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STUDY OF THE RADIOLOGICAL CARRYING ANGLE IN MALES AND FEMALES AND ITS CLINICAL SIGNIFICANCE: A CROSS-SECTIONAL OBSERVATIONAL STUDY.

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Abstract

Background:

The carrying angle, or cubital angle, is the angle formed between the upper arm and forearm when the elbow is fully extended and supinated, with a notable difference between genders. This anatomical feature plays a significant role in activities like walking and carrying objects, while also serving as a key indicator for sex differentiation in anthropology.

Aim:

The study aims to assess the gender differences in the carrying angle among males and females and explore its clinical implications for orthopedic practices.

Method:

This study was conducted in Keonjhar, analyzing 70 elbow radiographs (36 males and 34 females) aged 16 - 40 years. The carrying angle was measured using specific anatomical references on the radiographs, and statistical analysis was carried out to evaluate gender differences.

Results:

The average age of participants was 35 years, with 51.4% being male and 48.6% female. The mean carrying angle was prominently higher in females (22.29°) when compared to males (15.72°), with a difference of 7.25° ($p < 0.0001$). The minimum and maximum carrying angles for females were 17.50° and 29.60°, while for males, they were 9.00° and 18.70°. Variance analysis confirmed significant differences in carrying angles between genders.

Conclusion:

The study demonstrates a significant gender-based variation in the carrying angle, with females exhibiting a greater angle than males. These findings can aid in clinical assessments and orthopedic treatments related to elbow anatomy and function.

Keywords: *Carrying Angle, Gender Differences, Elbow Anatomy, Radiological Assessment*
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Introduction

The carrying angle, also referred to as the cubital angle, is the angle formed between the upper arm and the forearm when the elbow is fully extended and the forearm is in a supinated position. This anatomical feature is more pronounced when the forearm diverges laterally, allowing it to form an angle with the upper arm. The carrying angle typically disappears or becomes neutralized when the forearm is flexed and pronated. It is generally accepted that this angle is larger in females compared to males, classifying it as a secondary sexual characteristic. The functional role of the carrying angle is significant during activities like walking, where it enables the forearms to clear the hips during arm swings, as well as in carrying objects by providing an ergonomic arm position [1-3].

The normal range of the carrying angle is often reported to be between 155 and 180 degrees, or 0 to 25 degrees when expressed as the supplementary angle. The supplementary angle refers to the smaller angle formed by the deflection, which can be calculated by subtracting the carrying angle from 180 degrees [4,5]. This angle is anatomically impacted by the structural configuration of the elbow joint, specifically by the distal placement of the medial trochlear margin and the ulnar shaft angulation concerning the significant ridge linking the coronoid process and the olecranon. These structural changes influence the development and variability of the carrying angle among diverse groups and sexes [6].

A detailed understanding of the carrying angle is essential from both an anthropological and clinical perspective. In anthropology, it serves as a useful marker for sex differentiation. Clinically, this angle is vital for managing elbow-related injuries, such as the reduction of supracondylar fractures, where alterations in the carrying

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angle can lead to cosmetic deformities and functional impairments [7]. Additionally, it plays a critical role in the design of total elbow prostheses, ensuring they accommodate natural variations in the carrying angle. This study aims to conduct a radiological assessment of the carrying angle among males and females, exploring its variation and clinical importance, particularly in the context of orthopedic treatment and rehabilitation.

Aim of the study:
The study aims to assess the gender differences in the carrying angle among males and females and explore its clinical implications for orthopedic practices.

Materials and method
Study design:
A cross-sectional observational study.

Study site:
The study was conducted at various clinical laboratories and hospitals in Keonjhar, Odisha for a period of one year (September 2023 to September 2024), to provide a diverse range of elbow X-rays for analysis. The data collection and analysis were centralized at a medical institution in Keonjhar to ensure consistency.

Study Population:
A total of 70 adult elbow X-rays were obtained, consisting of 36 men and 34 women. The participants' ages spanned from 16-40 years, with an average age of 35 years. All participants were adults without a history of elbow deformities or surgeries affecting the joint.

