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Chest wall deformities detected in lung radiographs during routine health screening in young healthy male athletes training for police services duty

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Abstract

Objectives: Chest wall deformities are a series of abnormalities that extend from the sternum to the vertebral column and often cause aesthetic and psychological problems. Most chest wall deformities are caused by cartilaginous malformations such as pectus excavatum and pectus carinatum. The aim of this study was to provide a detailed description of chest wall abnormalities in young male athletes with no existing complaints.

Methods: A comprehensive health assessment was performed on 1600 young men at the Erzincan Police Vocational Training Centre in March 2023. The evaluation included chest radiographs, pulmonary function tests, electrocardiography, transthoracic echocardiography, haemogram, biochemical test findings and comorbidities. Haller index scale was used to grade the severity of pectus deformity in individuals with pectus excavatum.

Results: Pectus excavatum deformity was detected in 16 individuals (1%). Pectus carinatum was detected in only one individual (0.06%). Only one of the patients with chest wall deformity had an abnormal pulmonary function test, especially in the form of a minor obstructive pattern. In addition, 11 individuals in this group had associated electrocardiographic abnormalities. These abnormalities did not cause significant clinical findings.

Conclusion: Our study showed that the prevalence of chest wall deformities in physically active young men is comparable to the prevalence of chest wall deformities reported for the general population in the available literature. Furthermore, this study demonstrated a higher prevalence of electrocardiographic abnormalities in subjects with chest wall deformities.

Keywords: chest radiograph; electrocardiography; pectus carinatum; pectus excavatum; respiratory function tests

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Introduction

Chest wall deformities (CWDs) cover a wide range of abnormalities from the sternum to the vertebral column. The main reasons why individuals seek medical advice are usually related to aesthetic issues and psychological well-being. A small proportion of those with deformities present with clinically significant complaints. Depending on the specific type of abnormality, its severity and associated conditions, functional breathing problems and significant cardiopulmonary consequences may occur.[1,2] Hence, it is crucial for patients to accurately identify abnormalities and determine any associated conditions.

The literature reports a frequency of 1% for chest abnormalities in the general population.[3] CWDs that occur from the sternum to the vertebral column can be categorised into five types based on their specific anatomical region: cartilaginous, costal, combination of costochondral, sternal, and costovertebral. The categorization of CWDs developed by Acastello is shown in **Table 1**.[4,5]

The majority of CWDs globally are caused by cartilaginous malformations (pectus excavatum and pectus carinatum).[1] Pectus excavatum (PE) occurs in around 1 to 10 per 1000 live births and represents 90% of CWDs. This deformity is defined by the existence of a sternal depression of varying depth caused by irregular growth of the

Table 1
The Acastello classification of chest wall deformities based on the deformity region.[5]

	The anatomical region of deformity	Specific appearance
Type 1	Cartilaginous	Pectus excavatum Pectus carinatum
Type 2	Costal	Simple or complex (Agenesis, hypoplasia, bifid…)
Type 3	Combination of costochondral	Poland's syndrome VACTER syndrome
Type 4	Sternal	Sternal cleft (+/– ectopia cordis) Currarino Silvermann syndrome
Type 5	Costovertebral	Simple or syndromic

basal costal cartilage structures. PE, the exact etiology of which remains unknown, usually appears as a congenital disorder that arises throughout childhood or adolescence. In moderate and severe cases, PE may force the heart to rotate to the left, cause sternal depression, and reduce the chest's anteroposterior width.[1,2,5] The Haller index (HI) is used to determine the severity of the PE deformity. HI is the ratio of the transverse diameter of the rib-cage to its anteroposterior diameter. It is around 2.5 in a normal chest, but in pectus excavatum the index is >3.25, it is necessary to use radiological imaging techniques such as radiography or computed tomography.[6,7]

