, the participants were distributed across all age groups, with slightly higher representation in the 18-29 and 40-49 age groups.

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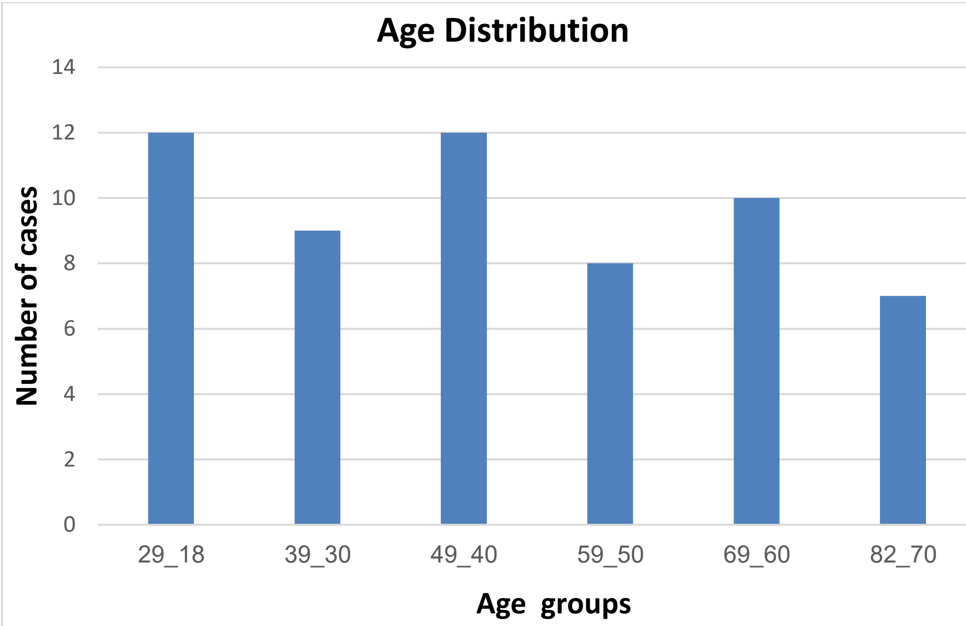

Figure (2) displays the age distribution of the participants.

Smoking status Distribution :

Figure (3) displays the distribution of smoking status among the participants in this study. The majority of participants (34, or 59%) were current smokers, followed by non-smokers (16 participants, 27%) and former smokers (8 participants, 14%). Overall, these results show that the current smokers represented the majority of the study sample.

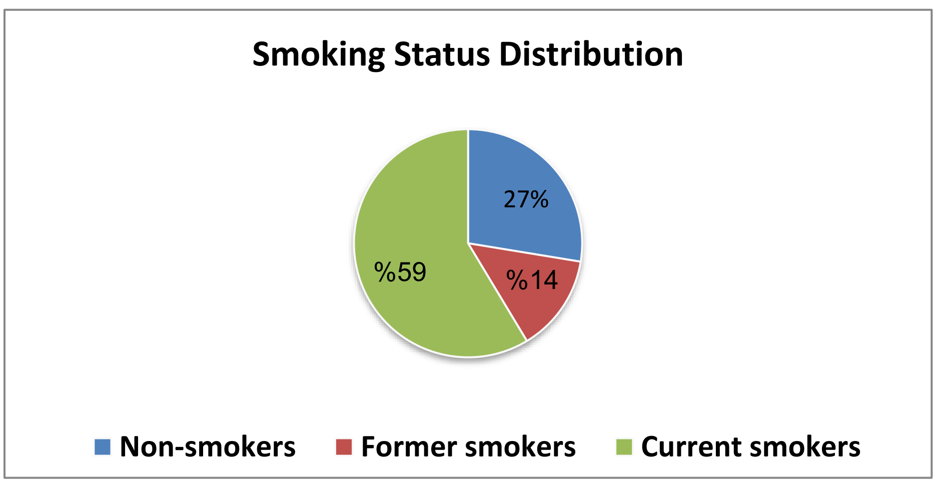

Figure 3 shows the smoking status distribution among the study group.

