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# Normative Data of Carpal Bone Measurements in the Sample Adult Indian Population

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## Abstract

**Introduction** Radiography is the most often accessible and affordable imaging modality. Accurate assessments of wrist X-rays can aid in the diagnosis and prognostic evaluation of various wrist problems. This study aims to identify normal radiographic anthropometry reference values and variations of carpal bones and joints by gender and age in sample Indian population, with the potential to be clinically applicable.

**Materials and Methods** Two investigators conducted a prospective analysis of normal wrist radiographs in a single center. Radiology Information Systems and Picture Archiving and Communication Systems were used to collect standard digitized normal X-rays without significant osseous pathology over a year. We conducted measurements of length, angles, and indices in a standard posteroanterior and lateral wrist X-rays in order to establish the standard dimensions and variances based on age and gender.

**Results** A total of 18 measurements which included eight linear measurements, eight angles, and two ratios were documented. A total of 500 X-rays of 250 males and 250 females with 125 of each in two age groups of 20 and 40 years and 41 and 60 years were evaluated.

**Conclusion** This work is a comprehensive database of the Indian population measuring parameters in normal wrist radiographs of posteroanterior and lateral views. The results of our study indicate that men and younger individuals had a significantly higher carpal height ratio. The width of distal radial ulnar joint space was significantly lesser in older subjects. Additionally, males showed a significantly higher lunate uncovered ratio and radial height. When compared to the literature, the study revealed a significant positive ulnar variance in elderly people and women. However, we noted an overall increase in the percentage of positive ulnar variance individuals in our study. We also recorded a marginal increase in radial inclination with no variations across gender and age.

**Keywords**
- ► normative
- ► wrist
- ► Indian
- ► carpal height ratio
- ► ulnar variance

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## Introduction

The source and cause of wrist pain are similar to searching the black box due to the complex anatomy of the joint. Apart from clinical examination, a systematic radiographic evaluation helps in early diagnosis and appropriate, definitive treatment of the underlying disorder. This requires a proper understanding of the normal radiographic morphology of the wrist. Even though new imaging technologies are available, simple radiographs are still the gold standard for assessing the bone structures of the wrist.

Health care professionals use carpal indices and metrics to diagnose and treat wrist conditions. There are observable morphological differences not just between ethnic and gender categories but also between monozygotic twins[1] Consequently, precise sex and age determinations need population-specific measurements.[2] Palmar tilt, radial inclination, radial height, and ulnar variance are terms used in diagnosing the very common distal radius fractures and evaluating the effectiveness of fracture reduction.[1] Ulnar variance, carpal height ratio (CHR), and its determinants are useful in evaluating Kienbock's disease and other degenerative wrist conditions.[2] Intercarpal angles play an important role in determining carpal instability.[3] The contralateral wrist cannot be used as a reference in bilateral conditions. Some conditions that appear to be unilateral have very modest asymptomatic involvement on the side considered normal.[4] Previous research on normative data on wrist indices has talked about factors that matter in either the posteroanterior view[1,2] or the intercarpal angles,[3] with a smaller sample size. Indian studies on normative data mention mainly the morphometry of the distal end radius.[5,6] There is very limited Indian study on the morphometry of carpal bones and its possible variations according to age and sex. This article aims to provide a standard and comprehensive normative database of radiographic measurements in both posteroanterior and lateral views of the wrist in an Indian population.

## Materials and Methods

After institutional board ethical clearance, we conducted a prospective analysis of normal posterior–anterior (PA) and lateral wrist radiographs. Using the Radiology Information Systems and Picture Archiving and Communication Systems (RIS-PACS), we collected standard digitized normal wrist X-rays and measured various linear and angular parameters over 1 year.

Normal wrist X-rays were based on radiographs of patients presenting with abrasion, contusion, and laceration to the hand and wrist and radiographs of the wrist obtained from patients presenting with carpal tunnel syndrome, tenosynovitis, and benign swellings such as ganglion and lipoma. Contralateral radiographs of patients presenting with radius malunion, scaphoid nonunion, and Kienbock's disease, which were taken as controls, were also included in the study.

