



Research article

ECU tendon subluxation: A nonspecific MRI finding occurring in all wrist positions irrespective of ulnar-sided symptoms?



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ABSTRACT

Background: Recurrent subluxation or dislocation of the extensor carpi ulnaris (ECU) tendon from the ulnar groove is an important cause of ulnar-sided wrist pain. Demonstration of ECU subluxation on MRI is of unclear clinical significance. Previous studies have suggested wrist positioning can affect the ECU's position relative to the ulnar groove. This study evaluates the relationship between ECU subluxation and wrist positioning on MRI, and separately their association with ulnar-sided symptoms.

Methods: 161 wrist MRI scans of 141 patients from four hospitals were retrospectively evaluated for wrist position (defined by radio-ulnar angle), degree of ECU subluxation and the presence of ulnar-sided symptoms and MRI abnormalities. 30 scans were scored by two different raters to assess interrater reliability. A linear regression model was constructed to assess the relation between wrist positioning and subluxation, accounting for other variables. A logistic regression model was constructed to evaluate which variables are predictive of ulnar-sided symptoms.

Results: ECU subluxation was neither significantly correlated to wrist position ($p = 0.338$) nor predictive of the presence of ulnar-sided symptoms (odds ratio 1.28, 95% CI 0.39–4.18). ECU position varied widely for all wrist positions and subluxation occurred in all wrist positions, both in symptomatic and asymptomatic subjects. No trend was observed towards more frequent subluxation in supination, contrary to previous studies. Interrater reliability for radioulnar angle and ECU displacement was excellent (intraclass correlation coefficient for consistency 0.993 and 0.943, respectively).

Conclusion: ECU subluxation occurs frequently in all wrist positions, irrespective of ulnar-sided symptoms, and is not associated with ulnar-sided symptoms.

1. Introduction

An important cause of pain at the dorso-ulnar side of the wrist is recurrent subluxation or dislocation of the extensor carpi ulnaris (ECU) tendon from the ulnar groove [1,2].

It is a well-known injury in athletes playing tennis, golf and baseball [3,4]. The ECU tendon is also at risk for degeneration in rheumatoid arthritis [5,6], and dislocation of the ECU seems to predict rupture of other tendons justifying prophylactic surgery [6,7].

Subluxation of the ECU tendon is frequently observed on imaging but it is unclear whether this is clinically relevant [2,8–13], particularly when there are no ulnar-sided symptoms and there is no clinical concern for ECU tendon instability.

The ECU tendon lies in an ulnar groove and is contained by a separate fibro-osseous subsheath of 1.5–2 cm in length, of which the medial attachment is reinforced by the fibrous linea jugata, which resists medial and volar subluxation [3,14,15]. The overlying retinaculum lacks direct bony insertions, unlike the other extensor compartments,

Abbreviations: ECU, extensor carpi ulnaris; MRI, magnetic resonance imaging; PD, proton density; TE, echo time; TR, repetition time

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allowing for unrestricted rotation of the radius around the ulna [16]. The ECU tendon and subsheath presumably also help to stabilize the distal radioulnar joint and the distal carpal row [17,18].

The ECU tendon forms an obtuse angle in the sixth compartment between forearm and insertion at the fifth metacarpal, causing ulnar translation and stress on the subsheath during contraction. Therefore, the anatomy of the ECU tendon predisposes it to change position when wrist positioning is altered. This is increased by supination, flexion and ulnar deviation [19].

The subsheath may rupture due to forced wrist supination and flexion with ulnar deviation, such as during maximizing top spin in tennis or in the late phases of swinging a baseball bat or golf club [20,21]. Most frequently the subsheath is not completely torn, but stripped at its medial border, resulting in ECU subluxation during rotation [3,19]. Treatment is either conservative through immobilization and alteration of athletic techniques or by surgery [1,15,19,21,22], all resulting in a considerable rehabilitation period for the patient.

