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Association between thoracic inlet diameter ratio and clavicle fractures: A case-control study

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ABSTRACT

Background: Clavicle fractures account for 2–10 % of skeletal injuries, often resulting from lateral shoulder falls (87 % of cases), and are common in pediatric and young adult populations. Despite their clinical importance, the role of anatomical factors like thoracic inlet dimensions in fracture risk is poorly understood.
Methods: This STROBE-compliant case–control study evaluated the association between thoracic inlet measurements—anterior–posterior (AP) diameter, transverse diameter, and area—and clavicle fracture risk, with secondary analyses by age, sex, and BMI.
Results: We studied 27 patients with clavicle fractures and 53 matched controls (aged 18–65 years) who underwent chest CT evaluation for suspected clavicle fracture following upper chest trauma but were confirmed to have no fracture; their CTs were then used for thoracic inlet measurements. Statistical analyses compared AP diameter, transverse diameter, and transverse/AP ratio between groups. The fracture group showed a significantly larger AP diameter (5. 80 ± 0.90 cm vs. 5. 34 ± 0.77 cm, $p = 0.0181$) and a significantly lower transverse/AP ratio (1. 88 ± 0.31 vs. 2. 08 ± 0.39, $p = 0.025$) than controls, suggesting a relatively broader, narrower inlet shape is associated with fractures. Transverse diameter (10. 68 ± 1.15 cm vs. 10. 85 ± 0.93 cm, $p = 0.424$) and inlet area (59. 15 ± 10.60 cm^2 vs. 57. 84 ± 9.34 cm^2, $p = 0.5742$) were similar between groups. Subgroup analyses indicated stronger differences in males (e.g., transverse/AP ratio: 1. 77 ± 0.33 vs. 2. 09 ± 0.40, $p = 0.005$) and those with BMI <23 kg/m ^{2} (e.g., transverse/AP ratio: 1. 69 ± 0.39 vs. 2. 14 ± 0.42, $p = 0.007$).
Conclusions: We conclude that increased AP diameter and reduced transverse/AP ratio of the thoracic inlet may elevate clavicle fracture risk, highlighting anatomical influences on susceptibility. Further biomechanical and preventive studies are needed.

Introduction

Clavicle fractures are a notable clinical entity, comprising up to 10 % of all fractures and representing the most common fracture type in the pediatric population [1]. These injuries typically arise from a lateral impact to the shoulder, most frequently due to falls. Diagnosis is established radiographically, with treatment determined by the fracture's severity and displacement. Although most clavicle fractures are managed nonoperatively, those exhibiting severe displacement or comminution may require surgical stabilization.

The primary etiology of clavicle fractures is direct trauma, with approximately 87 % of cases attributed to falls onto the lateral shoulder. Less frequent causes include direct blows and falls onto an outstretched hand. Epidemiologically, clavicle fractures account for 2 % to 10 % of all fractures, with an annual incidence of approximately one per 1000 individuals [2]. A bimodal age distribution is observed, predominantly affecting young males due to sports-related injuries and older adults due to falls [3]. The clavicle's distinctive S-shaped configuration and subcutaneous position render it susceptible to fracture, even from relatively low-impact trauma [4].

Significant advancements have been made in elucidating the injury mechanisms and optimizing management strategies for clavicle fractures. However, anatomical risk factors influencing fracture susceptibility and outcomes have received comparatively little attention. Notably, the dimensions of the thoracic inlet—including its anteroposterior and transverse diameters and overall level—may modulate

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the biomechanical forces acting on the clavicle during trauma. While previous studies have extensively detailed the epidemiology, pathophysiology, and imaging modalities for clavicle fractures [5–7] anatomical predictors like thoracic inlet geometry remain poorly characterized, necessitating biomechanical investigations.

To address this gap, we conducted an observational study adhering to STROBE guidelines to investigate whether thoracic inlet dimensions are associated with the risk of clavicle fractures. By delineating the association between thoracic inlet dimensions and clavicle fractures, this study aims to enhance the understanding of anatomical risk factors, potentially refining both nonoperative and surgical management approaches. Furthermore, these findings may provide a basis for incorporating thoracic inlet measurements into clinical risk assessment tools for patients with shoulder injuries.

