Changes in ulnar variance in relation to forearm rotation and grip

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We studied radiographs of the wrists of 120 healthy volunteers in order to determine the normal range of ulnar variance. They had been taken in various positions under both unloaded (static) and loaded (dynamic) conditions. Pronation posteroanterior, supination anteroposterior and neutral posteroanterior views were taken of each wrist before and during a maximum grip under identical conditions. The mean normal ulnar variance in neutral rotation was $+0.74 \pm 1.46$ mm, a value which was significantly lower in males than in females. We found negative variance in 26% of cases. We measured maximum ulnar variance (UV_{max} , $+1.52 \pm 1.56$ mm) when gripping in pronation and minimum ulnar variance (UV_{min} , $+0.19 \pm 1.43$ mm) when relaxed in supination. We subtracted UV_{min} from UV_{max} to calculate a mean maximum dynamic change in ulnar variance of 1.34 ± 0.53 mm. We consider this database of normal values to be useful for both the diagnosis and treatment of conditions related to discrepancy in radio-ulnar length and for clinical research.

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In 1928, Hultén¹ measured the difference in the length of the radius and ulna (ulnar variance) in 400 normal wrists and in 23 patients with Kienböck's disease. He found a high proportion (74%) of negative ulnar variance in the group with Kienböck's disease compared with normal wrists (8%). He suggested that negative ulnar variance, in which the ulna is shorter than the radius, was one of the

predisposing factors for Kienböck's disease. Since then, ulnar variance has been implicated in various disorders of the wrist including Kienböck's disease,²⁻⁴ carpal instability,⁵ and ulnocarpal impingement syndrome.^{6,7} Some laboratory studies^{8,9} have shown that the distribution of axial loads relative to the radius and ulna alters with changes in ulnar variance. The biomechanical changes created by ulnar variance may also affect degenerative conditions of the wrist.^{6,7}

Consequently, many surgical operations have been designed to alter ulnar variance in the treatment of those disorders of the wrist related to a discrepancy in radio-ulnar length. Accurate correction of ulnar variance is crucial in these procedures,^{3,4,10} but it is difficult to determine the degree of adjustment required because of the dynamic changes which may accompany forearm rotation or forceful grip.¹¹⁻¹³ There is little information on these dynamic changes in normal wrists.

In this study we measured forearm rotation- and grip-related changes in ulnar variance to establish guidelines for the diagnosis and treatment of disorders related to discrepancy in radio-ulnar length.

Subjects and Methods

We examined radiographs of the wrists of 120 normal skeletally mature volunteers. We excluded those with a history of trauma of the upper limb, disease, or surgery, with generalised skeletal disorders, or earlier participation in gymnastics or similar activities with high-impact to the wrist. Our subjects were all Korean, had an equal gender distribution (60 women and 60 men) and a mean age of 26 years (20 to 35).

Six radiographs consisting of pronation posteroanterior (PA), supination anteroposterior (AP) and neutral PA views were taken of each dominant wrist before and during maximum grip with the elbow flexed to 90° and the wrist in a neutral position. The arm was aligned perpendicularly to the cassette for the pronation PA or supination AP views, but abducted 90° for the neutral PA view. In order to exclude the effects of the angle of beam incidence and distance, the x-ray tube was aligned perpendicularly to the radial styloid in both transverse and sagittal planes and 76 cm from the table. We standardised forearm rotation and

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Fig. 1a

Fig. 1b

Custom-made wooden frames were composed of two parts, the arm positioner and the base frame. A base frame with Velcro fastener was used for the standard relaxed position during radiography, and another with a grip bar for maximal power grip. Figure 1a – The frame for relaxed pronation or supination position. Figure 1b – The frame for neutral rotation position with power grip.

wrist position using two custom-made wooden frames, each composed of two parts, the arm positioner and the base frame (Fig. 1). The base frame, with a Velcro (Velcro USA Inc, Manchester, New Hampshire) hook and loop fastener, was used for the unloaded condition (relaxed state) and the other frame with a grip bar for the assessment when loaded (power grip). Load was achieved by maximal power grip of the bar, but strength was not measured. The standard six positions are illustrated in Figure 2. Measurements were made by a single surgeon (JMJ) using the method of perpendiculars¹⁴ (Fig. 3) with a lead marking pencil and a Vernier microcaliper (Mitutoya Corp, Sakato, Japan) with a 0.01 mm scale.

It is well recognised that biological measurements may not follow a normal distribution and therefore the normal range is described with percentiles.^{15,16} Most previous articles report only the mean and standard deviation (SD). We present these as well as the range for comparison with other publications. Statistical analysis was performed using the Mann-Whitney U test and regression analysis, and statistical significance was accepted as $p < 0.05$.