Patients with a history of previous trauma or surgery, as well as those whose wrist radiographs indicated skeletal immaturity, were excluded from the study. The sample size for the study was calculated to be 500 X-rays, which was attempted to be evenly distributed among the age groups of 21 to 40 years and 41 to 60 years. We compared the carpal measurements in these age groups and also between males and females within those age groups. Only the true PA and lateral (SPC [Scaphoid, pisiform and capitate]) radiographs were included in the study, as any deviation from this would result in improper measurement of indices.[7]

### Various Normal Radiographic Measurements on a Posterior–Anterior View

1. Radial height: This is the distance between two lines perpendicular to the long axis of radius, one passing through the tip of radial styloid and other passing through the most distal aspect of the ulnar articular surface[5] (►**Fig. 1A**).
2. Distal radial ulnar joint (DRUJ) space: This is the width of the space at the middle of the DRUJ. It is measured by marking a point at the center of the ulnar part of DRUJ, and another point corresponding to this on the radial part of DRUJ. The distance between these two points gives the width of DRUJ space[1] (►**Fig. 1B**).
3. Lunate width: A line is drawn tangential to the radial part of DRUJ. Another line perpendicular to the above line is drawn passing through the center of the lunate. Lunate width is the distance between the medial and lateral surfaces of the lunate on this line[1] (►**Fig. 1C**).
4. Lunate uncovered width: It is the length of the lunate extending to the ulnar side as measured along its width[1] (►**Fig. 1C**).
5. Length of the capitate: This is measured as the distance between the point of intersection of the capitate articular facets for the second and third metacarpals and the proximal subchondral bony cortex of the capitate head along a line passing through the center of the capitate head[1](►**Fig. 1D**).
6. Length of the third metacarpal: This is the distance between the distal-most point on the distal end and the proximal-most point on the proximal end of third metacarpal in its long axis[1](►**Fig. 1E**).
7. Carpal height: This is the distance from the base of the third metacarpal to the distal articular surface of radius measured along the long axis of the third metacarpal[1] (►**Fig. 1F**).
8. Ulnar variance: Here a line is drawn through the distal ulnar aspect of the radius perpendicular to the long axis of the radius. The distance between this line and the distal cortical margin of the ulna gives the ulnar variance[1] (►**Fig. 1G**).

### Angles

1. Radial inclination: This is measured as the angle between the lines (1) the line perpendicular to the long axis of the distal end of the radius and passing through the ulnar-most point of the distal radial articular surface. (2) The line passing through the distal-most point on the radial styloid tip and the ulnar-most point of the distal radial articular surface[5] (►**Fig. 2A**).
2. Radius, third metacarpal angle: This is the angle between the long axis of the distal end of the radius and the long axis of third metacarpal[1] (►**Fig. 2B**).

 