Although the ECU tendon can be readily assessed both with magnetic resonance imaging (MRI) and ultrasound, MRI provides additional information on tissue characteristics. Furthermore, deeper anatomical structures are better visualized. This study aims to unravel the relationship between wrist positioning, subluxation and the presence of ulnar-sided symptoms by assessing the relationship between wrist positioning and the degree of ECU subluxation in a large MRI series of both symptomatic and asymptomatic subjects and provides an overview of the literature and the clinical relevance of observed ECU tendon positional variation on routine MRI. This will help in clinical practice to assess the significance of incidentally demonstrated ECU subluxation.

2. Material and methods

2.1. Subjects

161 consecutive wrist MRI scans of 141 patients acquired between 1 May 2014 and 1 May 2015 were retrospectively included from 4 training hospitals in the Netherlands, including 2 academic centers and 2 general hospitals. Out of the consecutive series only patients with pathology severely affecting the anatomy of the ulnar groove or the wrist in general were excluded, e.g. fractures, congenital or acquired deformities. Out of 161 final study subjects 38 (24%) had ulnar-sided symptoms. Baseline characteristics are summarized in Table 1.

2.2. Magnetic resonance imaging

MRI scans were performed on 1.5 or 3T Philips or Siemens MRI scanners. Images were acquired in routine clinical context with superficial coils varying in design to accommodate wrist only or also other small body parts. The MRI protocols varied among institutions, but all scans included either axial proton density (PD) or PD fatsat series that

Table 1
Baseline characteristics.

	all subjects	no ulnar-sided pain	ulnar-sided pain
number of subjects	161	123	38
<i>Demographic parameters</i>			
sex (% male)	62%	64%	58%
age (years)	32.8 (19)	30.9 (19)	39.2 (16)
<i>Clinical parameters</i>			
radioulnar angle (degrees)	5.0 (33)	8.7 (33)	-6.7 (28)
ulnar groove width (mm)	9.7 (1.4)	9.7 (1.4)	9.9 (1.4)
ECU displacement (mm)	0.6 (2.8)	0.5 (2.7)	0.8 (3.2)
ECU displacement (%)	5 (30)	5 (30)	7 (33)
MRI abnormalities ECU (%)	18%	11%	39%

data presented as "average (standard deviations)"; radioulnar angle = positive for more supination.

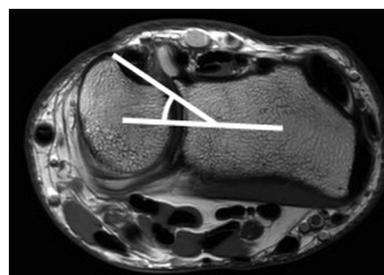


Fig. 1. Measurement of radioulnar angle.

Angle measured between a line tangent to the ulnar groove and a line connecting the centers of radius and ulna

included the ulnar groove in the field of view. For these sequences the slice thickness was at most 3 mm (minimum 1 mm), matrix ranged between 384 × 384 and 512 × 512, echo time (TE) ranged between 30–31 ms and repetition time (TR) between 2500–4094 ms.

2.3. Data analysis

All measurements were performed on the axial PD or PD fatsat image that included the deepest point of the ulnar groove. First, wrist position was quantified by measuring the radio-ulnar angle (Fig. 1) as the angle between a line tangent to the ulnar groove and a line connecting the centers of the radius and ulna. An angle of zero degrees corresponded to the neutral position, positive angles indicated a degree of supination, and negative angles indicated pronation. For the sake of presenting data in tables and figures we arbitrarily defined a neutral wrist position as a radioulnar angle between -15 and +15°, a pronated position at angles below -15° and a supinated wrist at angles above +15°. These categories were not employed in the analysis in any way; wrist position was analyzed as a continuous variable throughout.

Subsequently, the length of the ulnar groove was assessed and the distance between the (ulnar border of the) ECU tendon and the (ulnar border of the) ulnar groove was measured (Fig. 2). From these measurements relative and absolute displacement of the ECU tendon was determined. Subluxation over the apex of the ulnar border of the ulnar groove was expressed as positive, and as negative when it remained in the groove, a standardized approach established by the Australian Melbourne Orthopedic Group in the study by Pratt et al. [8] and also employed by the group of Lee et al. [2].