Pectus carinatum (PC), the second most prevalent malformation, results in significant physical, aesthetic, and psychological issues as a result of the anterior protrusion of the sternum and cartilaginous ribs. Prevalence of PC among teenagers is around 1 in 1000. PC is less common than PE, however in specific geographic regions, PC is nearly the same or more common than PE. Just like PE deformity, the exact cause of pectus carinatum is yet unclear.[8–10]

Pectus excavatum has been related to reduced exercise capacity, pain in the chest, and a negative self-image. Furthermore, as pectus excavatum and carinatum abnormalities are linked to hereditary disorders like Marfan Syndrome, it is crucial to identify them early on for the prompt detection of life-threatening aortic conditions, particularly in those engaged in athletic activities.[11]

The goal of our study was to provide a detailed description of chest wall abnormalities observed on chest radiographs during health screening in young male persons who practice sports without existing complaints, to establish the incidence of these deformities, and to determine any potential associated medical conditions.

Materials and Methods

In March 2023, a comprehensive health assessment was performed in our hospital for a group of 1600 young men selected for training at the Erzincan Police Vocational Training Centre. The retrospective evaluation included chest radiographs, pulmonary function tests, electrocardiography (ECG), transthoracic echocardiography, haemogram, biochemical test findings and analysis of comorbidities.

The study population consisted of 1600 individuals screened for CWD by chest radiography. This study cohort was compared with those diagnosed with CWD in terms of abnormalities in pulmonary function tests, ECG, transthoracic echocardiography findings and laboratory test data. Chest radiographs were performed two-view, posteroanterior and lateral. The x-ray scans were evaluated by a radiologist who has 10 years of expertise. Patients with thoracic wall deformity detected using plain radiography were recorded. The HI was computed for every person with suspected PE in this study, using the formula suggested by Haller et al.[12] The HI is calculated by dividing the transverse diameter of the chest in PA radiographs by the shortest width between the front edge of the vertebral body and the posterior surface of the sternum measured in lateral radiographs (**Figure 1**).

The HI scale was also used to grade pectus deformity in patients with PE. During the grading process, we considered the study conducted by Daunt et al.[6] In accordance with their findings, instances with the HI ranging from 2.7 to 3.2 were classified as mild PE, instances with the HI between 3.2 and 3.5 were classified as moderate PE, and those with the HI over 3.5 were classified as severe PE.

The study population's respiratory function tests, electrocardiography, and transthoracic echocardiography