Results

Table I gives the mean $\pm$ SD and the range of ulnar variance under various conditions. We found the mean maximum ulnar variance (UV_{max}) to be 1.52 ± 1.56 mm (-1.42 to $+5.24$) with gripping in pronation and the mean minimum ulnar variance (UV_{min}) to be 0.19 ± 1.43 mm (-2.46 to $+3.70$) when relaxed in supination. Ulnar variance tended to increase with pronation and grip. The normal range of ulnar variance in neutral rotation with a relaxed upper limb was -2.08 to $+4.08$ mm with a mean of 0.74 ± 1.46 mm. We found negative variance in 26%. We subtracted UV_{min} (UV_S) from UV_{max} (UV_{PG}) to calculate the mean maximum dynamic change in ulnar variance (ΔUV_{PG-S}) which was 1.34 ± 0.53 mm.

There was a positive linear relationship ($p < 0.05$) between ΔUV_{PG-S} and the ulnar variance in neutral rotation

(UV_N), but the correlation coefficient was low ($R^2 = 0.071$). The equation of the regression line was $Y = 1.12652 + (0.0974(X))$ (Fig. 4).

We found significant gender-related differences in ulnar variance (Table II). The mean UV_N in men was $+0.45 \pm 1.28$ mm (-2.08 ± 3.64) which was lower than that in women ($+1.03 \pm 1.57$ mm; range -2.28 to 4.68) and negative ulnar variance was present in 14 men (23%) and 17 women (28%). The mean ΔUV_{PG-S} in men was 1.45 ± 0.54 mm which was greater than that in women (1.22 ± 0.50 mm).

Discussion

Several methods of measuring ulnar variance have been described, although none has been universally accepted. Three techniques, the project-a-line technique,^{2,17} the concentric circle technique,¹³ and the method of perpendiculars,¹⁴ are commonly used. All have a high degree of intra- and interobserver reliability, but the method of perpendiculars is the most reliable.⁸

One observer made all our measurements using the method of perpendiculars. Its reliability is so high that we presumed that there would be no significant interobserver error. Previous authors^{12,18-23} have measured ulnar variance although a large series by Schuind et al¹⁸ measured only dominant wrists. In our study, we also measured only dominant wrists to allow for comparison.

Several parameters, other than forearm rotation and power grip, can influence the measurement of ulnar variance. According to Epner et al,¹¹ radial deviation of the wrist in a supinated forearm increases negative ulnar variance by 0.20 mm. Ulnar deviation has the opposite effect. Changes in the angle of incidence of the beam in the sagittal plane will also influence ulnar variance. Directing the beam more distally increases negative variance. In our study we maintained the wrist in neutral deviation and the x-ray beam perpendicular to the radial styloid in both transverse and sagittal planes using our custom-made

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2d

Fig. 2e

Fig. 2f

The standard six positions for radiography showing a) full supination with relaxed upper limb, b) neutral rotation with relaxed upper limb, c) full pronation with relaxed upper limb, d) full supination with maximal power grip, e) neutral rotation with maximal power grip and f) full pronation with maximal power grip.

device. We ignored any effect of thickness of the wrist on radiographic magnification.

To ensure maximal changes, each subject was asked, when appropriate, to grip as tightly as possible. We considered a specific degree of grip force to be less important than a relative one since every person varies in physique and the degree of grip force required to change ulnar variance.

Many other investigators have reported on ulnar variance (UV_N) in a standardised position, although in a broad age range, making it difficult to compare directly with our study. Reported values were -0.84 mm^{19} and -0.9 mm^{18} in

Occidentals, $+0.313 \text{ mm}^{20}$ in Chinese, and $+0.20 \text{ mm}^{21}$ in Japanese subjects. In our study, the mean UV_N was $+0.74 \pm 1.46 \text{ mm}$ (-2.08 to $+4.08$). It appears that Koreans had significantly higher ulnar variances than other nationalities, even when compared with Japanese or Chinese subjects. Previous authors have not observed gender-related differences in Occidentals^{18,19} but Nakamura et al²¹ reported that ulnar variance was lower in Japanese males. Our results also showed a similar sex-related difference in Koreans. We assume that there are racial differences in ulnar variance, even in Orientals, although we doubt that our results can be applied to all nationalities. These data, however, help to

Fig. 3

The method of perpendiculars for measuring ulnar variance.

Table I. The mean $\pm$ sd and range (mm) of ulnar variance in relation to forearm rotation and power grip in 120 normal subjects

Ulnar variance	Mean $\pm$ sd	Range
In supination with relaxed upper limb (UV_S)	$+0.19 \pm 1.43$	-2.46 to +3.70
In neutral rotation with relaxed upper limb (UV_N)	$+0.74 \pm 1.46$	-2.08 to +4.08
In pronation with relaxed upper limb (UV_P)	$+1.07 \pm 1.51$	-1.99 to +4.43
In supination with power grip (UV_{SG})	$+0.86 \pm 1.46$	-1.85 to +4.80
In neutral rotation with power grip (UV_{NG})	$+1.22 \pm 1.52$	-1.45 to +4.67
In pronation with power grip (UV_{PG})	$+1.52 \pm 1.56$	-1.42 to ± 5.24
ΔUV_{P-S} ($UV_P - UV_S$)	0.89 ± 0.46	0.15 to 1.95
ΔUV_{NG-N} ($UV_{NG} - UV_N$)	0.48 ± 0.33	0.05 to 1.52
ΔUV_{PG-S} ($UV_{PG} - UV_S$)	1.34 ± 0.53	0.46 to 2.42