Percentage of ulnar ECU subluxation defined as ac/ab (i.e. amount of tendon past ulnar border divided by ulnar groove width), also conforming to Pratt's method [8].

Measurements were performed by four radiologists in training with musculoskeletal imaging experience ranging between 3–5 years, with each scan being rated by one of these doctors blinded for clinical history

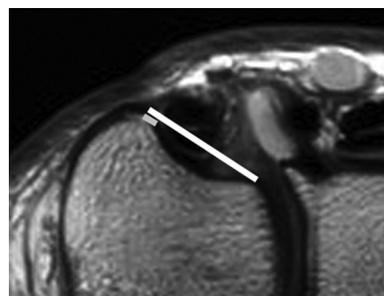


Fig. 2. Measurement of ulnar groove width and ECU displacement.

Longer line = ulnar groove width, shorter line = ECU displacement measured from ulnar lip of ulnar groove and most ulnar edge of ECU tendon which appears as a hypointense structure within the ulnar groove (in this example the displacement is negative as the tendon is positioned within the ulnar groove)

and MRI report. A subset of 30 patients from the same hospital was scored by two raters to assess interrater reliability.

From the hospital electronic patient databases and the imaging referral forms information was collected on the presence of ulnar-sided symptoms. Also, the presence of abnormalities on the MRI scan was registered and subdivided in abnormalities of the ECU tendon proper or ulnar-sided pathology.

2.4. Statistical analysis

A multiple linear regression model was constructed quantifying the effect of wrist positioning (predictor variable) on subluxation (outcome variable), after accounting for other variables. The assumptions of multiple linear regressions were satisfied, as judged by testing for linearity, normality assumptions of the residues, outliers, independence of errors, homoscedasticity, and multicollinearity. Separately a binary logistic regression model was used to assess the association between having ulnar-sided wrist symptoms and the variables ECU displacement, distal radioulnar angle, age and gender.

Age and radioulnar angle were rescaled by dividing them by 10 to improve the communicability of the resulting models. The variables were maintained as continuous variables within the model, without any information loss. For example, an age of 15 years was rescaled to an age of 1.5, thus leaving the direction and statistical significance of any observed associations/effects unaffected, but rescaling the estimate by a factor of 10. This produces an estimate for the effect of a decade of aging and an estimate of rotating the wrist 10°, rather than aging 1 year or rotating 1° (which may be expected to produce very small effects). Two-way intraclass correlation coefficient for consistency was used to assess interrater reliability [23]. The R statistical software environment was used (version 3.2.4, Vienna, Austria, 2016) [24]. Results were considered significant at $p \leq 0.05$ for all statistical tests.

3. Results

The baseline characteristics of all subjects and subgroups with and without ulnar-sided symptoms are presented in Table 1. Subjects with ulnar-sided symptoms are older (39.2 vs. 30.9 years) and more often show MRI abnormalities (39% vs. 11%). Interestingly, while the average radioulnar angle of both groups may be considered to be neutral, the average wrist position tends towards pronation (-6.7°) in symptomatic subjects, whereas it tends towards supination in asymptomatic subjects (8.7°).

The two-way intraclass correlation coefficient for consistency for the measurement of radioulnar angle and ECU displacement were 0.993 (95% CI 0.985 – 0.997) and 0.943 (95% CI 0.885 – 0.973), respectively. This illustrates that these measurements have excellent inter-rater reliability.

The linear regression model for percentage ECU displacement shows that none of the included variables significantly explains the variation in ECU displacement when adjusted for the other variables (Table 2).