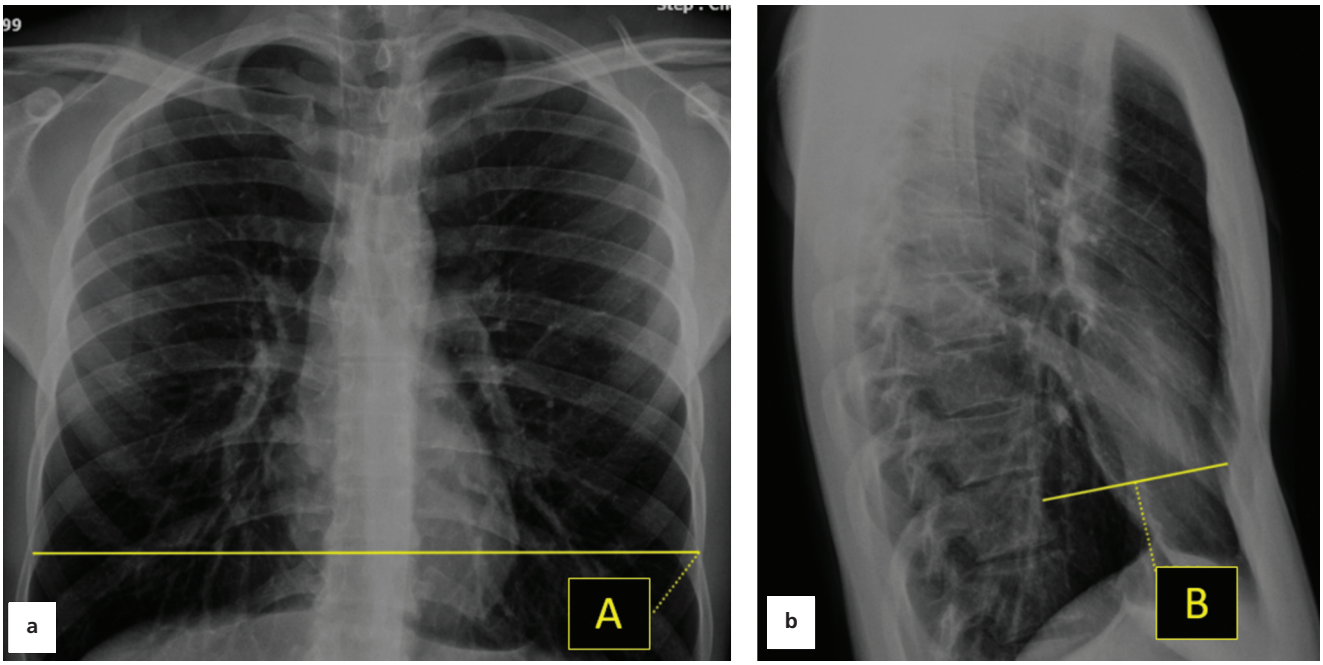

Figure 1. The figure shows how the measurements determining the Haller index were performed. Posteroanterior (**a**) and lateral (**b**) two-view chest radiography of a 24-year-old male with pectus excavatum. **A:** the transverse diameter of the thorax is measured from the inner surface of the costae on both sides, where the diameter is widest; **B:** measurement of the shortest distance between the anterior edge of the vertebral body and the posterior surface of the sternum on lateral radiographs.

findings were acquired from the hospital information system and recorded. Haemoglobin (Hb), hematocrit (Htc), platelet count (Plt), white blood cell count (WBC), neutrophil count, lymphocyte count, and serum lactate dehydrogenase (LDH) levels were retrieved from the hospital's laboratory data.

IBM SPSS Statistics for Windows version 25.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. The normal distribution of the data was tested with Kolmogorov-Smirnov test. Continuous parameters without normal distribution were stated as median (minimum-maximum). Categorical data were stated as frequencies (n) and percentages (%). Mann-Whitney U test was used to compare the median values of the age and the laboratory parameters between chest wall deformity and healty groups. Chi-Square test was used to compare the percentages of ECG and respiratory function test abnormalities between the groups. A two-tailed value of $p<0.05$ was considered statistically significant.

Results

The study population consists of 1600 people for whom we conducted CWD screening by chest radiography. The entire group consisted exclusively of male volunteers. Following the screening, CWD was identified in a total of 17 (1.06%) individuals of the 1600 participants tested. The overall age distribution of study population was found to be a minimum of 20, a maximum of 30, and a median age of 24. The age distribution of those diagnosed with CWD ranged from a minimum of 21 to a maximum of 28, with a median age of 25 ($p=0.28$).

Pectus excavatum deformity was identified in 16 (1%) individuals (**Figure 2**). According to the Haller index, 13 (0.81%) cases were categorised as mild excavatum, 2 (0.12%) cases as moderate excavatum, and 1(0.06%) case as severe excavatum. The subtypes of CWD identified throughout the screening are shown in **Table 2**. Out of the total cases, one (0.06%) was diagnosed with pectus carinatum (**Figure 3**).

Table 2
Types of chest wall deformities detected in the study.