Methods

Study design and setting

This case–control study was designed to investigate the association between the thoracic inlet diameter and the occurrence of clavicle fractures. The study was conducted at the Karaj Shahid Madani Educational-Therapeutic Center during 2023–2024. The study protocol was reviewed and approved by the Ethics Committee of Alborz University of Medical Sciences (IR.ABZUMS.REC.1403.097), and written informed consent was secured from all participants. Cases were defined as patients diagnosed with clavicle fractures secondary to high-energy upper chest wall traumas (e.g., vehicular accidents), while control subjects were age- and sex-matched individuals without any history of clavicle fractures.

Participant recruitment

Eligible participants were those aged between 18 and 65 years. The inclusion criteria for the case group were: a history of high-energy trauma affecting the upper chest, radiologically confirmed clavicle fracture on computed tomography (CT) imaging, and willingness to participate as evidenced by signed written informed consent. Individuals were excluded if they fell outside the age range, had missing critical data (e.g., unavailable CT scan information), or presented with other significant skeletal injuries such as vertebral or rib fractures, or clinically evident chest wall deformities (e.g., pectus excavatum or pectus carinatum). Control subjects comprised individuals who also experienced upper chest wall trauma and underwent chest CT evaluation for suspected clavicle fracture, but were subsequently confirmed radiologically to have no fracture. These controls were selected to ensure they did not have pre-existing conditions that would necessitate a CT for thoracic inlet syndrome or other known thoracic inlet abnormalities prior to their trauma evaluation. These controls were matched to cases by age (using five-year intervals) and sex.

Data collection

Data collection was conducted using a combination of direct measurements, patient interviews, and record reviews. Anthropometric measurements, including weight and height, were collected using standardized instruments. These quantitative data were complemented by information on smoking status, blood pressure, family history of heart disease, and dyslipidemia, which were obtained via structured questionnaires. Diabetes was defined as a fasting blood glucose level greater than 125 mg/dL, or current use of a special diet or medication for glycemic control. A systolic blood pressure exceeding 140 mmHg, a diastolic blood pressure exceeding 90 mmHg, or the use of antihypertensive drugs were considered as definition for the hypertension. Body mass index (BMI) was calculated using the formula: BMI = weight (kg) / [height (m)]^2.

Imaging assessment

All participants underwent chest CT scans using either 64-, 16-, or 325-slice scanners. Multi-slice CT protocols were applied according to local standards. Patients were scanned in a supine position with the neck in a neutral alignment and the arms resting at their sides; scans were performed with or without the administration of intravenous contrast. Axial, coronal, and sagittal reconstructions were generated with slice thicknesses between 1- and 5-mm. Eligibility was confirmed by reviewing these imaging studies. For the measurement of the thoracic inlet, multi-planar reconstructed (MPR) images from neck CT scans were utilized. Where necessary, angulation was standardized relative to the axial plane using the landmarks of the first dental arch and, if required, maximum intensity projection (MIP) was applied. The lateral, superior, and medial borders of the first dental arch; the posterior limit defined by the anterior border of the vertebral body; the T_1 vertebra; and the anterior border of the posterior limit of the sternal manubrium were used as anatomical boundaries. Additionally, the Haller index was defined by dividing the transverse diameter of the chest by the anterior-posterior distance on a chest CT scan, measured on the axial slice showing the shortest span between the anterior surface of the vertebral body and the posterior surface of the sternum [8]. Fig. 1 showcases the measurement of the anteroposterior (AP) and transverse diameters, and indicates the reference points for the Haller index measurement.

Measurements of the thoracic inlet (AP diameter, transverse diameter) were performed on axial CT images at the anatomically defined plane of the thoracic inlet, which is a central structure. The Haller Index was also measured centrally using sternal and vertebral body landmarks. Given the exclusion of severe co-existing thoracic skeletal injuries or deformities, and the typical nature of the clavicle fractures included, significant distortion of these central thoracic inlet measurements by the unilateral clavicle fracture itself was considered unlikely. These parameters reflect the inherent bony anatomy of the thoracic inlet rather than acute changes from the clavicle fracture.