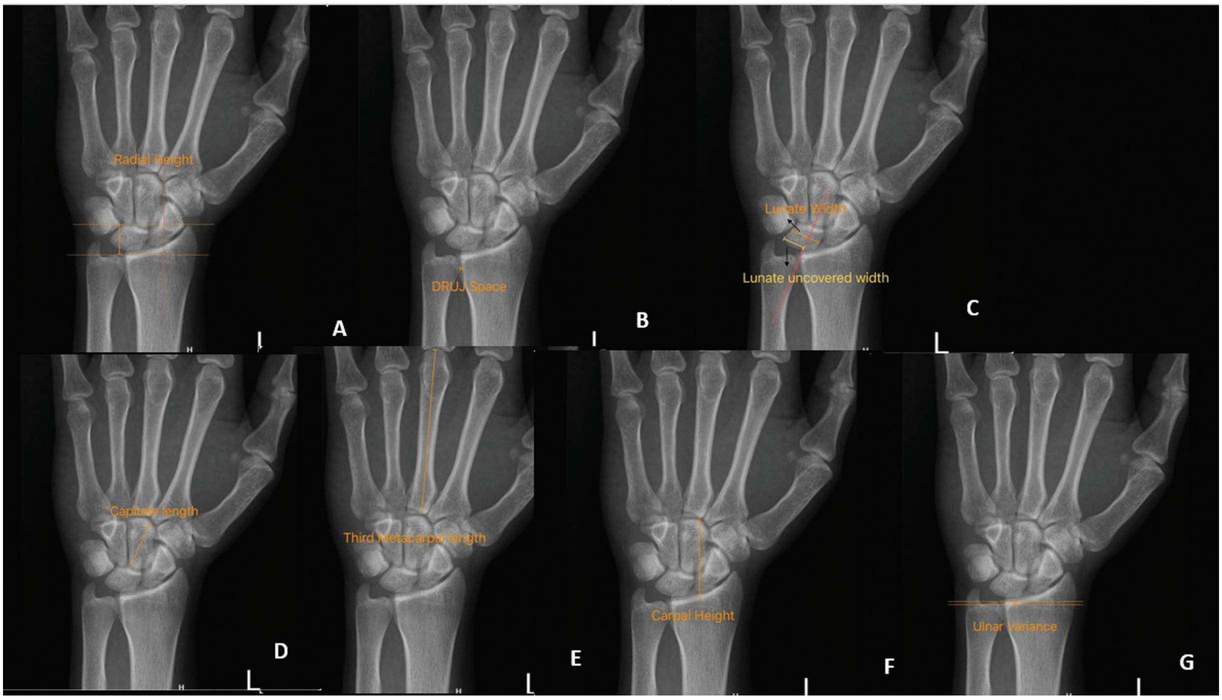


**Fig. 1** Various linear measurement on a posteroanterior view.

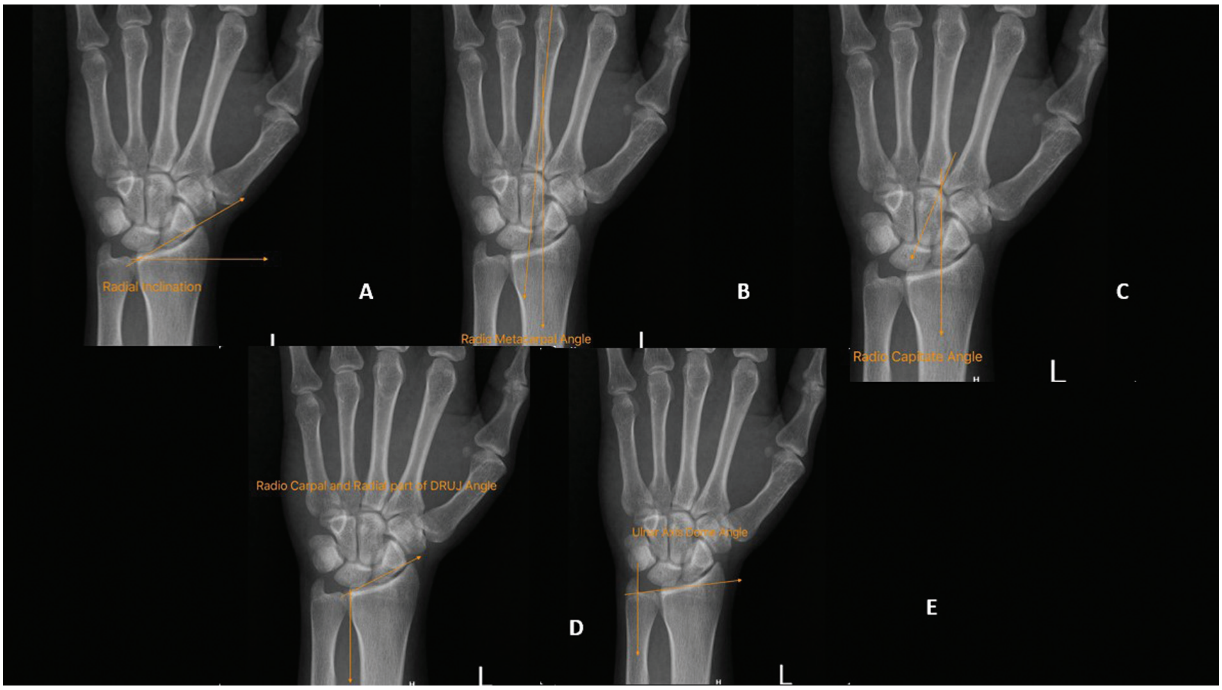


**Fig. 2** Various angular measurement on a posteroanterior view.

3. Radio capitate angle: This is the angle between the long axis of the distal end of the radius and the long axis of the capitate[1] (►**Fig. 2C**).
4. Radio-carpal/radial part of the DRUJ angle: This is the angle between the line of the distal radio carpal joint arc and the radial part of the distal radio ulnar joint[1] (►**Fig. 2D**).
5. Ulnar axis dome angle: This is the angle between the long axis of the ulna and a line passing through the distal-most point of the dome of ulna and the point of junction between the ulnar dome and the ulnar styloid[1] (►**Fig. 2E**).

## Indices

1. CHR: described by Youm et al.
   (carpal height/length of third metacarpal) (1).
2. Lunate uncovered ratio: (lunate uncovered length/lunate width) $\times$ 100.[1]

 