Clinical History:

The bar chart shows the distribution of clinical history among the participants. Breathlessness was the most prevalent symptom with 22 cases, suggesting that many patients' primary complaint is this. Twelve cases of hypertension followed, indicating that it is a common associated disease. Other frequently reported symptoms included cough (8 cases), chronic cough (10 cases), and chest pain (9 cases). The least common conditions were diabetes mellitus was present in seven cases, fever (3 cases) and renal failure (1 case). Figure 4 summarizes these results.

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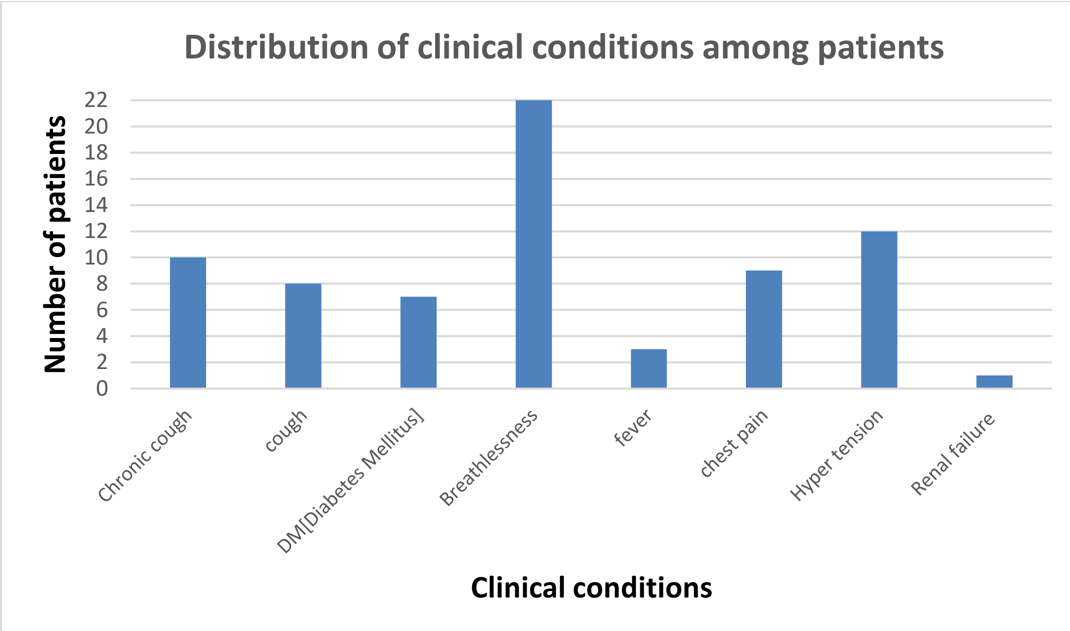

Figure 4 shows the clinical conditions among patients.

Comparison of CTR Between Smokers and Non-smokers:

Table 1 presents the mean cardiothoracic ratio CTR according to smoking status. The mean CTR was 0.4113 ± 0.0312 among non-smokers, and 0.4343 ± 0.0623 among smokers. Although smokers had a higher mean CTR than non- smokers, the difference in CTR between the two groups was not statistically significant. Using Welch's independent samples t-test, the mean difference was (- 0.0230) (CI %95: - 0.048 to 0.002) (P value= 0.0684).

Table 1 :represents the Mean and standard deviation among two groups:

Variable	Non- smokers (16)	Smokers (42)	Mean difference (non-smokers & smokers)	CI %95	P-value
CTR (Mean ± SD)	0.411 ± 0.031	0.434 ± 0.062	- 0.023	- 0.048 to 0.002	0.068

Participants with Cardiothoracic Ratio above (>50%) by smoking Status:

Demonstrate the relationship between the percentage of participants with CTR greater than 50% and smoking status. None of the 16 participants who did not smoke had a CTR greater than 50% (0%). Only one participant of current smokers (n=34), had CTR greater than 50%, representing 2.94%. Among the eight former smokers, one had a CTR >50%, which represents 12.5%, the highest percentage of any of the three groups. Although the percentage appears higher among former smokers, the number of cases is quite low, and the results are summarized as indicated in table (2).