Sample size and sampling

Sample size calculations were performed using G*Power software. Based on an expected effect size of 0.6, a 95 % confidence level, and 80 % power, a minimum sample of 36 participants per group was initially estimated. Adjusting for a 1:2 ratio of cases to controls, the final sample comprised 27 individuals in the case group and 53 in the control group. Cases were selected through consecutive sampling based on the study criteria, and control subjects were recruited from eligible patients presenting with similar trauma but without confirmed fractures, ensuring matching on age and sex.

Data analysis

Data were entered into SPSS version 26 (IBM Corp., Armonk, NY, USA). Quantitative variables are presented as mean ± standard deviation, while categorical variables are summarized as frequencies and percentages. The normality of distributions was assessed using the Shapiro–Wilk test. Comparisons of group means for continuous variables were performed using independent-samples *t*-tests or Mann-Whitney U tests as appropriate based on normality, while categorical variables were analyzed using the chi-square test or Fisher's exact test when necessary. A p-value of <0.05 was considered statistically significant.

Reporting guideline

This Methods section has been developed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies.

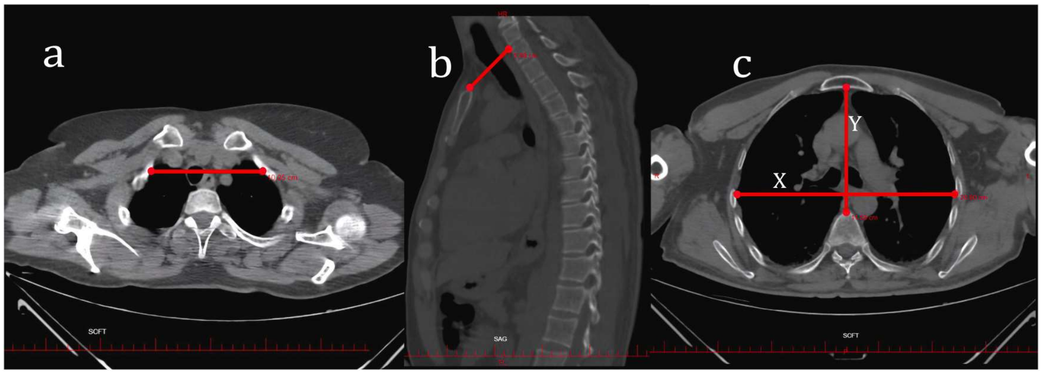

Fig. 1. Representative axial Computed Tomography (CT) images demonstrating thoracic inlet measurements. (a) Transverse diameter (double-headed arrow) measured as the widest distance between the medial aspects of the first ribs. (b) Anteroposterior (AP) diameter (doubleheaded arrow) measured from the posterior aspect of the manubrium sterni to the anterior superior aspect of the T1 vertebral body. (c) Landmarks for the Haller index: the transverse diameter of the chest (X) divided by the shortest anteroposterior distance (Y) between the posterior surface of the sternum and the anterior surface of the vertebral body at the same axial level (typically the level of the xiphisternal joint or narrowest point).

Results

A total of 80 participants were enrolled and allocated to either the case group ($n = 27$) or the control group ($n = 53$). The demographic characteristics of the study population are summarized in Table 1. The mean age did not differ significantly between the case (40. 0 ± 12.9 years) and control (42. 3 ± 12.8 years) groups ($p = 0.446$). However, participants in the case group had a significantly lower mean Body Mass Index (BMI) compared to the control group (22. 9 ± 2.1 kg/m ^{2} vs. 25. 4 ± 2.9 kg/m ^{2}, respectively; $p < 0.001$). The proportion of males was higher in the case group (70.4 %) than in the control group (58.5 %), but this difference was not statistically significant ($p = 0.427$). Fig. 1 provides a representative example of the radiological measurements performed.