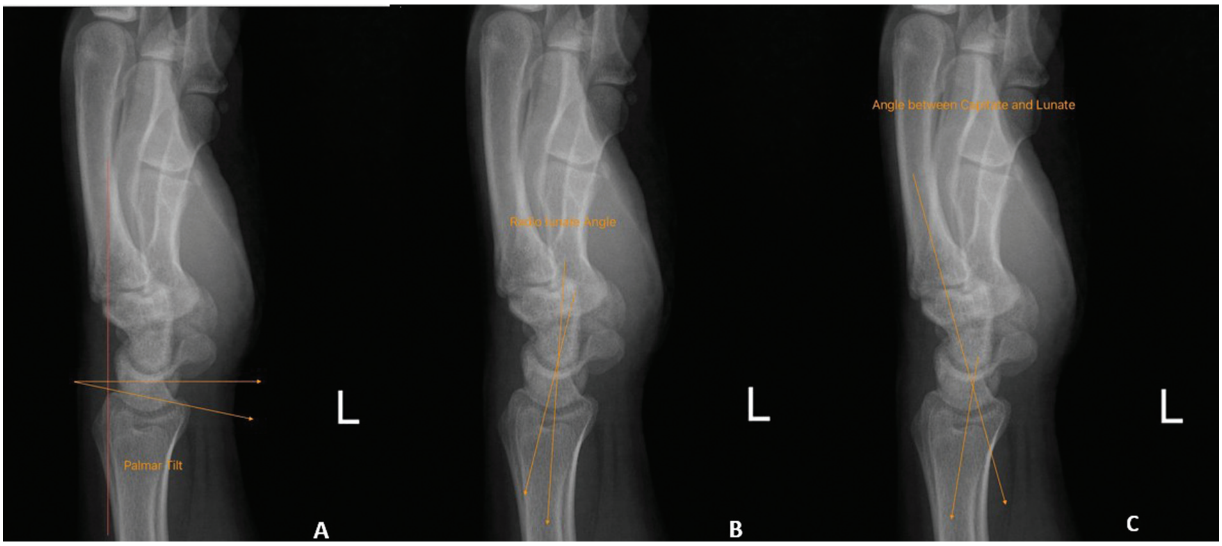


**Fig. 3** Various angular measurements on a lateral view.

### Various Normal Radiographic Measurements on a Lateral View

1. Palmar tilt: This is measured between the lines, one perpendicular to the long axis of the radius and passing through the most distal point on the dorsal rim of the distal articular surface of the radius and other line joining the most distal points of dorsal and ventral rims of the distal articular surface of the distal end of radius[5](►**Fig. 3A**).
2. Radio lunate angle: They are represented as positive if the carpal bones are palmar fixed and negative if they are dorsiflexed with respect to the long axis of radius[1] (►**Fig. 3B**).
3. Capito lunate angle: This is measured between the long axis of the capitate and the long axis of the lunate[1] (►**Fig. 3C**).

## Statistical Analysis

The coefficient of variation (CoV) was calculated for all the measurements in the literature (CoV = standard deviation/mean multiplied by 100). The sample size was calculated using the formula $Z^2 \sigma^2/D^2$ where $Z$ is the critical value (1.96), σ is the standard deviation, and $D$ is the margin of error. The sample size for the study was calculated to be 500 x-rays, which was attempted to be evenly distributed among each group. The data were analyzed using the latest SPSS version and expressed as the sample mean, median, and standard deviation. A $p$-value less than 0.05 was considered statistically significant. Interobserver comparisons of the measurements were done using an intraclass correlation test of two observers for 150 radiographs. Intraobserver comparisons, measurements were done by the principal investigator 1 month apart as a pilot study.

## Results

The wrist radiographs of 500 subjects comprising 250 males and 250 females were studied. They were equally divided into 125 of each in two age groups of 20 to 40 years and 41 to 60 years The mean age of patients was 38.5 years. To evaluate the reliability of our measurements, we calculated the intraclass correlation coefficient for both intraobserver and interobserver variability. The results ranged from 0.824 to 0.986, indicating good-to-excellent agreement between the two observers for all 18 parameters measured.

The morphometric data of all the measurements in 500 normal subjects are shown in ►**Table 1**.

►**Table 2** shows the change in the morphometry of wrist bones according to gender.

Significant observations were made between males and females (►**Table 2**). Lengths of the radial height, lunate width, lunate uncovered width, capitate length, third metacarpal length, carpal height, and ulnar variance showed significantly higher values in males compared to females. The ulnar axis dome angle was larger in females, while the CHR was larger in males. Both the findings were statistically significant.

►**Table 3** shows changes in the morphometry of the wrist according to age.

The DRUJ space ($p = 0.004$) and the CHR ($p < 0.001$) exhibited statistically significant higher values in the group of 20 to 40 years. The ulnar variance was significantly positive in the elderly age group of 41 to 60 years ($p = 0.01$) (►**Table 3**).