Separately, when assessing the association between these variables and the presence of ulnar-sided symptoms, the logistic regression model does not show a significant odds ratio (OR) for ECU-displacement (OR 1.28, 95% CI 0.39–4.18) (Table 3) for the presence of ulnar symptoms. Thus, besides ECU-displacement not being explained by wrist position

Table 2
Multiple linear regression model for percentage ECU displacement.

covariates	coefficient	p-value
radioulnar angle (degrees)	0.00073	0.338
age (years)	0.00137	0.306
sex (male = 1)	0.02757	0.582
ulnar-sided symptoms (yes = 1)	0.01926	0.743

Table 3
Binary logistic regression model for the presence of ulnar-sided symptoms.

covariates	odds ratio (95% CI)	p-value
ECU-displacement (%)	1.28 (0.39-4.18)	0.683
radioulnar angle (10 degrees)	0.99 (0.97-1.00)	0.024
age (10 years)	1.23 (1.01-1.50)	0.042
sex (male = 1)	1.12 (0.52-2.41)	0.778

(i.e. radioulnar angle) in the overall group, it is also not predictive of the presence of ulnar-sided symptoms in this data.

However, age (OR 1.23, 95% CI 1.01–1.50) and radioulnar angle (OR 0.99, 95% CI 0.97–1.00) do demonstrate significant odds ratios ($p < 0.05$), meaning that increasing age and decreasing radioulnar angle are associated with a greater likelihood of having ulnar-sided symptoms. In other words, subjects with ulnar-sided symptoms are more likely to be older and have their wrist scanned in pronation.

The proportions of non-displaced and subluxed ECU tendons in the overall group and by presence of ulnar-sided symptoms are presented in Table 4; any ECU displacement larger than 0 being considered as subluxation. In all groups there is a similar percentage of subluxation in pronation and supination without a clear trend towards more frequent subluxation in supination. Fig. 3 further illustrates the lack of specificity of subluxation as an imaging finding. Both in symptomatic (triangles) and asymptomatic (circles) subjects there is a large variation in ECU displacement in all wrist positions, examples of which are shown in Figs. 4–6.

4. Discussion

This study comprehends the largest series of MRIs to date that assesses ECU subluxation. Our findings demonstrate that the ECU tendon is subluxed on MRI imaging very frequently and this occurs in all wrist positions irrespective of the presence of ulnar-sided symptoms. It therefore seems to be a very aspecific finding.

A review of the available literature confirms our finding of the aspecific nature of ECU subluxation. In an MRI study that looked primarily at the best positioning for evaluation of the triangular fibrocartilaginous complex Pfirmann et al. qualitatively registered the ECU position in 10 cadavers and noted that subluxation occurred only in supination to a maximum of 2 mm, which the authors considered to be physiological [25].

4.1. Ultrasound studies

MacLennan et al. investigated 21 symptomatic patients dynamically with ultrasound and observed ECU subluxation in all of them, with the onset of pain matching the subluxation [3]. While this illustrates the potential of ECU subluxation to be painful, other ultrasound studies have showed that subluxation is also seen in asymptomatic subjects. In 10 asymptomatic subjects Pratt et al. reported ulnar subluxation on flexion in 9/20 wrists and radial subluxation on extension in 2/20 wrists [8]. Lee et al. assessed ECU subluxation in 12 wrist positions, which showed that subluxation occurred in all positions, but markedly more often in positions involving supination [2].

4.2. MRI studies

While ultrasound is able to dynamically document gradual subluxation of the ECU, MRI scans are currently static by nature. However, the same pattern emerges in MRI studies. Jeantroux et al. reported general MRI findings in a study that was principally focused on a comparison of MRI sequences. In 16 symptomatic athletes 69% showed ECU subluxation in supination, whereas no subluxation at all was observed in pronation. However, subluxation was not assessed in a group

Table 4
Numbers of subluxed ECU tendons by wrist position.

	all subjects		no ulnar-sided pain		ulnar-sided pain	
	non-displaced	subluxed*	non-displaced	subluxed*	non-displaced	subluxed*
pronation	21 (45)	26 (55)	11 (37)	19 (63)	10 (59)	7 (41)
neutral	18 (33)	37 (67)	14 (33)	28 (67)	4 (31)	9 (69)
supination	24 (41)	35 (59)	19 (38)	31 (62)	5 (56)	4 (44)

Percentages in brackets; subluxation defined as ECU displacement larger than 0 mm. * any ECU displacement larger than 0 being considered as subluxation.