Radiological measurements

Comparisons of thoracic inlet radiological measurements between case and control groups are presented in Table 2. Cases exhibited a significantly greater mean anteroposterior (AP) diameter compared to controls (5. 80 ± 0.90 cm vs. 5. 34 ± 0.77 cm; $p = 0.018$). While the mean transverse diameter did not differ significantly between groups (Cases: 10. 68 ± 1.15 cm; Controls: 10. 85 ± 0.93 cm; $p = 0.424$), the ratio of transverse diameter to AP diameter was significantly lower in the case group (1. 88 ± 0.31) compared to the control group (2. 08 ± 0.39; $p = 0.025$). No significant difference was observed in the chest inlet area between cases and controls (59. 15 ± 10.60 cm^2 vs. 57. 84 ± 9.34 cm^2; $p = 0.574$). Furthermore, there was no significant difference in the Haller index between the case and control groups (1. 81 ± 0.24 vs. 1. 86 ± 0.22; $p = 0.413$).

Table 1
Demographic characteristics of study participants.

Variable		Cases ($n = 27$)	Controls ($n = 53$)	p-value[c]
Age (years), mean ± SD[a]		40. 0 ± 12.9	42. 3 ± 12.8	0.446
BMI[b] (kg/m ^{2}), mean ± SD		22. 9 ± 2.1	25. 4 ± 2.9	<0.001
Gender, n (%)	Female	8 (29.6 %)	22 (41.5 %)	0.427
	Male	19 (70.4 %)	31 (58.5 %)	

[a] SD: Standard Deviation.
[b] BMI: Body Mass Index.
[c] p-values derived from independent *t*-tests for continuous variables and Chi-square test for categorical variables.

Table 2
Comparison of thoracic inlet radiological measurements between cases and controls.

Variable	Cases ($n = 27$)[a]	Controls ($n = 53$)	p-value[b]
Anteroposterior (AP) Diameter (cm)	5. 80 ± 0.90	5. 34 ± 0.77	0.018
Transverse Diameter (cm)	10. 68 ± 1.15	10. 85 ± 0.93	0.424
Chest Inlet Area (cm^2)	59. 15 ± 10.60	57. 84 ± 9.34	0.574
Ratio (Transverse Diameter / AP Diameter)	1. 88 ± 0.31	2. 08 ± 0.39	0.025
Haller Index	1. 81 ± 0.24	1. 86 ± 0.22	0.413

[a] Data presented as mean ± standard deviation.
[b] p-values derived from independent *t*-tests.

Subgroup analyses

Analyses stratified by gender, age, and BMI provided further insights.

Gender-specific analysis

Gender-specific comparisons are detailed in Table 3. Among males, cases had a significantly larger AP diameter (5.85 ± 0.74 cm vs. 5. 25 ± 0.81 cm; $p = 0.011$) and a significantly lower transverse-to-AP diameter ratio (1. 77 ± 0.33 vs. 2. 09 ± 0.40; $p = 0.005$) compared to controls. A trend towards a smaller transverse diameter was observed in male cases compared to male controls (10. 14 ± 1.16 cm vs. 10. 72 ± 1.02 cm; $p = 0.073$). In contrast, the Haller index did not differ significantly between male cases and controls (1. 79 ± 0.22 vs. 1. 86 ± 0.22; $p = 0.256$). Among females, no statistically significant differences were found between cases and controls for any of the measured radiological parameters (AP diameter: $p = 0.535$; transverse diameter: $p = 0.101$; inlet area: $p = 0.844$; ratio: $p = 0.346$; Haller index: $p = 0.822$).

