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Evaluation of radiographic measurements of the wrist in the Turkish population

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Ethics Committee Approval
The study was approved by Gaziosmanpasa Education and Research Hospital Ethical Committee (No: 130 / Date: 05.08.2020). All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Abstract

Background/Aim: Wrist parameters measured on direct radiography are essential in diagnosing distal radius fractures and many specific wrist disorders and determining prognosis after treatment. Previous studies have shown the intercommunity variability of these parameters in the literature. To our knowledge, no study in the literature reflects the normal values in the Turkish population. This study aimed to determine the distribution and normal limits of parameters measured in posteroanterior (PA) and direct lateral radiographs of the wrist in our population between age and gender groups.

Methods: In this retrospective cohort study, patients who presented to 2 centers in our clinic between 2014-2020 and had PA and lateral wrist radiographs were retrospectively reviewed. Images from patients who had no significant osseous pathology and had not undergone wrist surgery were randomly selected, and 320 (201 female, 119 male) digital images were retrospectively analyzed. The mean age was 40.45 (13.71). The sample was divided into three groups (18-30, 31-50, over 51) according to age and into two groups according to gender. Radial inclination (RI), lunate fossa inclination (LFA), cord of radiocarpal arch (cord RC), radial shift (Radsh), radial height (RadH), ulnar variance (UV), third metacarpal height (3^{rd} MH), carpal height (CH), capitate height (CapH), lunate transverse length (LL), lunate uncovering length (LUL), scapholunate joint distance (SLD), distal radioulnar joint distance (RUD), volar tilt on lateral radiographs (VT), scapholunate angle (SLA) were measured. The lunate uncovering ratio (LUR) was measured in proportion to the lunate uncovering length (LUL) / lunate transverse length (LL); carpal height ratio (CHR) by proportioning carpal height (CH) / third metacarpal height (3^{rd} MH); revised carpal height ratio (rCHR) was calculated by proportioning the carpal height (CH) / capitate height (CapH).

Results: Although the RI and SL values of angular parameters were similar between the gender groups, the LFI and VT values were significantly higher in the female group (P=0.014 and P=0.004, respectively). All metric parameters were significantly superior in the male group (P<0.001). CHR and rCHR values were similar for proportional parameters, while LUR -values were significantly higher in the male group (P<0.001).

All angular measurement parameters, Cord RC, RadH, RadS, LL, LUL, SLD of metric parameters, and CHR and rCHR values of proportional parameters were similar between age groups (P>0.05). While UV values of metric parameters increased in parallel with age, RUD values decreased significantly (P<0.001). The values of the metric parameters CH 3^{rd} MH, CapH, and proportional parameters LUR values also differed between the groups without being correlated with age (P=0.011, P=0.003, P=0.009, P=0.019, respectively).

Conclusion: In our study, we have given the measurement parameters that can be used as a reference for the Turkish population, the relationships between gender and age groups, and the variability. These parameters can be helpful in the diagnosis and treatment of wrist pathologies, the design and development of implants for the treatment of wrist pathologies for our population.

Keywords: Database, Carpal indices, Turkish population, Wrist measurements, Distal radius angle

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Introduction

Even though the diagnosis of wrist disorders has become easier with the development of imaging techniques, direct radiography is the most common and the first imaging technique we use to evaluate the bony structures of the wrist compared to other radiological examinations [1].

Many parameters are associated with normal wrist structure and carpal pathology clinic on posteroanterior and lateral radiographs [2, 3]. These parameters are commonly used in orthopedic practice to diagnose and treat wrist and carpal pathologies.

For example, parameters such as volar tilt, radial inclination, radial shift, radial height, and ulnar variance are essential for understanding distal radius anatomy, anticipating instability, assessing reduction quality, and making surgical decisions after fractures and in the wrist with malunion [3, 4].

In addition, the carpal height index and the revised carpal height index are used to diagnose carpal collapse due to scapholunate injuries, Kienbock's disease, or rheumatologic diseases [2, 5].

The relationship of parameters such as ulnar variance, radial inclination, lunate fossa inclination, and lunate uncovering index with the pathogenesis of Kienbock's disease has also been studied in the literature [6]. Measurement of scapholunate angle and scapholunate distance; helps assess conditions such as scapholunate disintegration or DISI (dorsal intercalary segment instability) [2, 7]. Studies conducted in the literature show the variability of normal values of these parameters between different populations [2, 5, 8-12].

To our knowledge, no study in the literature reflects the normal values in the Turkish population. This study aimed to determine the distribution and normal limits of the parameters measured in posteroanterior (PA) and direct lateral radiographs of the wrist in our population between age and gender groups.

Materials and methods

The study was approved by Gaziosmanpasa Education and Research Hospital Ethical Committee (No: 130 / Date: 05.08.2020). This study was conducted according to the Helsinki Declaration principles.

In this retrospective cohort study, patients who presented to 2 centers in our hospital between 2014-2020 and had radiographs of the wrist PA and lateral wrist were retrospectively evaluated.

Radiographs of patients who presented with mild trauma to the hand and wrist, contralateral wrist radiographs of patients who presented with severe trauma for control, carpal tunnel, tenosynovitis, simple benign masses (such as ganglion, hemangioma, lipoma), and radiographs of patients who presented for any other reason were included in the study. Radiographs of patients whose skeletal maturity was not complete were excluded from the study. Radiographs of patients whose wrist radiographs showed evidence of osseous pathology, who had a history of previous fracture or orthopedic surgery, and whose radiographs showed malunion were excluded from the study. Consequently, the digital PA and lateral wrist radiographs of 320 patients (201 females, 119 males) were retrospectively analyzed.

The mean age was 40.45 (13.71), and the median was 41 (range 18-81). The sample was divided into three groups according to age. A total of 87 radiographs (27.2%) aged 18-30 years in group a, 150 radiographs (46.9%) aged 31-50 years in group b, and 83 (25.9%) radiographs (over 51 years) in group c. The radiographs of 201 females (62.8%) and 119 males were analyzed for gender characteristics. The descriptive data are summarized in Table 1.