## Discussion

In routine clinical practice, two-dimensional plain X-rays in both the PA and lateral planes are the primary method for imaging the wrist. Pathological problems are diagnosed largely through X-ray evaluation, with additional investigations conducted as needed. When examining the congruity of the carpus, lateral radiographs are necessary because intercarpal bone congruence is diagnostic for many wrist diseases. Larsen et al[3] measured carpal bone angles on lateral wrist radiographs for the first time in 1991 in Denmark with 75 wrist X-rays. This study used a standardized radiographic approach to determine

 

**Table 1** Morphometric data of wrist bones in 500 normal adults

| Sl. No. | Measurements | Mean | Median | SD |
|---|---|---|---|---|
| 1. | Radial height | 14.2 | 14.1 | 2.2 |
| 2. | DRUJ space | 1.52 | 1.48 | 0.53 |
| 3. | Lunate length | 13.2 | 13 .4 | 2.2 |
| 4. | Lunate uncovered width | 6.9 | 7.1 | 2.2 |
| 5. | Length of capitate | 21.4 | 21.2 | 5.1 |
| 6. | Third metacarpal length | 62.4 | 62.2 | 6.4 |
| 7. | Carpal height | 32.6 | 32.2 | 3.4 |
| 8. | Ulnar variance | −0.12 | 0.001 | 1.414 |
| Angles in degrees in posteroanterior view | | | | |
| 9. | Radial Inclinations | 24.7 | 24.4 | 3.9 |
| 10. | Radius third metacarpal angle | 10.3 | 8.6 | 5.2 |
| 11. | Radio capitate angle | 25.4 | 25.2 | 7.8 |
| 12. | Radio carpal/radial part of DRUJ angle | 106.7 | 107.8 | 10.2 |
| 13. | Ulnar axis dome angle | 77.4 | 76.5 | 9.6 |
| Ratio in posteroanterior view | | | | |
| 14. | Carpal height ratio | 0.51 | 0.51 | 0.05 |
| 15. | Lunate uncovered ratio (%) | 39.2 | 38.9 | 11.7 |
| Angles in lateral view in degrees | | | | |
| 16. | Palmar tilt | 11.8 | 11.9 | 2.3 |
| 17. | Radiolunate angle | 16.1 | 14.5 | 7.7 |
| 18. | Capitolunate angle | 16.8 | 16.2 | 11.1 |

Abbreviations: DRUJ, distal radial ulnar joint; SD, standard deviation.

**Table 2** Changes in the morphometry of the wrist bones according to gender

| Sl. No. | Measurements | Male (*n*: 250) mean ± SD | Female (*n*: 250) mean ± SD | *p*-Value |
|---|---|---|---|---|
| Length in mm in posterior anterior view | | | | |
| 1. | Radial height | 14.4 ± 2.4 | 13.2 ± 2.2 | <0.001[a] |
| 2. | DRUJ_space | 1.62 ± 0.52 | 1.53 ± 0.48 | 0.2 |
| 3. | Lunate width | 14.4 ± 2.2 | 12.4 ± 2.1 | <0.001[a] |
| 4. | Lunate uncovered width | 7.4 ± 0.2 | 6.3 ± 0.1 | <0.001[a] |
| 5. | Length of capitate | 22.3 ± 2.2 | 19.4 ± 2.3 | <0.001[a] |
| 6. | Third metacarpal length | 64.3 ± 5.1 | 59.2 ± 5.3 | <0.001[a] |
| 7. | Carpal height | 34.2 ± 3.3 | 31.4 ± 3.2 | <0.001[a] |
| 8. | Ulnar variance | −0.612 ± 1.3 | 0.413 ± 1.42 | 0.0001 |
| Angles in degrees in posteroanterior view | | | | |
| 9. | Radial inclinations | 24.72 ± 3.9 | 24.6 ± 3.8 | 0.9 |
| 10. | Radius third metacarpal angle | 10.73 ± 5.4 | 9.84 ± 4.9 | 0.2 |
| 11. | Radio capitate angle | 25.82 ± 8.2 | 24.94 ± 7.3 | 0.4 |
| 12. | Radiocarpal - radial part of DRUJ angle (degrees) | 105.94 ± 10.7 | 107.95 ± 9.6 | 0.3 |
| 13. | Ulnar axis dome angle (degree) | 74.84 ± 9.1 | 79.93 ± 9.3 | <0.001[a] |

(*Continued*)

 

**Table 2** (*Continued*)

| Sl. No. | Measurements | Male (*n*: 250) mean ± SD | Female (*n*: 250) mean ± SD | *p*-Value |
|---|---|---|---|---|
| Ratio in posteroanterior view | | | | |
| 14. | Carpal height ratio | 0.53 ± 0.05 | 0.50.43 ± 0.05 | <0.001[a] |
| 15. | Lunate uncovered ratio (%) | 39.9 ± 11.97 | 36.7 ± 11.1 | <0.001[a] |
| Angles in lateral view in degrees | | | | |
| 16. | Palmar tilt | 11.54 ± 2.2 | 11.93 ± 2.3 | 0.2 |
| 17. | Radiolunate angle | 15.72 ± 7.9 | 16.54 ± 7.4 | 0.5 |
| 18. | Capitolunate angle | 16.83 ± 11.1 | 16.86 ± 11.2 | 0.9 |

Abbreviations: DRUJ, distal radial ulnar joint; SD, standard deviation.
[a]*p*-Value < 0.05 is considered statistically significant.