Age-group analysis

Comparisons within specific age groups are presented in Table 4. In the 30–39-year age group, cases demonstrated a significantly lower transverse-to-AP diameter ratio compared to controls (1. 73 ± 0.31 vs. 2. 07 ± 0.29; $p = 0.040$), with a trend towards a larger AP diameter (6. 14 ± 1.07 cm vs. 5. 39 ± 0.46 cm; $p = 0.061$). However, the Haller index did not show a significant difference in this age group (1. 76 ± 0.22 vs. 1. 86 ± 0.17; $p = 0.329$). In the 20–29-year group, a trend towards a smaller transverse diameter was noted in cases relative to controls (10. 05 ± 0.92 cm vs. 10. 78 ± 0.68 cm; $p = 0.056$). Similarly, in the 40–49-year group, trends towards a larger AP diameter ($p = 0.193$), smaller

Table 3
Comparison of radiological measurements stratified by gender.

Variable	Gender	Cases[a]	Controls	p-value[b]
Anteroposterior (AP) Diameter (cm)	Male	5. 85 ± 0.74	5. 25 ± 0.81	0.011
	Female	5. 70 ± 1.24	5. 47 ± 0.71	0.535
Transverse Diameter (cm)	Male	10. 14 ± 1.16	10. 72 ± 1.02	0.073
	Female	10. 40 ± 1.20	11. 03 ± 0.76	0.101
Chest Inlet Area (cm²)	Male	59. 08 ± 8.81	56. 23 ± 10.31	0.322
	Female	59. 32 ± 14.76	60. 12 ± 7.41	0.844
Ratio (Transverse / AP Diameter)	Male	1. 77 ± 0.33	2. 09 ± 0.40	0.005
	Female	1. 90 ± 0.46	2. 06 ± 0.37	0.346
Haller Index	Male	1. 79 ± 0.22	1. 86 ± 0.22	0.256
	Female	1. 87 ± 0.30	1. 85 ± 0.21	0.827

[a] Data presented as mean ± standard deviation.
[b] p-values derived from independent *t*-tests comparing cases vs. controls within each gender stratum.

transverse diameter ($p = 0.061$) and lower ratio ($p = 0.097$) were observed in cases, although these did not reach statistical significance. No significant differences were observed in the 50–59- or 60–69-year age groups for any parameter.

BMI-based analysis

Comparisons stratified by BMI category are shown in Table 5. Within the BMI <23 kg/m ^{2} category, cases had a significantly larger AP diameter (6. 03 ± 1.00 cm vs. 5. 24 ± 0.70 cm; $p = 0.030$), a significantly smaller transverse diameter (9. 87 ± 1.18 cm vs. 11. 01 ± 0.99 cm; $p = 0.013$), and a significantly lower transverse-to-AP diameter ratio (1. 69 ± 0.39 vs. 2. 14 ± 0.42; $p = 0.007$) compared to controls. No significant differences were detected between cases and controls in the BMI 23–26 kg/m ^{2} category for any parameter. In the BMI 26–29 kg/m ^{2} category, comparisons were limited by insufficient data for cases in some measures, and no significant differences were observed ($p \geq 0.050$ for all parameters).

Discussion

Our findings indicate that specific thoracic inlet morphology, characterized by a relatively larger anteroposterior (AP) diameter and a correspondingly lower transverse/AP ratio, is associated with an increased risk of clavicular fractures. This suggests that the *shape* of the thoracic inlet—specifically one that is more ovoid in the sagittal plane and relatively narrower transversely—may play a more critical role in fracture susceptibility than absolute dimensions like transverse diameter or overall inlet area, which did not significantly differ between our groups. Such a morphology could plausibly alter biomechanical force transmission across the shoulder girdle during trauma, potentially concentrating stress on the clavicle.

The observed associations appeared more pronounced in certain subgroups, although these findings should be interpreted cautiously due to smaller sample sizes within these strata. Specifically, the link between thoracic inlet shape and fracture risk was evident in males and individuals with a lower BMI (<23 kg/m ^{2}), where a more anteroposteriorly elongated and transversely narrower inlet was associated with fractures. These observations may suggest that factors such as sex-specific anatomical differences, bone mineral density, or the amount of soft-tissue cushioning could modulate the influence of thoracic inlet geometry on clavicle vulnerability. For instance, lower BMI might indicate less protective soft tissue or potentially lower bone mass, exacerbating the biomechanical disadvantages of certain inlet shapes. The lack of significant findings in females or higher BMI groups warrants further investigation with larger cohorts.