Table 1: Descriptive statistical data for the measured parameters

	Mean ± SD	Median (Min-Max)
Age(years)	40.45 ± 13.71	41 (18 - 81)
Radial Inclination – RI (degrees)	24.14 ± 5.4	24.5 (9 - 39)
Lunate Fossa Inclination – LFI (degrees)	10.85 ± 5.0	11 (-4 - 27)
Volar Tilt – VT (degrees)	13.61 ± 10.96	13 (0 - 32)
Scafolunate Angle – SLA (degrees)	56.16 ± 12.22	58 (10 - 90)
Cord Of Radiocarpal Joint Arc – Cord RC (mm)	29.64 ± 2.69	29.25 (24.2 - 38.8)
Radial Height – RadH (mm)	12.34 ± 2.06	12.2 (6 - 17.1)
Radial Shift – Radsh (mm)	13.41 ± 2.09	13.2 (8 - 20)
Ulnar Variance – UV (mm)	-0.08 ± 3.84	0 (-4 - 4)
Carpal Height – CH (mm)	32.69 ± 3.37	32.2 (23 - 42)
Length Of Third Metacarpal – 3rd MH (mm)	65.09 ± 34.7	63 (31 - 677)
Length Of Capitate – CapH (mm)	21.95 ± 2.28	21.9 (17 - 28.1)
Lunate Length – LL (mm)	14.96 ± 5.42	14.55 (10.6 - 106)
Lunate Uncovering Length – LUL (mm)	5.56 ± 1.71	5.4 (0 - 20.4)
Scafolunat Joint Space – SLD (mm)	1.97 ± 0.99	1.9 (0.7 - 17)
Distal Radioulnar Joint Space – RUD (mm)	1.69 ± 0.54	1.6 (0.8 - 3.6)
Carpal Height Ratio – CHR	0.52 ± 0.06	0.52 (0.05 - 1.13)
Revised Carpal Height Ratio – rCHR	1.49 ± 0.1	1.49 (1.23 - 1.81)
Lunate Uncovering Ratio – LUR	0.38 ± 0.1	0.38 (0 - 0.87)

Radiographic technique

Standard PA radiographs of the wrist; wrist in flexion-extension and ulnar-neutral position relative to radial deviation, forearm in pronation-neutral position relative to supination, elbow in 90 degrees-flexion, shoulder in 90 degrees -abduction. Radiographs of the ulnar styloid seen laterally from the ulnar head were accepted [10].

Standard lateral radiographs: Wrist and forearm in a neutral position, elbow in 90 degrees -flexion, shoulder in 0 degrees -abduction. In the lateral radiographs, the radius, capitate, and the third metacarpals were approximately in line with the sagittal plane. The pisiformis was between the volar edge of the scaphoid tuberosity and the capitate. Patients whose standardization of radiographs was inadequate and could not be taken in the appropriate position were excluded from the study.

Radiographs were performed using the automatic collimator Drgem Diamond 6 A (2013 South Corea) and the digital radiography system Drgem 82 SD (2012 South Corea); the technical values were kV: 60-70, mA: 200, mAs: 8.

By plotting reference lines on PA graphs, radial inclination (RI), lunate fossa inclination (LFA) angles, the cord of the radiocarpal arch (cord RC), radial shift (Radsh), radial height (RadH), ulnar variance (UV), third metacarpal height (3. MH), carpal height (CH), capitate height (CapH), lunate transverse length (LL), lunate uncovering length (LUL), scapholunate joint distance (SLD), distal radioulnar joint distance (RUD). Volar tilt (VT) and scapholunate angles (SLA) were measured on lateral radiographs.

The lunate uncovering ratio (LUR) was measured in proportion to the lunate uncovering length (LUL) / lunate transverse length (LL); carpal height ratio (CHR) by proportioning carpal height (CH) / 3 metacarpal height (3. MH); revised carpal height ratio (rCHR) was calculated by proportioning the carpal height (CH) / capitate height (CapH) (Figure 1). Two board-certified orthopedic surgeons performed measurements twice a month using PACS (Picture archiving and communication systems) Infinitt Pacs 7.0 software (INFINITT

Healthcare Co. Ltd., Seoul, South Corea) to reduce intraobserver and interobserver errors. To calculate the correlation between any two numerical variables Spearman Correlation Analysis was used. Statistical significance was determined as P=0.05 for all cases. Statistical analysis was conducted using IBM SPSS (Statistics Package for Social Sciences for Windows, version 21.0, Armonk, NY, IBM Corp.) package program.

The intraclass correlation coefficient (ICC) with 95% confidence interval (CI) was used to evaluate intraobserver and interobserver reliability. We defined values below 0.4 as indicating poor reliability, values between 0.4 and 0.59 as moderate reliability, values between 0.6 and 0.75 as good reliability, and above 0.75 as excellent reliability (Table 2).

Results

Although the RI and SL values of angular parameters were similar between the gender groups, the LFI and VT values were significantly higher in the female group (P=0.014 and P=0.004, respectively). All metric parameters were significantly superior in the male group (P<0.001). CHR and rCHR values were similar for proportional parameters, while LUR -values were significantly higher in the male group (P<0.001) (Table 3).

All angular measurement parameters, Cord RC, RadH, RadS, LL, LUL, SLD of metric parameters, and CHR and rCHR values of proportional parameters were similar between age groups (P>0.05). While UV values of metric parameters increased in parallel with age, RUD values decreased significantly (P<0.001). The values of the metric parameters CH 3rd MH, CapH, and proportional parameters LUR values also differed between the groups without being correlated with age (P=0.011, P=0.003, P=0.009, P=0.019, respectively) (Table 4).