Type of CWD	n (%)
Pectus excavatum (PE)	16 (1%)
Mild PE	13 (0.81%)
Moderate PE	2 (0.12%)
Severe PE	1 (0.06%)
Pectus carinatum	1 (0.06%)

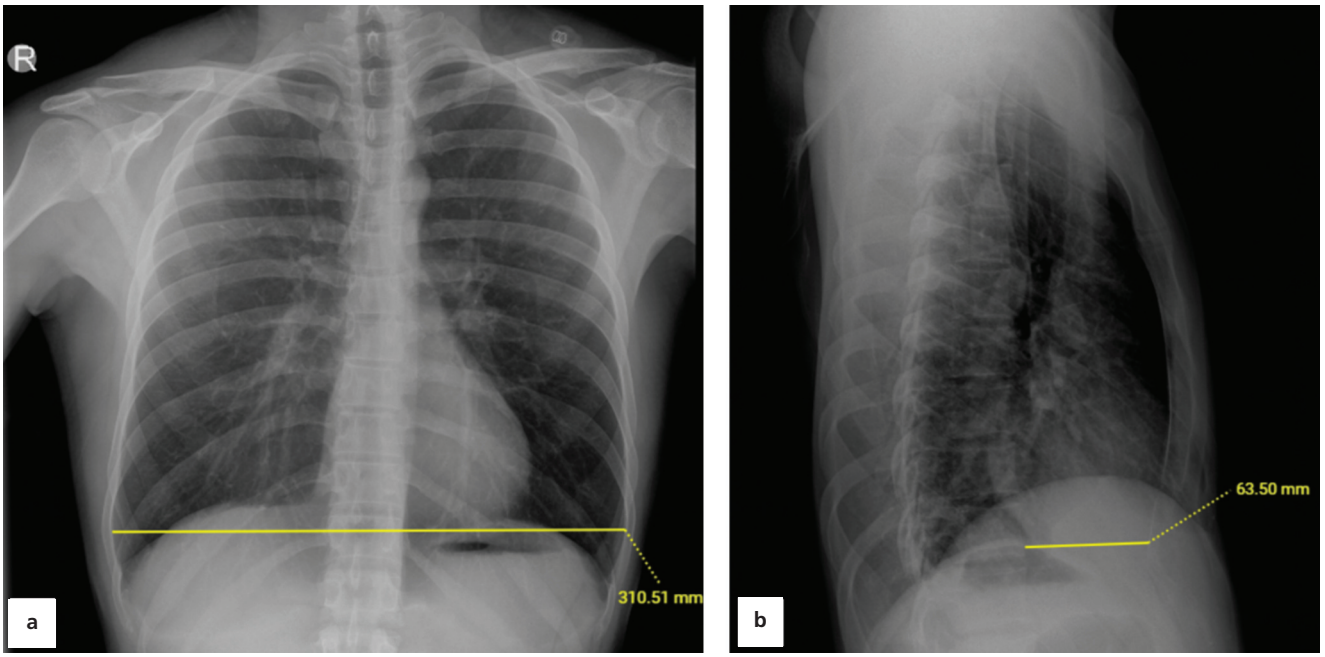

Figure 2. Posteroanterior (**a**) and lateral (**b**) two-view chest radiography of a 25-year-old male with pectus excavatum. Haller index was calculated as 4.89.

Mild obstructive abnormalities were detected in pulmonary function test results in 26 out of 1600 participants (1.6%). CWD was detected in only 1 (0.06%) of them and this person had mild PE deformity (p=0.19). The prevalence of test abnormality in PE has been shown to be 6.2%.

ECG abnormalities, including T wave inversions, bradycardia, tachycardia, arrhythmias, bundle branch