Table 2: explains the distribution of participants with CTR (%)> 50% by Smoking Status

Smoking status	Total participants (n)	participant	%with CTR >50%

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Non- smokers	16	0	0%
Current smokers	34	1	2.94%
Former smokers	8	1	12.50%

Relationship between Pack-years and CTR among Smokers (current and former smokers):

Spearman's rank correlation was used to assess the relationship between Pack-years and CTR in 42 current and former smokers. A weak, positive, non-significant correlation was observed

(r_s = 0.147, P = 0.353). As illustrated in Table 3 and Figure 5.

Table 3: illustrates the relationship between pack-years and CTR among smokers:

Variable	**Number of Smokers**	r_s	**P- value**
CTR + Pack year	42	0.147	0.353

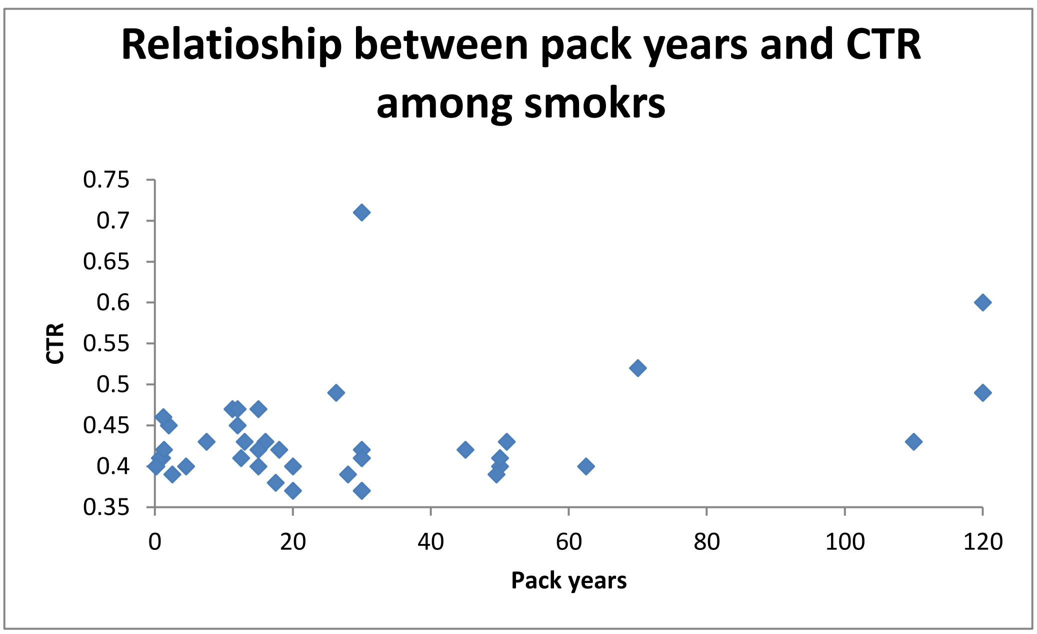

Figure 5: Shows the relationship between pack-years and CTR among smokers by using Spearman correlation (r_s = 0.147, P = 0.353).

Smoking History and Pack Years Among Current and Former Smokers:

The smoking characteristics of both current smokers and former smokers. For current smokers, the average smoking duration was 25.8 years, whereas for former smokers, it was 22 years. The average daily cigarette consumption indicated by current smokers was 21 cigarettes, while the average daily cigarette consumption recorded by former smokers was slightly greater at 23.75 cigarettes. For current smokers, the pack-year index, which measures cumulative smoking exposure, was 30.9; for former smokers, it was marginally higher at 31.4. These results, which are displayed in Table 4 and Figure 6, show that both groups experienced long-term smoking.