Table 2: Inter and Intra Observer Reliability Estimates

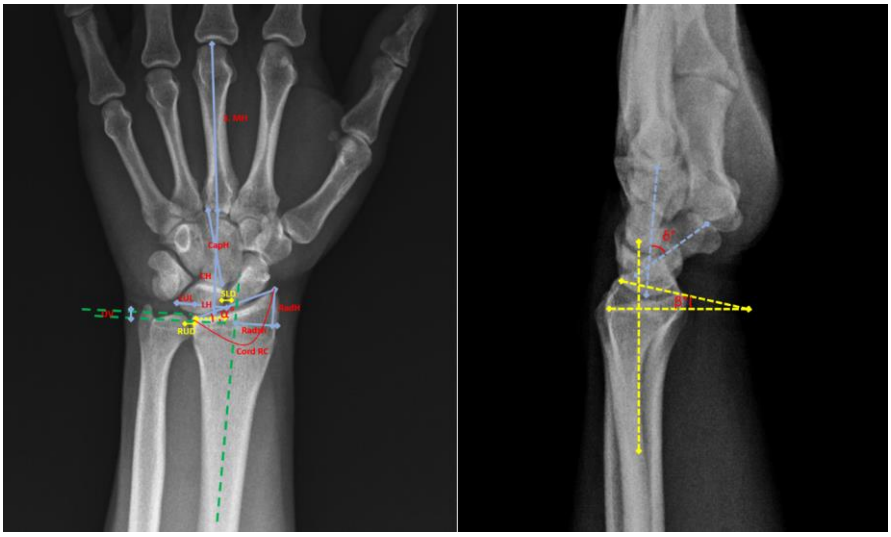
Parameter	Inter ICC	%95 CI	Intra ICC	%95 CI
Radial Inclination – RI (degrees)	0.907	0.907 (0.89-0.922)	0.924	0.924 (0.909-0.936)
Lunate Fossa Inclination – LFI (degrees)	0.912	0.912 (0.895-0.926)	0.929	0.929 (0.916-0.941)
Volar Tilt – VT (degrees)	0.906	0.906 (0.888-0.921)	0.928	0.928 (0.914-0.939)
Scafolunate Angle – SLA (degrees)	0.906	0.906 (0.887-0.921)	0.929	0.929 (0.916-0.941)
Cord Of Radiocarpal Joint Arc – Cord RC (mm)	0.897	0.897 (0.878-0.914)	0.92	0.92 (0.905-0.933)
Radial Height – RadH (mm)	0.902	0.902 (0.883-0.918)	0.925	0.925 (0.911-0.938)
Radial Shift – Radsh (mm)	0.905	0.905 (0.887-0.92)	0.926	0.926 (0.911-0.938)
Ulnar Variance – UV (mm)	0.902	0.902 (0.883-0.918)	0.924	0.924 (0.91-0.937)
Carpal Height – CH (mm)	0.908	0.908 (0.89-0.923)	0.925	0.925 (0.911-0.938)
Length Of Third Metacarpal – 3rd MH (mm)	0.91	0.91 (0.893-0.925)	0.929	0.929 (0.915-0.941)
Length Of Capitate – CapH (mm)	0.898	0.898 (0.879-0.915)	0.92	0.92 (0.905-0.933)
Lunate Length – LL (mm)	0.908	0.908 (0.891-0.923)	0.924	0.924 (0.909-0.936)
Lunate Uncovering Length – LUL (mm)	0.89	0.89 (0.869-0.908)	0.913	0.913 (0.896-0.927)
Scafolunat Joint Space – SLD (mm)	0.867	0.867 (0.842-0.888)	0.896	0.896 (0.876-0.913)
Distal Radioulnar Joint Space – RUD (mm)	0.789	0.789 (0.752-0.821)	0.802	0.802 (0.767-0.833)

Table 3: Comparison of parameters according to gender groups

Gender	Female (201)	Male (119)	P-value
Radial Inclination – RI (degrees)	24.32 ± 4.89	23.45 ± 4.13	0.073(m)
Lunate Fossa Inclination – LFI (degrees)	25 (9 - 39)	24 (11 - 32)	
Volar Tilt – VT (degrees)	11.34 ± 5.38	10.01 ± 4.18	0.014(a)
Scafolunate Angle – SLA (degrees)	11 (-4 - 27)	10 (1 - 23)	
Cord Of Radiocarpal Joint Arc – Cord RC (mm)	13.79 ± 5.51	12.03 ± 4.97	0.004(m)
Radial Height – RadH (mm)	14 (0 - 32)	12 (0 - 30)	
Radial Shift – Radsh (mm)	56.82 ± 12.62	55.04 ± 11.5	0.158(m)
Ulnar Variance – UV (mm)	58 (10 - 90)	56 (20 - 90)	
Carpal Height – CH (mm)	28.27 ± 1.67	31.96 ± 2.49	<0.001(a)
Length Of Third Metacarpal – 3rd MH (mm)	28.3 (24.2 - 32.6)	32.1 (25.4 - 38.8)	
Length Of Capitate – CapH (mm)	11.87 ± 2.02	13.13 ± 1.9	<0.001(a)
Lunate Length – LL (mm)	12 (6 - 17.1)	13 (6.3 - 17)	
Lunate Uncovering Length – LUL (mm)	12.88 ± 1.84	14.3 ± 2.18	<0.001(m)
Scafolunat Joint Space – SLD (mm)	13 (8 - 17.2)	14.5 (10 - 20)	
Distal Radioulnar Joint Space – RUD (mm)	0.25 ± 1.42	-0.15 ± 1.29	0.012(m)
Carpal Height Ratio – CHR	0 (-4 - 4)	0 (-4 - 3.2)	
Revised Carpal Height Ratio – rCHR	31.26 ± 2.65	35.1 ± 3.08	<0.001(a)
	31 (23 - 39)	35 (26 - 42)	
Radial Inclination – RI (degrees)	61.55 ± 4.0	66.21 ± 5.14	<0.001(m)
Lunate Fossa Inclination – LFI (degrees)	62 (49 - 73.7)	67 (49 - 79)	
Volar Tilt – VT (degrees)	20.93 ± 1.77	23.67 ± 2.0	<0.001(a)
Scafolunate Angle – SLA (degrees)	20.7 (17.1 - 25.9)	23.6 (17 - 28.1)	
Cord Of Radiocarpal Joint Arc – Cord RC (mm)	14.16 ± 1.74	15.61 ± 1.75	<0.001(m)
Radial Height – RadH (mm)	14 (10.8 - 23.5)	15.5 (10.6 - 20.2)	
Radial Shift – Radsh (mm)	5.08 ± 1.34	6.29 ± 1.47	<0.001(a)
Ulnar Variance – UV (mm)	5 (0 - 9.7)	6.6 (2.4 - 9.7)	
Carpal Height – CH (mm)	1.82 ± 0.51	2.12 ± 0.52	<0.001(m)
Length Of Third Metacarpal – 3rd MH (mm)	1.8 (0.7 - 3.3)	2 (1.1 - 4.3)	
Length Of Capitate – CapH (mm)	1.62 ± 0.54	1.81 ± 0.53	<0.001(m)
Lunate Length – LL (mm)	1.5 (0.8 - 3.5)	1.6 (0.9 - 3.6)	
Lunate Uncovering Length – LUL (mm)	0.51 ± 0.04	0.52 ± 0.05	0.171(a)
Scafolunat Joint Space – SLD (mm)	0.51 (0.41 - 0.61)	0.52 (0.41 - 0.69)	
Distal Radioulnar Joint Space – RUD (mm)	1.5 ± 0.11	1.49 ± 0.1	0.324(a)
Carpal Height Ratio – CHR	1.5 (1.23 - 1.81)	1.49 (1.26 - 1.72)	
Revised Carpal Height Ratio – rCHR	0.36 ± 0.1	0.4 ± 0.08	<0.001(m)
	0.36 (0.11 - 0.87)	0.4 (0.19 - 0.66)	