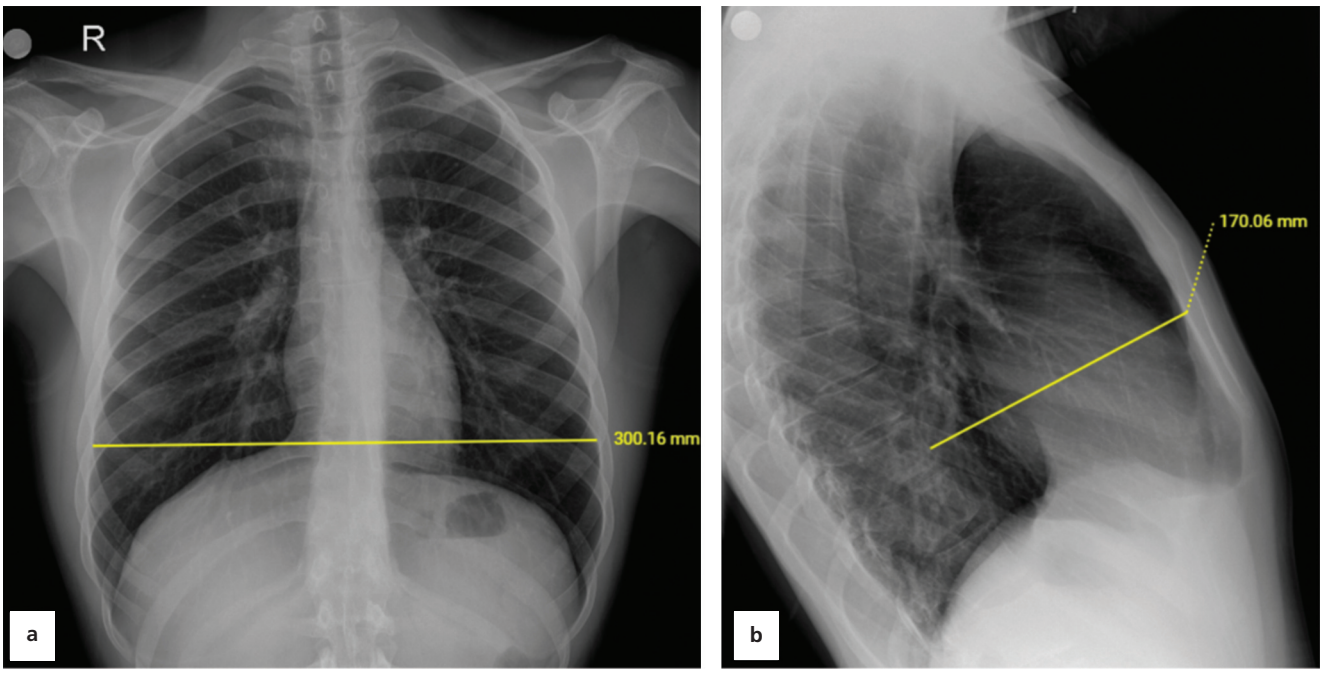

Figure 3. Posteroanterior (**a**) and lateral (**b**) two-view chest radiography of a 21-year-old male with pectus carinatum. Haller index was calculated as 1.76.

Table 3
Electrocardiography (ECG) abnormalities detected in the study population.

	Type of ECG abnormality	n (%)
Study population		1600
	T wave inversions	45 (2.81%)
	Bradycardia	47 (2.942%)
	Tachycardia	70 (4.38%)
	Arrhythmias	7 (0.44%)
	Bundle branch blocks	5 (0.31%)
	Ventricular extra beats	2 (0.12%)
Chest wall deformities		17
Mild PE	T wave inversions	3 (17.6%)
	Bradycardia	3 (17.6%)
	Tachycardia	2 (11.8%)
	Right bundle branch blocks	1 (5.9%)
Moderate PE	T wave inversions	1 (5.9%)
	Right bundle branch blocks	1 (5.9%)

block and ventricular extrasystoles, were detected in 176 (11%) of the total 1600 participants (Table 3). Among persons who have been diagnosed with CWD, 11 (67.7%) patients had specific abnormalities in their ECGs. These abnormalities included T wave inversions (V1–V4 leads) in 4 (23.5%), bradycardia in 3 (17.6%), tachycardia in 2 (11.8%) and right bundle branch blocks in 2 (11.8%) patients. Out of 11 particioants, 9 had a mild excavatum deformity while 2 had a moderate excavatum deformity. Individuals with CWD had a higher occurrence of ECG abnormalities compared to the research participants (p=0.01). However, these abnormalities did not cause significant clinical findings.