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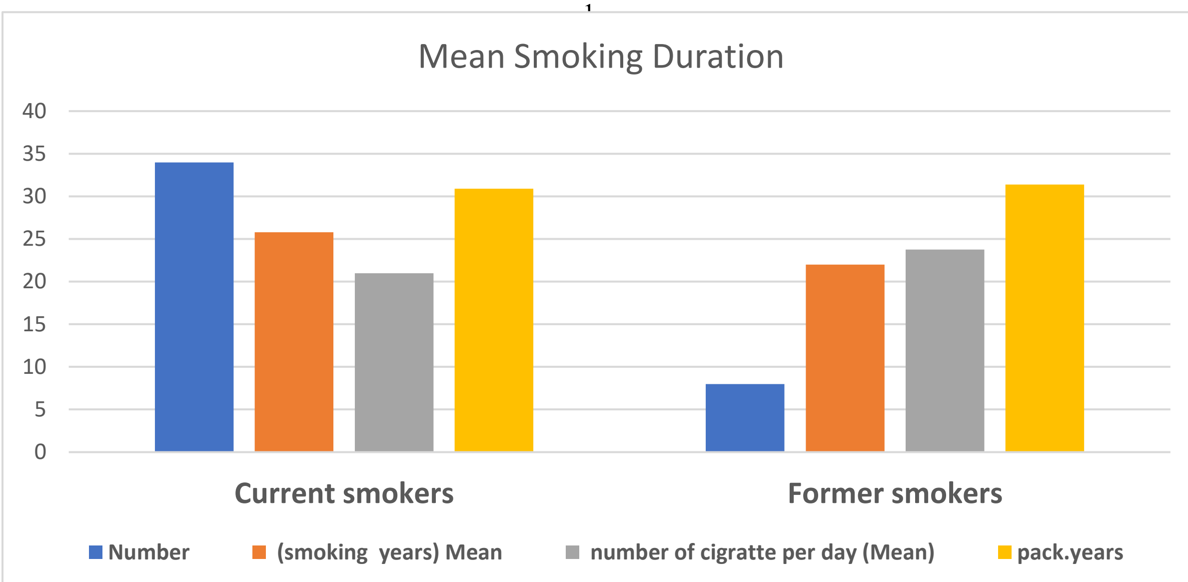

Figure 6 shows the mean smoking duration in current and former smokers.

Table 4 explains the smoking characteristics of current and former smokers

Smoking status	Number	(smoking years) Mean	number of cigarette per day (Mean)	pack. Years
Current smokers	34	25.8	21	30.9
Former smokers	8	22	23.75	31.4

Distribution of current smokers by pack-year categories:

The current smokers in the sample (n = 34) were categorized by their smoking intensity using the Pack-Year index. A significant portion of the participants were identified as mild smokers (1–20 pack-years), making up 52.9% (n = 18). Those classified as severe smokers (>40 pack-years) represented 29.4% (n = 10), while the moderate smoking group (21–40 pack-years) comprised the smallest share at 17.6% (n = 6). Overall, over half of the current smokers were classified as mild smokers, while almost one-third showed a high intensity of smoking, exceeding 40 pack-years, as shown in Table 5.

Table 5: Distribution of current smokers by Pack. Year categories.

Categories of pack-years	Number of cases	Percentage
(1_20) Mild	18	52.90%
(21_40) Moderate	6	17.60%
(>40)Severe	10	29.40%
Sum	34	100%

Distribution of Former Smokers by Pack-Year Categories :

Former smokers in the study sample are distributed based on their smoking intensity, evaluated using the Pack-Year technique. With five cases (62.5%) in the Mild category, the majority of patients did not exceed twenty pack-years in total. There were two cases (25%) in the Moderate category and just one case (12.5%) in the Severe group

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(>40 pack-years). An overview of the behaviour of the former smokers is given by this distribution, which demonstrates that many participants smoked less or quit early, as indicated in Table 6.

Table (6): Distribution of former smokers by pack-years. categories.

Categories of pack-years	Number of cases	Percentage
(1_20)Mild	5	62.50%
(21_40)Moderate	2	25%
(>40)Severe	1	12.50%
Sum	8	100%

Time since quitting for former smokers :
Among the former smokers (n = 8), the average duration since stopping smoking was 7.5 years.
As Table (7) illustrates, some participants continued to display health effects, such as higher CTR, despite having abstained from smoking for a comparatively long time. This suggests that previous smoking can have long-term consequences.