(a) Anova T-test - (m) Mann Whitney U Test, Mean ± SD/Median (Min–Max)

Figure 1: Measurements made on PA and lateral radiographs



- Radial inclination (RI): is the angle formed by the line drawn from the tip of the radial styloid to the medial edge of the radial articular surface with the line drawn perpendicular to the long axis of the ulna [7].
- Lunate fossa inclination (LFI): it is the angle between the sclerotic line of the lunate fossa and the line drawn perpendicular to the long axis of the ulna [7].
- Volar tilt (VT): it is the angle between the line drawn perpendicular to the long axis of the radius and the line drawn between the most volar and dorsal points of the radial articular surface [7].
- Scaphulonate angle (SLA): it is the angle between the lunate axis and the scaphoid axis [7].
- Cord of the radiocarpal articular arc (cord RC): it is the direct measurement distance between the tip of the radial styloid and the medial edge of the radial articular surface [9].
- Radial height (RadH): the distance between the tip of the radial styloid and the lines drawn tangential to the distal cortical margin of the ulna and perpendicular to the long axis of the radius [13].
- Radial shift (Radsh): the distance between the long axis of the radius and the line tangential to the end of the radial styloid and drawn parallel to it through the most lateral point of the radial metaphysis [13].
- Ulnar variance (UV): it is the distance between the line intersecting the distal cortical margin of the ulna and drawn perpendicular to the long axis of the radius and the line passing through the medial part of the radial articular surface [7].
- 3rd metacarpal height (3rd MH): the length of the third metacarpal was measured along its long axis from the distal articular surface to the proximal articular surface [14].
- Carpal height (CH): the carpal height was measured along the proximal extension of the long axis of the third metacarpal bone from the articular surface of the base of the third metacarpal bone to the distal articular surface of the radius [14].
- Capitate height (CapH): the capitate length is the longest distance from the subchondral edge of the distal pole at the joint of the third metacarpal to the subchondral edge of the proximal pole at the joint between the carpals [14].
- Carpal height ratio (CHR) and revised carpal height ratio (rCHR): the carpal height ratio is determined by the ratio of the carpal height to the height of the third metacarpal. The revised carpal height ratio is also determined by the ratio of the carpal height to the capitate height [14].
- Lunate length (LL): distance between the ulnar and radial poles of the lunate [7].
- Lunate uncovering length (LUL): It is the perpendicular distance between the ulnar pole of the lunate bone and the line drawn parallel to the radial axis from the ulnar edge of the radius [7].
- Lunate uncovering ratio (LUR): is determined by the ratio of the LUL to the LL [7].
- Scapholunate joint distance (SLD): the scapholunate joint distance was measured from the most radial edge of the lunate to the most radial edge of the proximal scaphoid [15].
- Distal radioulnar joint distance (RUD): the width of the gap at the center of the distal radioulnar joint [16].