Transthoracic echocardiography was normal in all individuals with thoracic deformity and no abnormality was found in haemogram and biochemistry parameters (Table 4). Furthermore, no other systemic or syndromic disease was identified in the patients.

Discussion

For many years, most chest wall anomalies, such as pectus excavatum, were considered an incidental finding with no significant clinical consequences. In general, it does not cause symptoms severe enough to require surgical intervention. However, there is evidence in the literature that it can lead to complaints and symptoms such as palpitations,

Table 4
The relationship between laboratory parameters and the presence of chest wall deformities.

	CWD exist (n=17)	No CWD (n=1583)	
	M (min-max)	M (min-max)	p-value*
Age (years)	25 (21–28)	24 (20–30)	0.280
Hemoglobin (g/dL)	14.3 (13–16.8)	13.8 (12.5–17.7)	0.341
WBC (×10³/μL)	7.76 (6.45–9.53)	7.1 (4.75–10.59)	0.207
Platelet (×10³/μL)	215.3 (196.4–318)	231.1 (178.2–364)	0.195
Lymphocyte (×10³/μL)	3.21 (2.76–4.24)	3.02 (1.96–5.75)	0.255
Neutrophil (×10³/μL)	4.23 (3.48–7.45)	4.06 (3.05–8.18)	0.354
Hematocrit (%)	41.35 (38.3–44.6)	40.45 (36.7–48.7)	0.315
LDH (U/L)	215 (139–455)	239 (107–847)	0.169

*P-value was obtained from Mann–Whitney U test. **CWD:** chest wall deformity; **LDH:** lactate dehydrogenase; **M:** median.

fatigue and exertional dyspnea.[13] In this study, the frequency of chest wall deformities detected during health screening in young male athletes without any complaints was evaluated and possible related pathologies were tried to be determined.

Aligned with the existing body of research, our findings indicate that PE was the most commonly observed CWD, with a prevalence rate of 88%. Fokin et al.[2] revealed that PE accounts for roughly 90% of all CWDs in their study. In line with the findings reported by Fokin et al.,[2] our investigation revealed a prevalence rate of 1 in 1000 for PE.

We conducted HI assessments using 2-way chest radiographs to determine the severity of PE deformities. There has been a growing difference of opinion in recent years about the evaluation of individuals with PE deformity using imaging techniques. There are two separate groups that recommend evaluating the severity and morphology of PE with conventional radiographs or thorax CT. Studies have shown that there is no significant difference between the HI calculated from conventional radiography and that from CT. Mueller et al.[14] conducted a comparison between the Haller index acquired from chest radiographs and the one obtained from CT scans. The average HI among the 12 children was 3.97 in CT, whereas the chest X-ray HI was 4.08 (Pearson correlation value: 0.984). Accordingly, they recommend that performing chest CT scans on patients without symptoms is unnecessary and that the level of radiation exposure can be minimised by using chest X-rays to measure the HI. This study conducted by Mueller et al. demonstrates that there is no significant difference in the measurement of HI when using either chest CT or chest X-ray. Therefore, the utilisation of chest CT is not essential for accurately estimating HI. This literature data confirms that not measuring the HI values from chest CTs, as we did in our study by using chest radiographs, will not result in a limitation.

The prevalence of PC detected in our study was 0.06%, which is similar to the rates reported by McHam et al.[9] Nevertheless, in particular some geographic regions and race, the prevalence of PC is nearly equivalent to or greater than that of PE.[1,15,16] Further radiographic data reveals that minor subtypes of PC may be present in around 5% of the population. Our study population did not include any patients with mild PC deformity.

Malek et al.[17] supports that PE is associated with reduced exercise capacity due to impaired cardiovascular performance rather than physiological disorders (physical deconditioning) and respiratory dysfunction. We found that individuals with PE deformity were more likely to have electrocardiographic abnormalities rather than respiratory problems, which supports this observation. Hence, it is crucial to detect CWDs, particularly PE, as the exercise capacity of individuals in our study population who will be trained to work in security services should not be low. Moreover, some case reports demonstrate how PE deformity can lead to episodes of syncope in young athletes due to compression of the right ventricle.[18] In addition, it is important to identify individuals with CWD within our study population, as well as their decreased capacity for exercise.