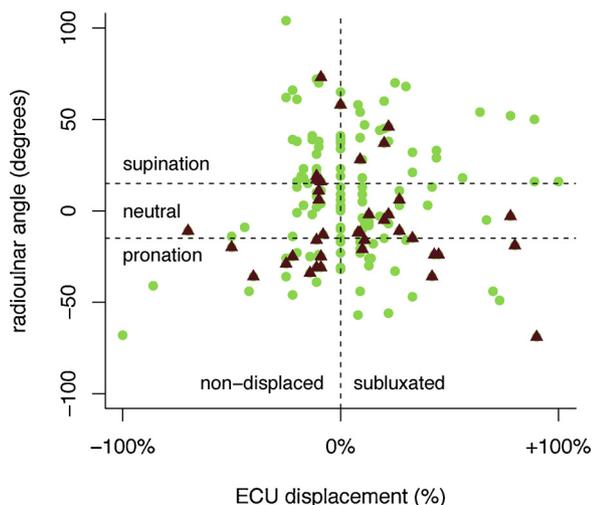


Fig. 3. ECU-displacement (%) versus radioulnar angle. circles = asymptomatic subjects, triangles = subjects with ulnar-sided symptoms

of 31 asymptomatic control subjects that also participated [10].

Petchparapa et al. assessed 38 wrists of 19 asymptomatic subjects in pronation, neutral position and supination. In only 16% the ECU tendon remained within the ulnar groove in all positions. In 76% a progressive subluxation was observed from pronation to supination, resulting in subluxation or dislocation in 82% and 40% respectively in supination, as opposed to 21% and 0% in pronation [13].

In a series of 24 MRI scans in computer users that varied between neutral and supine wrist position Burgess et al. reported ECU instability on MRI in 58% and 8% complete dislocations, further noting that no subjects had ulnar-sided wrist pain [9].

A larger MRI studies of 71 patients with ECU pathology reported subluxation in 32%. A comparison with the 46 asymptomatic subject control group was not possible, however, as subluxation was used as an exclusion criterion for this group [26].

Exploring the feasibility of real time wrist MRI Boutin et al. managed to dynamically image the wrist during pronation and supination in 10 asymptomatic subjects, also finding more frequent subluxation and dislocation in supination (36% and 45%) than in pronation (14% and

7%) [11].

A 10 cadaver study by Ghatan et al. showed subluxation in all positions except pronation-extension in at least one specimen, with maximum displacement in supination-flexion [27].

4.3. Other abnormalities in asymptomatic subjects

Subluxation does not seem to be the only ulnar-sided wrist abnormality that exists in asymptomatic persons. In a study among 26 asymptomatic long-term middle-aged amateur tennis players Sole et al. frequently observed subluxation (38%), partial or full thickness tears (33 and 23%) and ECU tendinosis (19%). Less frequent abnormalities were tenosynovitis, tendon sheath effusions and complete ECU dislocation, leading the authors to hypothesize that repetitive stress results in chronic attritional changes that are within the realm of normal effects of athletic activity that should not necessarily have clinical implications when observed on imaging in symptomatic individuals [12].

Another recurrent finding is the association between the morphology of the ulnar groove and ECU subluxation; that a flat or short ulnar groove predisposes to subluxation [3,13,26]. Contradicting this, one study reported no significant difference in ulnar groove depth between symptomatic and asymptomatic subjects [28]. In our study population both undisplaced and subluxed tendons were seen in flat ulnar grooves (Fig. 7).

Both the current and previous studies converge on the finding that ECU subluxation occurs in both symptomatic and asymptomatic subjects and in all wrist positions. Previous studies have repeatedly showed a tendency of more frequent subluxation in wrist positions involving supination. This finding was however not reproduced in our study and it is somewhat counterintuitive that ulnar-sided symptoms were more likely to be accompanied by pronation in our study population.