Table 4: Comparison of parameters according to age groups

Age group	(a) 18-30 (87)	(b) 31-50 (150)	(c) >=51 (83)	*P*-value
Radial Inclination – RI (degrees)	24.49 ± 4.32	24.19 ± 4.91	23.12 ± 4.36	0.153(k)
Lunate Fossa Inclination – LFI (degrees)	25 (15 - 35)	25 (11 - 39)	24 (9 - 32)	
Volar Tilt – VT (degrees)	11.69 ± 4.89	10.61 ± 4.84	10.39 ± 5.36	0.174(a)
Scafolunate Angle – SLA (degrees)	11 (1 - 27)	11 (-3 - 24)	10 (-4 - 25)	
Cord Of Radiocarpal Joint Arc – Cord RC (mm)	12.94 ± 5.43	12.89 ± 5.19	13.77 ± 5.65	0.598(k)
Radial Height – RadH (mm)	12 (0 - 32)	13 (0 - 30)	13 (2 - 32)	
Radial Shift – Radsh (mm)	55.7 ± 11.74	55.87 ± 11.67	57.16 ± 13.7	0.486(k)
Ulnar Variance – UV (mm)	57 (10 - 90)	56 (20 - 90)	59 (20 - 89)	
Carpal Height – CH (mm)	29.03 ± 2.58	30.0 ± 2.88	29.62 ± 2.36	0.062(k)
Length Of Third Metacarpal – 3rd MH (mm)	28.8 (24.2 - 33.9)	29.5 (25 - 38.8)	29.4 (25.7 - 37.1)	
Length Of Capitate – CapH (mm)	12.21 ± 2.01	12.62 ± 1.98	11.97 ± 2.22	0.058(a)
Lunate Length – LL (mm)	12 (6.3 - 17)	12.35 (8 - 17.1)	12 (6 - 17)	
Lunate Uncovering Length – LUL (mm)	13.29 ± 1.99	13.62 ± 2.14	13.17 ± 2.08	0.227(a)
Scafolunat Joint Space – SLD (mm)	13.3 (8 - 17.9)	13.7 (8 - 20)	13 (9 - 18.5)	
Distal Radioulnar Joint Space – RUD (mm)	-0.41 ± 1.21	0.33 ± 1.39	0.24 ± 1.42	<0.001(k)
Carpal Height Ratio – CHR	0 (-3.6 - 2)	0 (-4 - 4)	0 (-4 - 3)	
Revised Carpal Height Ratio – rCHR	32.56 ± 3.59 33 (23 - 41.2)	33.22 ± 3.22 33 (26 - 42)	31.85 ± 3.27 31.7 (25 - 40.6)	0.011(a)
Radial Inclination – RI (degrees)	63.66 ± 5.4	63.93 ± 4.81	61.71 ± 4.55	0.003(a)
Lunate Fossa Inclination – LFI (degrees)	64 (49 - 76)	64 (51 - 79)	62.1 (49 - 73.7)	
Volar Tilt – VT (degrees)	22.07 ± 2.21	22.21 ± 2.27	21.35 ± 2.29	0.009(k)
Scafolunate Angle – SLA (degrees)	22.3 (17 - 26.7)	22.1 (17.2 - 28.1)	20.9 (17.1 - 28)	
Cord Of Radiocarpal Joint Arc – Cord RC (mm)	14.52 ± 1.61	14.9 ± 2.0	14.53 ± 1.9	0.283(k)
Radial Height – RadH (mm)	14.4 (11.5 - 18.3)	14.7 (10.6 - 23.5)	14.5 (11.2 - 23.5)	
Radial Shift – Radsh (mm)	5.82 ± 1.54	5.49 ± 1.46	5.31 ± 1.53	0.083(a)
Ulnar Variance – UV (mm)	5.8 (2.4 - 9.7)	5.4 (1.6 - 9.7)	5.1 (0 - 8.6)	
Carpal Height – CH (mm)	1.9 ± 0.52	1.98 ± 0.55	1.87 ± 0.51	0.372(k)
Length Of Third Metacarpal – 3rd MH (mm)	1.9 (0.7 - 3.4)	2 (1 - 4.3)	1.9 (0.9 - 2.9)	
Length Of Capitate – CapH (mm)	1.93 ± 0.54	1.67 ± 0.53	1.47 ± 0.46	<0.001(k)
Lunate Length – LL (mm)	1.8 (1.2 - 3.6)	1.5 (0.9 - 3.5)	1.4 (0.8 - 3.5)	
Lunate Uncovering Length – LUL (mm)	0.51 ± 0.05	0.52 ± 0.04	0.52 ± 0.05	0.244(k)
Scafolunat Joint Space – SLD (mm)	0.52 (0.41 - 0.69)	0.52 (0.41 - 0.63)	0.52 (0.41 - 0.69)	
Distal Radioulnar Joint Space – RUD (mm)	1.48 ± 0.11	1.5 ± 0.1	1.5 ± 0.1	0.262(a)
Carpal Height Ratio – CHR	1.48 (1.26 - 1.72)	1.49 (1.25 - 1.81)	1.51 (1.23 - 1.73)	
Revised Carpal Height Ratio – rCHR	0.4 ± 0.09 0.4 (0.19 - 0.65)	0.37 ± 0.09 0.37 (0.11 - 0.87)	0.37 ± 0.1 0.36 (0.11 - 0.63)	0.019(k)

(a) Anova T-test - (k) Kruskal Wallis Test --Mean ± SD/Median (Min–Max)

Discussion

The wrist is a region in the human body where many bones articulate. The anatomy of the bones and connective tissue is very complex. The radiographic anatomy of the wrist and hand have been discussed extensively in the literature. The angles, distances, and indexes that result from the relationship of these distances to each other on radiographs have been associated with many clinical situations [3, 4, 6, 7, 13-16].

Many articles in the literature examine the association of these measurement parameters with age and gender. We examined our radiographic studies in three subtitles: angular, metric, and proportional parameters.

Angular parameters are the angles measured between lines drawn between specific points on radiographic examinations.

Volar tilt (VT) and radial inclination (RI) angles are used to understand the anatomy and evaluate reduction quality after distal radius fractures [17]. Lower than normal VT and RI angles after distal radius fractures have been associated with poor clinical scores [3].

Normal values of the RI angle are reported in the literature to average 22 degrees (12-35) [18]. Schuind et al. [8] reported in their 1992 study that the average values of 23.8 ± 2.6 in 120 healthy individuals were 24.1 ± 2.5 degrees in men and 23.6 ± 2.7 degrees in women. Feipel et al. [2] in 1998 reported mean values of 25 ± 3 degrees in 80 healthy subjects. In the article published by Thienpont et al. [6] in 2004, values of 25.42 ± 4.8 degrees were reported on radiographs in 126 healthy subjects. Valencia et al. [11] reported mean values of 36.5 ± 4 degrees in their measurements of 112 healthy Mexican individuals in 2006. In a study performed on 300 healthy Egyptian individuals in 2009. 28.1 ± 8.1 degrees in males and 24.5 ± 5.9 degrees in females, and 25.5 ± 7.1 degrees in individuals aged 20-40 years and 27.1 ± 6.8 degrees in 40-60 years [9]. Katayama et al. [10] in a study conducted on 134 healthy Japanese individuals, values of 25.5 ± 2 degrees were found in men and 25.7 ± 1.9 1 in women.

In the graphs we examined, the mean RI angle was 24.14 ± 5.4 graphs (9-39). 24.32 ± 4.89 degrees (3-39) in the radiographs of the female group, 23.45 ± 4.13 degrees (11-32) in the radiographs of the male group, 24.49 ± 4.32 in the age group of 18-30 years, 24.19 ± 4.91 degrees in the age group of 31-50 years, and 23.12 ± 4.36 degrees in the group of over 50 years. No statistically significant difference was found between age and gender groups for RI values.