Table 4
Comparison of radiological measurements stratified by age group.

Variable	Age Group (years)	Cases[a]	Controls	p-value[b]
Anteroposterior (AP) Diameter (cm)	20–29	5. 49 ± 0.89	5. 24 ± 0.80	0.510
	30–39	6. 14 ± 1.07	5. 39 ± 0.46	0.061
	40–49	5. 91 ± 0.78	5. 37 ± 0.77	0.193
	50–59	5. 92 ± 1.02	5. 19 ± 0.88	0.184
	60–69	5. 64 ± 0.76	5. 56 ± 1.12	0.928
Transverse Diameter (cm)	20–29	10. 05 ± 0.92	10. 78 ± 0.68	0.056
	30–39	10. 40 ± 1.30	11. 02 ± 0.72	0.222
	40–49	9. 42 ± 1.39	10. 69 ± 1.20	0.061
	50–59	10. 97 ± 1.10	11. 11 ± 0.84	0.794
	60–69	10. 57 ± 0.23	10. 67 ± 1.10	0.910
Chest Inlet Area (cm²)	20–29	55. 25 ± 10.86	56. 84 ± 11.41	0.755
	30–39	63. 96 ± 14.09	59. 14 ± 3.17	0.284
	40–49	55. 03 ± 6.26	57. 16 ± 8.95	0.629
	50–59	64. 35 ± 8.46	57. 33 ± 8.72	0.171
	60–69	59. 52 ± 6.80	59. 89 ± 15.88	0.977
Ratio (Transverse / AP Diameter)	20–29	1. 88 ± 0.40	2. 09 ± 0.24	0.162
	30–39	1. 73 ± 0.31	2. 07 ± 0.29	0.040
	40–49	1. 63 ± 0.36	2. 05 ± 0.49	0.097
	50–59	1. 92 ± 0.48	2. 22 ± 0.51	0.303
	60–69	1. 89 ± 0.30	1. 97 ± 0.31	0.776
Haller Index	20–29	1. 86 ± 0.24	1. 86 ± 0.14	0.957
	30–39	1. 76 ± 0.22	1. 86 ± 0.17	0.329
	40–49	1. 70 ± 0.26	1. 83 ± 0.27	0.326
	50–59	1. 88 ± 0.32	1. 93 ± 0.28	0.764
	60–69	1. 88 ± 0.19	1. 79 ± 0.19	0.592

[a] Data presented as mean ± standard deviation.
[b] p-values derived from independent *t*-tests comparing cases vs. controls within each age stratum.

Our study diverges from much of the existing literature, which has predominantly focused on demographic and injury-specific factors like age, gender, trauma intensity, or fracture displacement as predictors of clavicle fracture occurrence or outcomes [9]. In our cohort, while overall age and gender distribution did not significantly differ between cases and controls ($p = 0.446$ and $p = 0.427$, respectively), the strong association with thoracic inlet dimensions highlights the potential under-recognized contribution of inherent anatomical variations. Furthermore, the significantly lower BMI observed in our fracture group ($p < 0.001$) introduces body composition as an important interacting factor, possibly influencing fracture risk independently or in conjunction

Table 5
Comparison of radiological measurements stratified by BMI category.

Variable	BMI Category (kg/m ^{2})	Cases[a]	Controls	p-value[c]
Anteroposterior (AP) Diameter (cm)	<23	6. 03 ± 1.00	5. 24 ± 0.70	0.030
	23–26	5. 61 ± 0.66	5. 43 ± 0.66	0.485
	26–29	4.61 ± nan[b]	5. 18 ± 1.00	0.590
Transverse Diameter (cm)	<23	9. 87 ± 1.18	11. 01 ± 0.99	0.013
	23–26	10. 56 ± 1.00	10. 92 ± 0.97	0.338
	26–29	11.68 ± nan	10. 71 ± 0.90	0.319
Chest Inlet Area (cm^2)	<23	59. 31 ± 11.42	57. 66 ± 8.91	0.684
	23–26	59. 40 ± 10.33	59. 26 ± 8.75	0.967
	26–29	53.84 ± nan	55. 32 ± 10.56	0.895
Ratio (Transverse / AP Diameter)	<23	1. 69 ± 0.39	2. 14 ± 0.42	0.007
	23–26	1. 90 ± 0.26	2. 04 ± 0.33	0.227
	26–29	2.53 ± nan	2. 15 ± 0.51	0.481
Haller Index	<23	1. 73 ± 0.26	1. 89 ± 0.22	0.093
	23–26	1. 88 ± 0.16	1. 84 ± 0.19	0.521
	26–29	2.27 ± nan	1. 89 ± 0.28	0.206