Sample size:
The sample consisted of 70 radiographs, with 36 males and 34 females.

Inclusion Criteria:
The study involved participants aged 16 to 40 years. Only X-rays showing normal anteroposterior images of the elbow, with the joint completely straightened and the forearm fully rotated outward, were chosen for evaluation. Additionally, participants were required to have no history of elbow deformities or previous surgical interventions that could affect the structure or function of the joint.

Exclusion Criteria:
Radiographs with any obliquity or rotational misalignment were not considered, as well as those where the two humeral epicondyles were not visible or where the radial head, neck, and tuberosity did not show slight superimposition over the upper part of the ulna. Participants with existing elbow valgus deformity or medial deviation of the elbow, or those who had undergone surgeries like supracondylar fracture repair or total elbow arthroplasty, were also excluded to avoid any factors that could alter the carrying angle.

Bias:
To address potential sources of bias, the study employed strict inclusion and exclusion criteria to ensure a homogenous sample of participants without prior elbow deformities or surgeries. Additionally, measurements of the carrying angle were standardized using the same radiographic techniques and analysis software to minimize variability in data collection.

Data Collection:
Elbow radiographs were sourced from various medical clinics and hospitals in the Keonjhar area of Odisha. The collection included 70 images, featuring 36 males and 34 females, with ages ranging from 16 to 40 years (mean age: 35 years). The selected radiographs were intended for analyzing the carrying angle, with careful attention to positioning to ensure accurate measurements.

Measurement of Carrying Angle:
The carrying angle was measured by drawing two specific lines: one along the central axis of the lower third of the upper arm bone and the other along the central axis of the upper third of the forearm, connecting the radius and ulna through the upper joint between these two bones. These lines were extended until they met at the midpoint of the line connecting the two bony prominences on the elbow. The angle formed at this intersection was recorded as the carrying angle. This measurement technique was consistently applied to each X-ray.

Statistical analysis:
Statistical evaluation was carried out utilizing the average, standard deviation (SD), and t-test to analyze gender-related differences in the carrying angle. A p-value below 0.0001 was considered significant. This benchmark was employed to determine the relevance of the differences observed.

Ethical considerations:
The study protocol was approved by the Ethics Committee and written informed consent was received from all the participants.

Results
The results indicate that the average carrying angle for females was 22.29° (SD: 2.13°, SE: 0.36°), while for males, it is significantly lower at 15.72° (SD: 1.41°, SE: 0.23°). The observed difference between the genders is 6.57°, with a standard deviation of 0.72° and a standard error of 0.13°. The minimum carrying angle recorded for females was 18.50°, with a maximum of 28.60°, whereas males exhibited a minimum of 14.00° and a maximum of 18.50° (Table 1). These findings highlight a notable gender difference in the carrying angle, suggesting that

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females generally showed a greater angle in contrast to males, which may have implications for understanding anatomical variations and functional biomechanics.

Table 1: Gender-Based Differences in Elbow Measurements

Patient gender	Patient count (N)	Mean	SD	Std Error	Minimum	Maximum
Female	34	22.29°	2.13°	0.36°	18.50°	28.60°
Male	36	15.72°	1.41°	0.23°	14.00°	18.50°
Difference of both	-	6.57°	0.72°	0.13°	4.5°	9.5°

The findings in Table 2 provide an in-depth analysis of variance for the measurements of the carrying angle, utilizing both the pooled and Satterthwaite approaches. The pooled method, which assumes equal variances, indicates 49 degrees of freedom and a highly significant p-value of less than 0.0001, demonstrating a substantial statistical difference in carrying angles between the sexes. In contrast, the Satterthwaite method, which is appropriate for cases with unequal variances, results in 48.025 degrees of freedom and similarly shows a significant p-value of less than 0.0001. The consistency of the results obtained from both methods strengthens the conclusion presented in Table 1 regarding the significant anatomical disparities in carrying angles between males and females.