The normal values of the VT angle have been reported as an average of 11 degrees (3-20) in the literature [18]. Thienpont et al. [7], in their 2003 article, reported an average angle of 10.75 ± 2.8 ° on radiographs of 126 healthy individuals. A study from the Mexican population showed a mean VT angle of 17.98 ± 2.25 degrees in 112 healthy individuals [11]. Katayama et al. [10] measured radiographs of 134 healthy Japanese subjects and reported a VT angle of 11.8 ± 2.9 2, in men and 12.3 ± 3.3 degrees in women.

Our study obtained a mean VT angle of 13.61 ± 10.96 0- (0-32). We found a statistically significant difference between the mean values we found 13.79 ± 5.51 degrees in the female group and 12.03 ± 4.97 degrees in the male group. When evaluated between age groups, no statistically significant difference was found between the VT angles, which we found as 12.94 ± 5.43 degrees in the 18-30 years age group, 12.89 ± 5.19 degrees in the 31-50 years age group, and 13.77 ± 5.65 degrees in the over 50 years age group.

The effect of the lunate fossa inclination angle (LFI) on the development of clinical conditions such as Kienbock's disease, scapholunate dissociation (SLD) and concomitant carpal collapse, dorsal intercalated segment instability (DISI), and scapholunate advanced collapse (SLAC) have been investigated in previous studies [6]. Thienpont et al. [7] in their study published in 2003 on 41 SLD patients and 126 healthy individuals t found a mean LFI angle of 10.59 ± 3.1 degrees in the SLD group, while they measured mean values of 13.61 ± 4.4 degrees in the healthy individuals and found this difference to be statistically significant.

In 2004, Thienpont et al. [6] found a mean LFI angle of 13.81 ± 4.1 degrees in the Kienbock group and 13.61 ± 4.4 degrees in the control group in a comparative radiological study between 54 Kienbock patients and 126 healthy individuals. They classified this difference as not statistically significant. Measurements in the Egyptian population in 2009 showed a mean LFI angle of 13.61 ± 4.4 degrees for males, 12.1 ± 3.6 degrees for females, 12.86 ± 0.6 degrees for 20-40-year-olds, and 12.85 ± 0.71 degrees for 40-60-year-olds [9].

In our study, the mean LFI values were 10.85 ± 5.0 degrees (-4-27). We found the mean value 11.34 ± 5.38 degrees in females and 10.01 ± 4.18 degrees in males. We found 11.69 ± 4.89 degrees in the age group 18-30, 10.61 ± 4.84 degrees in the age group 31-50, and 10.39 ± 5.36 degrees in the age group 50+. There was a statistically significant difference in LFI values between gender groups but no significant difference between age groups.

SL angle is the angle measured between the scaphoid and the lunate on the lateral radiograph. It has been associated with the scapholunate gap with scaphoid ligament injuries and pathologies such as carpal collapse and DISI. Measurements defined normal values of 46 degrees (30-60), values above 60 degrees were associated with scapholunate dissociation, values

above 70 degrees with DISI, and values below 30 degrees with VISI [19,20].

Nakamura et al. [21], in their study of 84 healthy wrist radiographs in 1989, found an average SL angle value of 56 ± 7 degrees (42-70). Thienpont et al. [7] found an average angle of 53 ± 3.5 ° in 126 healthy radiographs and an angle of 53.80 ± 4.1 ° SL in their measurement of 41 patients with a scapholunate ligament injury in 2003. They found that this was not statistically significant. No other radiological study was found in the literature that examined the distribution of SL angles by age and gender.

In our study, the mean SLA values found were 56.16 ± 12.22 degrees (10 - 90). We found values of 56.82 ± 12.62 degrees in females, 55.04 ± 11.5 degrees in males, 55.7 ± 11.74 degrees in the age group 18-30, 55.87 ± 11.67 degrees in the age group 31-50, and 57.16 ± 13.7 degrees in the age group 50+. We did not found statistically significant difference between gender and age groups.

Metric parameters are the distance values measured on radiographs of the wrist, expressed in mm. Proportional parameters are other parameters obtained by proportioning the metric parameters to each other.

Cord RC indicates the topographic distance of the surface where the distal radius articulates with the carpal bones. In the database study of Schuind et al. [8] with 120 radiographs of the wrist, the mean values were 30.9 ± 1.7 mm in men, 27.0 ± 1.5 mm in women, 28.8 ± 2.7 mm in the 25-40 age group, and 29.3 ± 2.3 mm in the 41-60 age group. In a 2009 study, mean values of 30.8 ± 1.8 mm, 27 ± 1.5 mm in males, 28.9 ± 2.7 mm in the 20-40 age group, and 29.3 ± 2.3 mm in the 40-60 age group were reported [9]. In the study published by Nakamichi et al. [22] in 1995, it was reported that carpal height, third metacarpal height, and hand height, as well as small distances between radiocarpal joint arches, were associated with idiopathic carpal tunnel syndrome.

In our study group, the mean value of Cord RC was 29.64 ± 2.69 mm, in females 28.27 ± 1.67 mm, in males 31.96 ± 2.49 mm, in the age group 18-30 years 29.03 ± 2.58 mm, in the age group 31-50 years 30.0 ± 2.88 mm and the group above 51 years 29.62 ± 2.36 mm. While there was a significant difference in the measurements between the gender groups, there was no significant difference between the age groups.

RadH, Radsh, and UV values, along with RI and VT, are the parameters we most often use to make a surgical decision when evaluating reduction after distal radius fractures [4].

In the article published by Freiberg et al. [23] in 1976, RadH values of 13.6 mm in men, 11.6 mm in women, and 12.6 mm in the total group were reported. Mann et al. [24], in their 1993 article, reported a RadH value of 14 mm in men and 13 mm in women, a range of 10-18 mm in their radiological measurements.

Radsh is the expression in mm for the offset of the distal radius in the coronal plane concerning the radial axis. Normal values of 13.5 ± 3.8 mm have been reported [3].