Table 7 explains the data since quitting for former smokers:

Characteristic	(Former smokers) (n=8)
Mean duration of quitting (years)	7.5

Multivariable Linear regression analysis of CTR:
Multivariable linear regression analysis was performed to assess the association between smoking status and CTR after adjustment for age, hypertension, and diabetes. Smoking status was not significantly associated with CTR. B coefficient = 0.0143, CI %95: -0.0182 to 0.0468, P value= 0.380. Age, hypertension and diabetes were also not significantly associated with CTR (P> 0.05), as shown in table (8).

Table 8 : multivariable linear regression analysis of factors associated with CTR:

Variable	B	CI %95	P- value
Smoking status	0.0143	- 0.0182 to 0.0468	0.380
Age	0.0005	-0.0004 to 0.0014	0.268
Hypertension	0.0393	- 0.0002 to 0.0787	0.051
Diabetes	0.0014	- 0.0406 to 0.0434	0.946

B: regression coefficient, CI: confidence interval.
$\mathbf{R^2}$ = 0.182
Adjusted $\mathbf{R^2}$ = 0.120
Overall model P = 0.028

Discussion

The present study aimed to compare the cardiothoracic ratio (CTR) between non- smokers and smokers, including current and former smokers, using posteroanterior chest radiography (PA CXR). A total of 58 participants were included in the study, comprising 16 non-smokers (27%) and 42 current and former smokers (73%). Overall, the majority of participants demonstrated mean CTR values within the normal range, while smokers had a slight higher mean CTR than non-smokers, the difference was not statistically significant at (p= 0.068). Additionally, no significant association was observed between pack-years and CTR among smokers.
Among the clinical symptoms reported in the study population, breathlessness was the most frequently observed, followed by hypertension and chronic cough. These findings may reflect the potential respiratory and cardiovascular effects associated with smoking. The

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presence of these symptoms highlights the importance of considering smoking history and associated clinical manifestations when interpreting chest radiographic findings.

In the current study, a CTR value of 0.50 was used as the conventional threshold for identifying cardiomegaly. However, recent evidence suggests that alternative thresholds may provide greater diagnostic specificity[13]. reported that increasing the CTR cutoff to 0.55 may improve specificity for the identification of clinically significant cardiac enlargement. Therefore, CTR should not be interpreted in isolation, but rather in conjunction with the patient's clinical history, symptoms, and other relevant diagnostic findings [13].

Although chest radiography remains a practical and cost-effective initial imaging modality for assessing the cardiac silhouette, echocardiography provides a more definitive assessment of cardiac structure and function[14].emphasized the importance of echocardiography for comprehensive cardiac evaluation [14]. In the present study, PA chest radiography was used as the primary imaging modality because of its accessibility, simplicity, and widespread use, particularly in the context of radiography education and practice.

A notable finding in the present study was that none of the non-smokers had a CTR above the 0.50 threshold. In contrast, elevated CTR values were observed among smokers, with 2.94% of current smokers and 12.5% of former smokers demonstrating values above the established threshold. These findings are generally consistent with those reported by[15]. They identified an association between smoking and an enlarged cardiac silhouette on chest radiographs. However, the prevalence of elevated CTR in the present study was considerably lower than that reported by [15]. [15] observed an elevated CTR in 58.3% of current smokers [15]. This difference may be related to the relatively limited smoking exposure and the smaller sample size in the present study.

Several limitations should be considered when interpreting the findings of this study. First, the sample size was relatively small, particularly among non-smokers and former smokers, which may limit the generalizability of the results. Second, the study population consisted exclusively of male participants, and women were not included. This limits the applicability of the findings to the general population. In comparison, [16] included both male and female participants in their study. Differences in the composition of the study populations may contribute to variations between the findings of the two studies. Furthermore, physiological differences between males and females may influence CTR measurements and should therefore be considered in future investigations [16].

Conclusion:

Smokers demonstrated a slightly higher mean CTR than non-smokers, but the difference was not statistically significant. Additionally, among smokers, pack-years were not significantly associated with CTR, and smoking status was not independently correlated with CTR after controlling for age, diabetes, and hypertension. These results indicate that factors other than smoking status alone, particularly cardiovascular risk factors such as hypertension, may contribute to variations in CTR. Further studies involving larger and more diverse populations, including both males and females, and participants with different levels of smoking exposure, are recommended to better clarify the relationship between smoking exposure and cardiac size.

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