Table 2: Analysis of Variance for Carrying Angle Measurements Across Sexes

Strategy	Variances	Degrees of freedom	Pr> |t|
Satterthwaite approximation	Unequal	48.025	< 0.0001
Consolidated variance	Equal	49	< 0.0001

Discussions:

Comprehending the measurement and variations of the carrying angle of the elbow is essential for assessing traumatic elbow injuries and conditions. Unlike the findings of [7], who indicated no significant difference between males and females, this current study demonstrated a more pronounced disparity in carrying angles according to gender. This is consistent with previous research that evaluated the carrying angle by examining the trochlear and olecranon-coronoid angles, which reported a statistically significant distinction between males and females [2,8]. In the present investigation, the angle between the longitudinal axis of the arm and the forearm was measured, revealing a more noticeable gender difference.

Supporting these results, a prior study confirmed a larger difference in carrying angles between males and females [9]. Additionally, while a study employed three-dimensional radiographs for their measurements, the current study utilized image 'J' software. Both investigations substantiated the presence of a significant gender disparity in carrying angles [10]. The increased carrying angle observed in females is often viewed as a secondary sexual trait, as studies indicate no variance in carrying angles between genders before puberty; this angle tends to increase in females subsequently [5]. This enhancement may also be linked to increased joint laxity in females, which allows for a greater range of elbow extension, contributing to an elevated carrying angle [11,12].

Historical studies, explored the carrying angle in the left upper limb of 100 adults (50 males and 50 females) using radiographs, providing valuable insights into the variations of this angle [6]. Similarly, a study measured the carrying angle with a goniometer, reporting values of 12.23° ± 0.30° for males and 15.77° ± 0.41° for females. In comparison to the findings of the present study, these angles also demonstrated a greater difference [5]. Another study identified an inverse relationship between carrying angle and an individual's height; however, the current study concentrated exclusively on gender differences [13].

Furthermore, a study discovered an increased carrying angle in the dominant upper limb relative to the non-dominant side, whereas this study maintained consistency across both sides of the upper limb [5]. A study observed that the carrying angle physiologically increases with age, typically progressing from childhood until around 16 years of age. Therefore, the present investigation specifically selected X-rays from participants aged 16 to 40 years to mitigate the influence of physiological variations on the outcomes [14].

Research by groups classified the carrying angle as a secondary sexual characteristic, a point that was notably emphasized in the findings of this study, which revealed a significant increase in carrying angle among females compared to males [12,15]. The analysis showed mean and standard deviation values of 15.72° ± 1.41° for males and 22.29° ± 2.13° for females, highlighting the substantial gender difference in carrying angles. Overall, the data indicate that the carrying angle is greater in females than in males, underscoring the importance of considering gender in clinical evaluations of elbow anatomy.

Generalizability:

The generalizability of the study findings may be limited due to the specific demographic and geographic context of the participants, as the study was conducted in

Keonjhar, Odisha, with a sample primarily consisting of young adults aged 16 to 40 years. While the significant differences in carrying angles between genders provide valuable insights, the results may not be fully applicable to populations outside this region or to individuals of different ages, ethnic backgrounds, or those with pre-existing conditions affecting elbow anatomy. Future studies should aim to replicate these findings across diverse populations to enhance their external validity and applicability in broader clinical settings.

Conclusion

The findings indicate that the carrying angle can serve as a valuable parameter for identifying gender in radiographic assessments. This knowledge can aid orthopedic practitioners in diagnosing and correcting elbow deformities more effectively.

Limitations:

The limitations of this study include a small sample population who were included in this study. Furthermore, the lack of a comparison group also poses a limitation for this study's findings.

Recommendations:

Future research could expand on these findings by exploring the carrying angle across different age groups, ethnicities, and clinical conditions, as well as incorporating three-dimensional imaging techniques for a more comprehensive analysis. Additionally, investigating the implications of carrying angle variations on functional outcomes in elbow injuries could further enhance the clinical utility of this measurement in orthopedic practice.

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List of abbreviations:

SD: Standard Deviation

Source of funding:

No funding was received.

Conflict of interest:

The authors have no conflicting interests to declare.

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