Although UV is used to assess fractures of the distal radius, Kienbock's disease and its association with SL disintegration is also the subject of studies in the literature [3,4].

It has been reported in the literature that UV loss on the first radiograph is crucial for the expectation of instability and loss of reduction after fractures of the distal radius [4]. In addition, many articles are investigating the association between ulna-plus-wrist fractures with ulnocarpal abutment syndrome, in which the radius is shorter than the ulna, and Kienbock disease in ulna-minus patients with the short ulna. The level of evidence regarding these conditions was not shown to be high [25].

Schuind et al. [8] found an average UV of 0.9 mm in measurements they made on 120 healthy individuals in 1992 and reported a distribution between -5.0 and + 2.9 mm. They reported mean values of -0.9 ± 1.5 mm in males, -0.9 ± 1.4 mm in females, -0.9 ± 1.4 mm in those aged 25-40 years, and -0.8 ± 1.5 mm in those aged 41-60 years, with no significant differences between these values. Feipel et al. [2] reported UV values of -0.3 ± 2.3 mm in 80 asymptomatic subjects in their study published in 1995.

In the study of Japanese subjects by Nakamura et al. [26]published in 1991, lower and negative UV values were reported in males, and their tendency to decrease with age. This study also examined the association of UV with Kienbock disease and found no significant difference.

In 2004, Thienpont et al. [6] performed UV measurements on radiographs of 54 patients with Kienbock's disease and 126 healthy subjects. They reported the values of -0.89 ± 0.9 mm in the Kienbock group and -0.42 ± 1.4 mm in the control group and could not find any statistically significant difference between these values.

Also, in 2003, Thienpont et al. [7] performed measurements on 41 SLD and 126 healthy individuals. They measured UV values of -0.55 ± 1.48 mm in the SLD group and -0.42 ± 1.51 mm in the control group and reported that this was not statistically significant.

An article published in 2016 compared the radiographs of 166 Kienbock patients and 166 healthy subjects and reported that the values they found in the Kienbock group -0.12 ± 0.087 control group -0.07 ± 0.059 mm were statistically significant between the groups [27].

The mean RadH values among individuals in our study group were found to be 12.34 ± 2.06 (6 - 17.1) mm. It was 11.87 ± 2.02 mm in females, 13.13 ± 1.9 mm in males, 12.21 ± 2.01 mm in the age group 18-30 years, 12.62 ± 1.98 mm in the age group 31-50 years, and 11.97 ± 2.22 mm in the age group above 51 years.

The mean Radsh values were 13.41 ± 2.09 (8-20) mm for the whole group. It was 12.88 ± 1.84 mm in females, 14.3 ± 2.18 mm in males, 13.29 ± 1.99 mm in the age group 18-30 years, 13.62 ± 2.14 mm in age group 31-50 years, and 13.17 ± 2.08 mm in the age group above 51 years.

A statistically significant difference was found between gender groups for RadH and radsh values, while the difference between age groups was not considered significant.

The mean UV was -0.08 ± 3.84 (-4 - 4) mm. It was 0.25 ± 1.42 mm in females, -0.15 ± 1.29 mm in males, -0.41 ± 1.21 mm in the age group 18-30 years, 0.33 ± 1.39 mm in the age group 31-50 years, and 0.24 ± 1.42 mm in the age group above 51 years. Statistical analysis revealed significant differences between age and gender groups. Moreover, when UV values

were correlated with age, it was found that there was a significant decrease in UV values with increasing age.

CHR is used to assess the severity of conditions that cause carpal collapse, such as rheumatoid arthritis, Kienboeck's disease, scaphoid fracture, and wrist ligament injuries [5]. CHR was described in 1978 Youm et al. [28] as the ratio between the height of the third metacarpal bone and the height of the carpus to standardize measurements of carpal height depending on the individual. rCHR was determined in 1994 by Nattrass et al. [14] by comparing the height of the capitate and the carpal height, which allows calculation of the ratio of carpal height on radiographs of the wrist that did not include the third metacarpal bone in the imaging. In their study, Schiund et al. [8] reported CHR values of 54.3 ± 3.9% in males, 52.6 ± 13.4% in females, 52.6 ± 3.8% in ages 25-40, 54.2 ± 13.5% in ages 40-60, and a mean of 52.4 ± 9.9%. Feipel et al. [2] reported the mean CHR rate as 0.52 ± 0.07 and the rCHR rate as 1.48 ± 0.14 in their study published in 1995.

In their 2010 study of 135 male and 126 female wrist radiographs from the Taiwanese population, Wang et al. [5] determined a mean CHR of 0.52 ± 00.3 (0.43-0.59) in males and 0.50 ± 0.03 (0.043-0.057) in females.

Jehan et al. [12], in their 2019 study, determined a mean CHR value of 0.52 ± 0.05 and an rCHR value of 1.50 ± 0.06 from measurements on the radiographs of 120 healthy subjects and found that these values showed no statistically significant difference between age and gender groups.

In our study, the mean CHR value was 0.51 ± 0.06 for the whole group, 0.51 ± 0.04 in the female group, 0.52 ± 0.05 in the male group, 0.51 ± 0.05 in the age group of 18-30 years, 0.52 ± 0.04 in the age group of 31-50 years and 0.52 ± 0.05 in the age group of above 51 years. The rCHR value was 1.49 ± 0.1 for the total group, 1.5 ± 0.11 in the female group, 1.49 ± 0.1 in the male group, 1.48 ± 0.11 in the age group of 18-30 years, 1.5 ± 0.1 in the age group of 31-50 years and 1.5 ± 0.1 in the age group of above 51 years. No statistically significant difference was found between age and gender groups for both the values.