**Table 3** Changes in the morphometry of the wrist according to age

| Sl. No. | Measurements | 20–40 y mean ± SD | 41–60 y mean ± SD | *p*-Value |
|---|---|---|---|---|
| Length in mm in posterior anterior view | | | | |
| 1. | Radial height | 14.4 ± 2.2 | 14.2 ± 2.2 | 0.48 |
| 2. | DRUJ_space | 1.644 ± 0.52 | 1.41 ± 0.48 | 0.004[a] |
| 3. | Lunate width | 12.5 ± 1.6 | 12.9 ± 1.6 | 0.7 |
| 4. | Lunate uncovered width | 6.5 ± 1.6 | 6.4 ± 1.6 | 0.42 |
| 5. | Length of capitate | 20.7 ± 2.8 | 20.7 ± 3.3 | 0.85 |
| 6. | Third metacarpal length | 62.1 ± 5.1 | 62.2 ± 5.2 | 0.80 |
| 7. | Carpal height | 31.8 ± 3.4 | 32.3 ± 3.4 | 0.24 |
| 8. | Ulnar variance | −0.4353 ± 1.3 | 0.134 ± 1.42 | 0.01[a] |
| Angles in degrees in posteroanterior view | | | | |
| 9. | Radial inclinations | 24.96 ± 3.77 | 24.25 ± 3.92 | 0.155 |
| 10. | Radius third metacarpal angle | 10.23 ± 4.91 | 10.23 ± 5.43 | 0.1 |
| 11. | Radio capitate angle | 25.87 ± 8.15 | 24.84 ± 7.34 | 0.3 |
| 12. | Radiocarpal-radial part of DRUJ angle | 1.06 ± 10.81 | 1.07 ± 9.58 | 0.488 |
| 13. | Ulnar axis dome angle | 76.41 ± 9.90 | 78.30 ± 9.04 | 0.124 |
| Ratio in posteroanterior view | | | | |
| 14. | Carpal height ratio | 0.53 ± 0.05 | 0.50 ± 0.05 | <0.001[a] |
| 15. | Lunate uncovered ratio (%) | 38.9 ± 12.16 | 39.1 ± 11.05 | 0.350 |
| Angles in lateral view in degrees | | | | |
| 16. | Palmar tilt | 11.52 ± 2.23 | 11.92 ± 2.23 | 0.171 |
| 17. | Radiolunate angle | 15.67 ± 7.98 | 16.42 ± 7.39 | 0.45 |
| 18. | Capitolunate angle | 16.8 ± 11.1 | 16.75 ± 11.19 | 0.98 |

Abbreviations: DRUJ, distal radial ulnar joint; SD, standard deviation.
[a]*p*-Value < 0.05 is considered statistically significant.

the normal intercarpal angles for wrist ligamentous injury evaluation.[3] Following that, in the United States, Schuind et al[1] conducted research in 1992 on a normal database of the PA radiographic measurement of the carpal bones in 300 wrist X-rays. The study records the typical differences in the wrist's posteroanterior and lateral dimensions based on age and sex, which is useful for analyzing the development of carpal instability, osteoarthritis, rheumatoid arthritis, clinical research, and wrist implant design.[1] In 1998, Feipel et al conducted a study on 80 wrist X-rays in Belgium to create a database of carpal posteroanterior radiographic measures for clinical application.[2] In 2006, Franco-Valencia et al studied 112 radiographs of healthy Mexican wrists in PA and lateral views and found that wrist measures vary by ethnicity and can provide useful information for surgical care and follow-up.[8] Mohammed Ali conducted research on 300 PA radiographic measurements of the wrist in healthy Egyptians and compiled a reference database of normal radiographic measurements, relationships, and variations between bones of the wrist according to age and gender.[9] Significant research has been dedicated to examining the morphometry of the distal radius,[5,6] ulnar variance[10] (10), and CHR[11] in India. However, no comprehensive studies have been conducted on wrist measurements of both PA and lateral radiographs encompassing all the relevant measurements. Hence, the study was undertaken.