[a] Data presented as mean ± standard deviation (SD).
[b] nan' indicates standard deviation could not be calculated due to insufficient sample size ($N = 1$) in that subgroup cell for cases.
[c] p-values derived from independent *t*-tests comparing cases vs. controls within each BMI stratum.

with skeletal geometry.

The importance of individual anatomical geometry in fracture risk, as suggested by biomechanical modeling studies like that of Duprey et al.[10]., is empirically supported by our findings. Their work using finite element models indicated that geometric variations could predict clavicle fracture risk; our CT-based measurements provide clinical evidence correlating specific thoracic inlet dimensions with actual fracture occurrence. While previous research has noted thoracic inlet pathologies in the context of broader trauma [11], the specific relationship between baseline thoracic inlet *dimensions* and isolated clavicular fracture risk has been less explored. This study begins to address this gap by demonstrating an association between these anatomical characteristics and fracture susceptibility.

Nonetheless, several limitations warrant consideration. First, the relatively modest sample size, particularly when stratified for subgroup analyses (e.g., females, specific age/BMI strata), may limit statistical power and the generalizability of these subgroup findings. While our overall sample met the pre-specified power calculation for the primary hypothesis, larger studies are indeed warranted to confirm these findings, especially within subgroups, and to detect potentially more subtle associations. Second, the case-control design identifies associations but cannot establish causality. Third, our study included cases resulting from high-energy trauma, often leading to CT imaging. While clavicle fractures certainly occur in such scenarios, this may limit the generalizability of our findings to the broader population of clavicle fractures, which frequently result from lower-energy mechanisms like ground-level falls or sports injuries where CT scans are less commonly performed. It is possible that the association between thoracic inlet anatomy and fracture risk differs by injury mechanism and energy level. Future research should explore these anatomical factors in cohorts with varied trauma mechanisms.

In summary, this study demonstrates that specific thoracic inlet dimensions, particularly an increased AP diameter and a decreased transverse-to-AP ratio, are associated with clavicular fractures. This association appears stronger in males and individuals with lower BMI. These findings offer novel insights into anatomical factors potentially influencing shoulder girdle injury risk and could inform future biomechanical research and potentially risk assessment strategies. Further prospective studies with larger, diverse populations and detailed trauma mechanism data are needed to validate these results and explore underlying biomechanical principles.

Conclusion

This observational study demonstrates that the ratio of thoracic inlet diameters may be a significant factor associated with the risk of clavicular fracture. Our findings indicate statistically significant differences in both the anteroposterior and transverse diameters between patients with clavicular fractures and the control group, suggesting that these measurements may serve as reliable markers for identifying individuals at an elevated risk of such fractures.

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Use of Large language models

Large language model (Gemini 2.5 Pro Preview 03–25, Google) was utilized to assist with language refinement and clarity check of the manuscript draft. All final content, analysis, and conclusions were determined solely by the human authors, who take full responsibility for the work.

Ethical approval

This study was approved by the Ethics Committee of Alborz University of Medical Sciences (IR.ABZUMS.REC.1403.097).

CRediT authorship contribution statement

Mohammad Sajjad Mirhosseini: Writing – review & editing, Project administration. **Arvin Najafi:** Writing – review & editing, Supervision, Resources. **Shayan Shahsavary Alavijeh:** Conceptualization, Methodology, Investigation, Writing – original draft, Visualization, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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