LUR; It is determined by proportioning LL and LUL values and is used to assess ulnar translation of the wrist, which develops after wrist ligament injuries and rheumatoid arthritis [29]. Schuind et al. [8] reported 32.3 ± 11.8% in males, 32.9 ± 10.3% in females, 32 ± 9.8% in the 25-40 age group, and 33.2 ± 12.1% in the 40-60 age group in their database study published in 1992. Wu et al. [29] reported mean LUR values of 35 ± 8% in males and 34 ± 9% in females for measurements performed on 176 male and 123 female radiographs. Thienpont et al. also reported 40.55 ± 10.2% in the SLD group and 39.33 ± 9.3% in the healthy group for the measurements they performed on the SLD group and healthy wrists. In addition, when they performed measurements between the Kienbock group and the healthy group, values of 33.65 ± 10.5% in the Kienbock group and 39.32 ± 9.3% in the healthy group were reported. No statistically significant difference was found in these values between the patient and control groups in either study [6, 7].

In our study, the mean LUR was 0.38 ± 0.1 for the whole group, 0.36 ± 0.1 for the female group, 0.4 ± 0.08 for the male group, 0.4 ± 0.09 for the age group 18-30 years, 0.37 ± 0.09 for the age group 31-50 years and 0.37 ± 0.1 for the group above 51 years. Statistical analysis revealed a significant difference between the age and gender groups.

SLD has been associated with SLA and scapholunate ligament injuries and related pathologies such as carpal collapse and DISI [15]. Although measurements greater than 5 mm are considered pathological, the 1991 article by Cautilli et al. [30] examined radiographs of 100 asymptomatic individuals. Mean values of 3.7 ± 0.6 mm were obtained, with females having 3.6 ± 0.5 mm and males having 4 ± 0.5 mm.

In the 2012 article by Picha et al. [15], radiographs of subjects with and without pain in the wrist were compared. It was measured that an SL interval of more than 5 mm was present in 52% of subjects who were also asymptomatic. Katayama et al. [10] data published in 2015 from 134 healthy subjects reported mean values of 1.24 ± 0.15 mm in men and 1.2 ± 0.17 mm in women.

In our study, the mean SLD was 1.97 ± 0.99mm, 1.82 ± 0.51mm in the female group and 2.12 ± 0.52mm in the male group. The mean value of SLD was 1.9 ± 0.52mm in the age group of 18-30 years, 1.98 ± 0.55mm in the age group of 31-50 years, and 1.87 ± 0.51mm in the age group of above 51 years. Although there was a statistically significant difference in the score between the gender groups, no significant difference was found between the age groups.

Clinical examination and investigations such as MRI, CT, arthrography, lateral views in direct radiography, or PA radiographs in the clenched fist position are usually used to assess the stability of the distal radioulnar joint [21].

Iida et al. [16] Measured the distances of the distal radioulnar joint from the injured side and contralateral wrist, standard PA graphy and PA graphy in clenched fist position of 30 subjects with distal radioulnar joint injuries. The average distance of 1.0 ± 0.5 mm (0-2.1) in the intact wrist on standard radiographs and 1.4 ± 1.0 mm (0-2.7) was measured on the injured side, and there was no statistically significant difference between these values. With the wrists in the clenched fist position, an average distance of 3.0 ± 1.5 mm (0.4-6.5) was measured on the healthy side, while a distance of 3.6 ± 2.1 mm (0.6-10) was measured on the injured side, and this difference was found to be statistically significant.

The distance of the distal radioulnar joint on the PA radiograph was measured to be 1.5 ± 0.5 mm in males, 1.2 ± 0.21 mm in females, 1.65 ± 0.5 mm in individuals aged 20-40 years, and 1.35 ± 0.5 mm in individuals aged 40-60 years in Mohammad's measurements [9]. The study conducted by Katayama et al. [10], was reported to be 1.19 ± 0.17 mm in males and 1.13 ± 0.09 mm in females. While no statistically significant difference was found in both studies comparing genders, a significant decrease in the distal radioulnar joint distance was observed with age [9, 10].

In our study, the distance of the distal radioulnar joint (RUD) was measured on PA radiographs taken in the open position, and it was found that the mean value was 1.69 ± 0.54 mm. It was 1.62 ± 0.54 mm in the female group, 1.81 ± 0.53 mm in the male group, 1.93 ± 0.54 mm in the age group of 18-30 years, 1.67 ± 0.53 mm in the age group of 31-50 years, and 1.47 ± 0.46 mm in the group of above 51years. The values we

measured produced a statistically significant difference between the age and gender groups.

Limitations

The number of individuals in the group we measured can be considered large compared to similar studies, but it is still insufficient to reflect all community data. Our study group is not homogeneous enough in terms of age and gender distribution. Also, it is an advantage that we use data from two hospitals addressing two different populations and the use of two different X-ray machines for imaging, and the fact that different technicians performed the X-rays. Because the study was retrospective, most of the patients who were x-rayed were people with hand and wrist conditions who are treated in clinics for certain reasons. Still, it is not very easy to get an x-ray of the wrist for completely healthy subjects, considering the potential risks of radiation. No positioning device was used before the X-ray limited the study. Two authors made all measurements electronically using the PACS system twice, and interobserver and intraobserver reliability was checked. Although interobserver reliability was determined to be perfect for many parameters, a human factor in the measurements introduces a margin of error in obtaining these data. With new developments in software, making such measurements using artificial intelligence will reduce the margin of error and provide an important resource and time-saving in such measurements.

Conclusion

Measurement parameters in radiographs of the wrist have been associated with prediction, diagnosis, and treatment decisions of many pathologies affecting the wrist and the assessment of treatment outcome. Database studies have been performed in many populations reporting that measurements of these parameters differ between different populations. In addition, variability has been found between gender and age groups for some parameters.

To the best of our knowledge, this is the first study in the Turkish population that can be considered a database considering the measurement parameters in normal wrist radiographs with age and gender characteristics.

In our study, we have given the normal roentgenographic measurement parameters that can be used as a reference for the Turkish population and the relationships and variability according to age and sex between the bones of the Turkish population that serve as a reference point. These parameters can be helpful in our population in clinical research and the diagnosis and treatment of wrist pathologies such as osteonecrosis, instabilities, osteoarthritis, and distal radius fractures. Also, these parameters can be helpful in the design and development of implants for the treatment of wrist pathologies.

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