### Carpal Height Ratio and its Determinants

The CHR is a useful predictor of carpal collapse, which can occur in various wrist disorders such Kienbock's disease and wrist arthritis of different causes such as rheumatoid, scaphoid nonunion, and scapholunate injury advanced diseases. It is derived from the third metacarpal length and the carpal height.

Our study demonstrated the average third metacarpal length (mm) to be $62.4 \pm 6.1$ which was comparable to various studies in the literature (►**Table 4**).[12–16] Our study demonstrated mean carpal height (mm) to be $32.4 \pm 0.3$ which was comparable to various studies in the literature (►**Table 4**).[12–16] Our study demonstrated capitate length to be $22.3 \pm 2.3$ which was comparable to various studies in the literature (►**Table 4**).[12–16] In the studies conducted by Tang et al,[17] Jafari et al,[12] and Vaezi et al,[13] males exhibited significantly greater carpal height, third metacarpal height, and capitate length compared to females. Notably, our study also demonstrated higher values of the above parameter in males compared to females ($p < 0.001$) with no difference across the age group. Youm et al,[18] who documented a standard value of $0.54 \pm 0.04$, first proposed the CHR. Foteva and Poposka[16] conducted a study in Macedonia and found that the CHR was $0.53 \pm 0.02$ based on wrist measurements. A radiographic study conducted in Taiwan recorded an average CHR of $0.51 \pm 0.03$.[19] Jehan et al,[11] Jafari et al,[12] and Yalcin et al[14] reported an average CHR of $0.52 \pm 0.04$. The CHR in the recently published indices on Nigerian population ($0.47 \pm 0.04$) by Ominde et al was lower than the CHR reported in all the studies described above.[15] Our study demonstrated mean CHR to be $0.51 \pm 0.05$ which was comparable to various studies in the literature. In accordance with the findings of Wang et al,[19] our study reveals a notable disparity between genders in the CHR with significantly higher values in males and in the age group of 41 to 60 years. In contrast, Jehan et al,[11] Jafari et al,[12] Yalçin and Polat,[14] and Foteva and Poposka[16] reported no significant gender difference in the CHR. In their research on the natural history of scaphoid nonunion, Mack et al[20] observed that the CHR dropped progressively as the duration of nonunion increased. They reported that carpal collapse occurred in 18% of nonunions after 5 to 9 years and in 50% of cases after 20 years or more. The study concluded that the carpus had been determined as collapsed when the CHR value was less than 0.50.

### Ulnar Variance

In our study using the method of perpendiculars, the ulnar variance was found to be $-0.148 \pm 1.44$ mm in contrast to the study by Schuind et al[1] which demonstrated the ulnar variance to be $-0.9 \pm 1.5$ mm. A study by Jung et al[21] examined 120 volunteers and found that the mean ulnar variance was $+0.74 \pm 1.46$. The variance was lower in men than in women. A study by Ghalimah et al[22] investigated 104 patients and found that 56.2% had a negative ulnar variance and 43.8% had a neutral variance. In a study conducted by Iqbal et al[23] including 156 patients, it was shown that ulnar positive was the most frequently seen variance, occurring in 39.7% of the patients. This was followed by ulnar negative in 35.9% of the patients, and neutral variance in 24.4% of the patients. Their average variance was $+0.36$ mm with a standard deviation of 1.5.

In a study conducted by Pradyuth Athikari et al,[10] ulnar variance was analyzed in a specific group of individuals from the Indian population. The results showed that 70% of cases had ulnar negative variance, while 30% had a neutral variant with no cases of positive variance. The mean-variance was found to be $+0.42 \pm 1.48$ mm, and it was observed that males had lower variance compared to females. In our study, it was negative in 48.75%, neutral in 18.75%, and positive in 32.5% of subjects. There was a significant change in ulnar variance in our study, between younger and older age groups with a more positive ulnar variance in older subjects ($p = 0.01$). This might be due to degenerative changes with thinning of triangular fibrocartilage and proximal migration of the ulna as described by Schuind et al.[1] The articular cartilage over the radial head becomes thinner and sometimes almost disappears with age.[24] In contrast to this, the articular cartilage over the proximal end of the ulna is rarely affected.[24] Ulnar variance was significantly more positive in women in our study ($p = 0.0001$). This may be attributed to a lesser incidence of lunatomalacia in females.[25]

### Parameters Associated with Distal End Radius

In a study on morphometry of distal radius in central Indian population of 242 subjects by Mishra et al,[5] the mean value of radial inclination was recorded to be