Existing studies demonstrates a positive correlation between the degree of deformity in individuals with PE and the occurrence of respiratory test abnormalities. Patients with mild deformities often exhibit obstructive type functional pathologies, however as the severity of deformity grows, the prevalence of restrictive pathologies has been seen to reach up to 14%.[17,19] We noticed a minor obstructive respiratory condition among one patient in the deformity group, which is in alignment with existing research on its prevalence. The absence of restrictive type respiratory dysfunction can be attributed to the limited number of individuals exhibiting moderate and severe PE deformity. Furthermore, another contributing factor to the low prevalence of spirometric test anomalies in our study sample is the inclusion of persons who engage in physical activities. Because previous studies have demonstrated that physical activity improves respiratory function.[17,20]

The prevalence of abnormal ECG findings in these cases of CWD was discovered to be 47.8%, which closely aligns with the values reported in existing literature.[21,22] Also, the ECG abnormalities we identified in individuals with CWD correlate with the anomalies often observed in existing literature. These abnormalities included T wave inversions, bradycardia, tachycardia, and right bundle branch blocks. Our idea suggests that the abnormal ECG results, which often arise from the right heart, are caused by mechanical compression of the right ventricle due to pectus excavatum in the mediastinal area.

Our study has some strengths. Firstly, the assessment of CWD was performed in an unbiased manner using radiological images. Furthermore, data were collected by documenting medical history, laboratory tests, pulmonary function tests and analysing ECG and echocardiography

data. Thus, cardiopulmonary function could also be objectively assessed. To the best of our knowledge, there is no study in the current literature examining the prevalence of CWD in a population without any medical problems and engaged in sports activities. Our study is unique in this respect and in terms of reflecting this situation in the Turkish population.

However, this study has some limitations. One of them is that the study was conducted in a single centre in a specific geographical area and age range. Furthermore, the study population included only male participants, thus excluding prevalence data from females. Finally, as radiographs were analysed by only one radiologist at a time, there is a lack of information on both inter- and intra-observer agreement.

Conclusion

The prevalence of CWD in young men who play sports and have no other medical problems is similar to the prevalence observed in the general population as documented in the available literature. Our study is the first and largest study on this specific population in the literature. CWD has not been shown to increase the risk of any comorbidities in this specific population, except for ECG abnormalities that are not clinically significant.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

KBM: designed and conducted the research, analyzed the data and wrote the manuscript; EÜ: designed the research; MÖÖ: performed the research, analyzed the data and wrote the manuscript; SA: designed the research, contributed towards analytic tools, analyzed the data and wrote the manuscript. All authors have read and approve the final manuscript.

Ethics Approval

This retrospective study was carried out in compliance with the Declaration of Helsinki and received approval from the Erzincan University Ethics Committee (Protocol code: EBYU-KAEK-2023-10/9, Date: 07/06/2023). Due to the research's methodology, the requirement for informed consent was waived.