Table II. Difference in the mean $\pm$ sd and range (mm) of ulnar variance as a function of gender

Ulnar variance	Men		Women		p value
	Mean $\pm$ sd	Range	Mean $\pm$ sd	Range	
UV_S	-0.18 ± 1.27	-2.65 to +2.68	$+0.55 \pm 1.50$	-2.46 to +4.29	0.004
UV_N	$+0.45 \pm 1.28$	-2.08 to +3.64	$+1.03 \pm 1.57$	-2.28 to +4.68	0.014
UV_P	$+0.81 \pm 1.37$	-1.99 to +4.23	$+1.33 \pm 1.61$	-2.12 to +5.04	0.064
UV_{SG}	$+0.52 \pm 1.29$	-1.85 to +3.15	$+1.20 \pm 1.54$	-2.09 to +4.90	0.008
UV_{NG}	$+0.95 \pm 1.35$	-1.45 to +4.52	$+1.49 \pm 1.64$	-1.90 to +5.02	0.046
UV_{PG}	$+1.27 \pm 1.38$	-1.42 to +4.62	$+1.77 \pm 1.69$	-1.58 to +5.28	0.089
ΔUV_{P-S}	0.99 ± 0.50	0.19 to 2.00	0.78 ± 0.38	0.13 to 1.59	0.033
ΔUV_{NG-N}	0.51 ± 0.37	0.00 to 1.56	0.46 ± 0.28	0.06 to 1.03	0.618
ΔUV_{PG-S}	1.45 ± 0.54	0.54 to 2.67	1.22 ± 0.50	0.39 to 2.21	0.030

understand the dynamic changes of ulnar variance. The ΔUV_{PG-S} was greater in men than in women suggesting that greater axial movement occurs at the distal radio-ulnar joint in men ($p < 0.05$).

The change in ulnar variance in a neutral position (ΔUV_{NG-N}) was 0.48 ± 0.33 mm in Koreans which is small when compared with that in other studies (0.9 mm,²² 1.95 mm,¹² 1.4 mm²³). This could be explained by differences in grip strength and physique between Orientals and Occidentals.

The positive linear relationship between the maximum dynamic change in ulnar variance and the ulnar variance in neutral rotation means that some instability may occur in the longitudinal plane in the presence of an abnormally high ulnar variance, although the correlation coefficient ($R^2 = 0.071$) was low. Some association was present, but correlation and predictive values were poor. Further studies in a larger population are therefore necessary.

The association between positive ulnar variance, the ulnocarpal impingement syndrome and tears of the triangular fibrocartilage complex (TFCC) has been studied, although there are still many controversies. Palmer and Werner⁶ noted that 73% of wrists with a perforated TFCC and erosions at the ulnar-lunate interface were either ulnar neutral or had positive variance, and suggested that a TFCC tear may result from ulnocarpal impingement syndrome. Uchiyama and Terayama²⁴ and Uchiyama and Nakatsuchi²⁵

Fig. 4

Graph showing that there was a very weak linear relationship between the maximum dynamic change in ulnar variance (ΔUV_{PG-S}) and ulnar variance in neutral rotation (UV_N).

also reported a strong correlation between a TFCC tear and positive ulnar variance. They suggested that positive ulnar variance plays an important role in inducing or causing the progression of degenerative changes in the wrist and that degeneration may lead to a TFCC tear, cartilage wear of the ulnar carpal bones, or instability due to a tear of the

lunotriquetral ligament. Werner et al⁹ found in a cadaver study that a more positive ulnar variance may not transmit a greater force to the head of the ulna than a wrist with a more negative ulnar variance. This is primarily because the TFCC is thicker in arms with a more negative ulnar variance. Reinus et al²⁶ found that TFCC perforations did not correlate with pain or positive ulnar variance. Indeed, there are difficulties in diagnosing ulnocarpal impingement syndrome because it may even occur in cases of negative ulnar variance. Friedman et al¹² tried to explain this unusual ulnocarpal impingement syndrome by suggesting that ulnar variance can increase intermittently with the activities of daily living or occupations that require repetitive gripping and forearm pronation. We agree that the ulnocarpal impingement syndrome occurs in wrists with negative or neutral ulnar variance. Friedman et al¹² suggested guidelines for performing an ulnar shortening osteotomy in negative or neutral ulnar variance, recommending that the amount of ulna removed should equal the difference in the ulnar variance between radiographs taken when resting and with maximal grip. We suggest that the amount removed should be the difference between resting (UV_N) and maximal ulnar variance (UV_{PG}) in pronation with power grip. The same applies to the diagnosis of dynamic impingement syndrome when the ulnar variance in pronation with power grip could be a more accurate index, particularly in patients with negative or neutral ulnar variance.

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