**Table 4** Comparison of our determinants of the carpal height ratio with other studies in the literature

| Measurements in millimeters across various studies | Jafari et al[12] | Vaezi et al[13] | Yalçın et al[14] | Ominde et al[15] | Foteva and Poposka[16] | Our study |
|---|---|---|---|---|---|---|
| Third metacarpal length (mm) | $61.4 \pm 5.6$ | $70.1 \pm 5.55$ | $65.09 \pm 3.47$ | $67.34 \pm 4.78$ | $65.3 \pm 5.09$ | $62.4 \pm 6.1$ |
| Carpal height (mm) | $32.2 \pm 2.8$ | $37.1 \pm 3.8$ | $32.69 \pm 3.37$ | $31.77 \pm 2.63$ | $32.78 \pm 3.0$ | $32.4 \pm 0.3$ |
| Capitate length (mm) | $21.8 \pm 2.3$ | $23.8 \pm 2.39$ | $21.95 \pm 2.28$ | $23.34 \pm 2.02$ | $22.0 \pm 1.3$ | $22.3 \pm 2.3$ |

 

23.27 ± 7.42 degrees, palmar tilt 10.07 ± (SD) 5.28 degrees, and radial height 11.31 ± 4.9 mm. However, the difference between the genders were not statistically significant except radial height which was significantly more in males than in females. Mann et al[26] who studied 100 normal wrists reported the palmar tilt of 3 to 20 degrees with more palmar tilt in women. In a study on radiographic morphometry of distal radius in the South Indian population by Nekkanti et al,[6] the mean value of the radial height was recorded to be 8.8 ± 2.9 mm, radial inclination to be 21.58 ± 3.35 degrees, and the palmar tilt averaged 11.36 ± 3.16 degrees. The mean radial height for males was 9.2 ± 2.7 mm which was significantly more than females. However, in our study palmar tilt was 11.8 ± 2.3 degrees with no significant change with respect to age and sex. Our study recorded a slightly higher mean radial height of 14 .2 ± 2.4 mm with significantly higher values in males and no difference across the age groups. Our study recorded a marginal increase in mean radial inclination of 24.7. ± 3.9 degrees with no variations across genders and age groups.

In a study by Schuind et al,[1] the mean DRUJ space was found to be 1.6 ± 0.5 with no difference across the gender. The mean width of DRUJ space in our study was found to be 1.52 ± 0.53. The width of DRUJ space was significantly lesser in older subjects ($p = 0.004$) with no difference across genders. This could be attributed to progressive degenerative changes in the joint as in other joints as described by Schuind et al.[1] The lunate uncovered ratio which is determined by the lunate uncovered width and the lunate width was described by Gilula et al.[27] It was described as a quantitative method to measure ulnar translocation.[27] Normally, this is less than 50%. According to Schuind et al, it is 32.6 ± 11. In our study, it was 39.91 ± 11.97 and significantly more in men ($p = 0.0001$). There has been no detailed data-based study among normal concerning this finding. This may be one of the predisposing factors for lunatomalacia (Kienbock's disease).

In contrast to previous studies conducted on a comparable topic, the sample size of the cohort under investigation in our study is substantial with a prospective design. Nonetheless, further efforts are required to ensure adequate representation of diverse ethnic backgrounds. The study group has acceptable homogeneity regarding age and gender distribution. Two authors utilized the PACS system to conduct all necessary procedures electronically, and subsequently, the reliability of both interobserver and intraobserver was assessed.

## Conclusion

In summary, our study found that the CHR was considerably higher in men and in the younger age group which was comparable to various studies in the literature. Furthermore, it was observed that males exhibited a considerably higher lunate uncovered ratio and the radial height. Our study also recorded a marginal increase in radial inclination with no variations across gender and age groups The study revealed that there was a considerable positive ulnar variance in the senior population and in women, which aligns with the findings of previous research. However, we noted an overall increase in the percentage of positive ulnar variance individuals compared to the literature. We provide comprehensive data which includes both radius and carpal indices in a single studied population. These measures are beneficial for studying the population in clinical research and for diagnosing and treating wrist conditions such as osteonecrosis, instability, osteoarthritis, and distal radius fractures. Furthermore, these factors can be advantageous in the design and development of indigenous implants for the treatment of wrist diseases.

### Authors' Contribution

A.K.B. served as the investigator, contributing to the concept, data measurement analysis, statistics, and manuscript editing. A.K.P. was involved in data collection, measurements, analysis, and manuscript editing. M.P.G. handled measurement analysis and manuscript writing. R.M.S., C.K.M., and S.V.S. all contributed to data collection, measurements, and analysis.

### Ethical Approval

Approval Letter Number: KHIEC/879/2021.

### Funding

None.

### Conflict of Interest

None declared.

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