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References

1. Saxena AK. Classification of chest wall deformities. In: Saxena A, editor. Chest wall deformities. Heidelberg: Springer; 2007. p. 19–35.
2. Fokin AA, Steuerwald NM, Ahrens WA, Allen KE. Anatomical, histologic, and genetic characteristics of congenital chest wall deformities. Semin Thorac Cardiovasc Surg 2009;21:44–57.
3. Katrancioglu O, Akkas Y, Sahin E, Demir F, Katrancioglu N. Incidence of chest wall deformity in 15,862 students in the province of Sivas, Türkiye. Turk Gogus Kalp Damar Cerrahisi Derg 2023;31: 116–22.
4. Andrea A, Tardieu G, Fisahn C, Iwanaga J, Oskouian RJ, Tubbs RS. Bifid ribs: a comprehensive review. Anatomy 2016;10: 221–7.
5. Acastello E. Patologias de la pared toracica en pediatria. Buenos Aires: Zagier & Urruty Pubns; 2012. p. 328.
6. Daunt S, Cohen J, Miller S. Age-related normal ranges for the haller ındex in children. Pediatr Radiol 2004;34:326–30.
7. Rattan AS, Laor T, Ryckman FC, Brody AS. Pectus excavatum imaging: enough but not too much. Pediatr Radiol 2010;40:168–72.
8. Park CH, Kim TH, Haam SJ, Jeon I, Lee S. The etiology of pectus carinatum involves overgrowth of costal cartilage and undergrowth of ribs. J Pediatr Surg 2014;49:1252–8.
9. McHam B, Winkler L. Pectus carinatum. [Updated 2023 Jul 31]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; PMID:31082165.
10. Desmarais TJ, Keller MS. Pectus carinatum. Curr Opin Pediatr 2013;25:375–81.
11. Glorioso J Jr, Reeves M. Marfan syndrome: screening for sudden death in athletes. Curr Sports Med Rep 2002;1:67–74.
12. Haller JA Jr, Kramer SS, Lietman SA. Use of CT scans in selection of patients for pectus excavatum surgery: a preliminary report. J Pediatr Surg 1987;22:904–6.
13. Höppener PF, Kragten HA, Winkens R. Cardiological aspects of symptomatic pectus excavatum in adults. In: Saxena A, editor. Chest wall deformities. Heidelberg: Springer; 2007. p. 261–78.
14. Mueller C, Saint-Vil D, Bouchard S. Chest X-ray as a primary modality for preoperative imaging of pectus excavatum. J Pediatr Surg 2008;43:71–3.
15. Robicsek F, Watts LT. Pectus carinatum. Thorac Surg Clin 2010; 20:563–74.
16. Westphal FL, Lima LC, Lima Neto JC, Chaves AR, Santos Júnior VL, Ferreira BL. Prevalence of pectus carinatum and pectus excavatum in students in the city of Manaus, Brazil. J Bras Pneumol 2009; 35:221–6.
17. Malek MH, Fonkalsrud EW, Cooper CB. Ventilatory and cardiovascular responses to exercise in patients with pectus excavatum. Chest 2003;124:870–82.
18. De Feria AE, Bajaj NS, Polk DM, Desai AS, Blankstein R, Vaduganathan M. Pectus excavatum and right ventricular compression in a young athlete with syncope. Am J Med 2018;131: e451–3.
19. Lawson ML, Mellins RB, Paulson JF, Shamberger RC, Oldham K, Azizkhan RG, Hebra AV, Nuss D, Goretsky MJ, Sharp RJ,

Holcomb GW 3rd, Shim WK, Megison SM, Moss RL, Fecteau AH, Colombani PM, Moskowitz AB, Hill J, Kelly RE Jr. Increasing severity of pectus excavatum is associated with reduced pulmonary function. J Pediatr 2011;159: 256–61.

20. Almeida VP, Ferreira AS, Guimarães FS, Papathanasiou J, Lopes AJ. The impact of physical activity level, degree of dyspnoea and pulmonary function on the performance of healthy young adults during exercise. J Bodyw Mov Ther 2019;23:494–501.

21. Tokur M, Demioz SM, Sayan M, Tokur N, Arpag H. Chest wall deformities and coincidence of additional anomalies, screening results of the 25,000 Turkish children with the review of the literature. Current Thoracic Surgery 2016;1:21–7.

22. Awad SF, Barbosa-Barros R, Belem Lde S, Cavalcante CP, Riera AR, Garcia-Nielba J, Anselm DD, Baranchuk A. Brugada phenocopy in a patient with pectus excavatum: systematic review of the ECG manifestations associated with pectus excavatum. Ann Noninvasive Electrocardiol 2013;18:415–20.

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