We speculate that the inclusion of wrist studies from multiple centers including patients with and without ulnar sided symptoms may have played a role. In symptomatic subjects ulnar-sided pain may be provoked by placing the wrist in supination. In an attempt to acquire adequate MRI images both the patient and the technician may therefore be inclined to avoid supination, an effect that could be less of an issue in asymptomatic subjects. The cross-sectional retrospective nature of our study does not allow for comparison of different wrist positions in the same patient to substantiate this.

Also, it should be noted that information on the presence of ulnar-

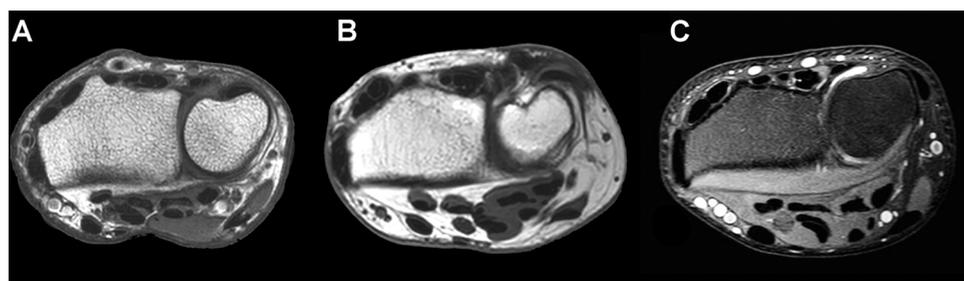


Fig. 4. Wrists in neutral position. ECU tendon within the ulnar groove (A), subluxed (B) and dislocated (C)

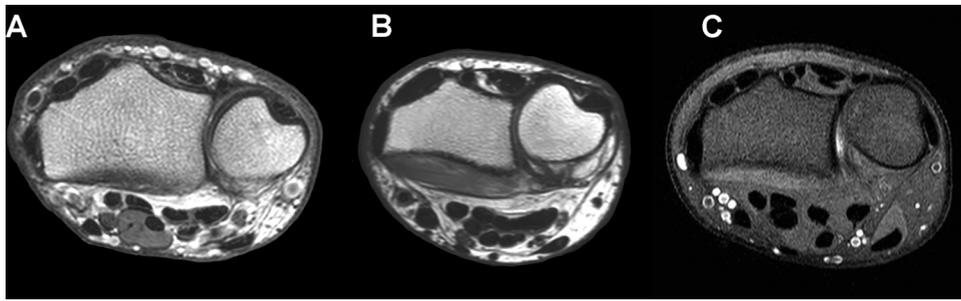


Fig. 5. Wrists in pronated position.

ECU tendon within the ulnar groove (A) and subluxed (B); C shows a wrist in extreme pronation with a flat ulnar groove with the ECU tendon within the ulnar groove.

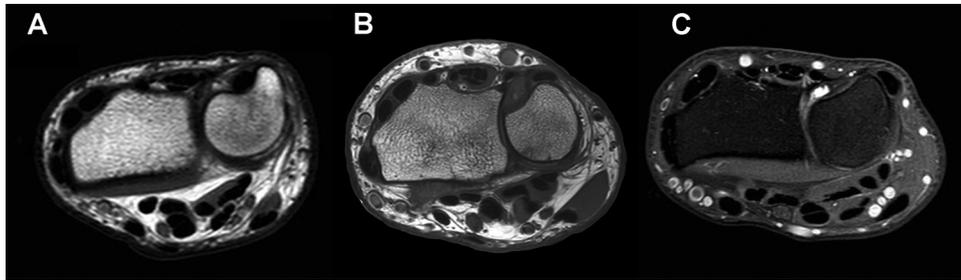


Fig. 6. Wrists in supinated position.

ECU tendon within the ulnar groove (A), subluxed (B) and dislocated (C)

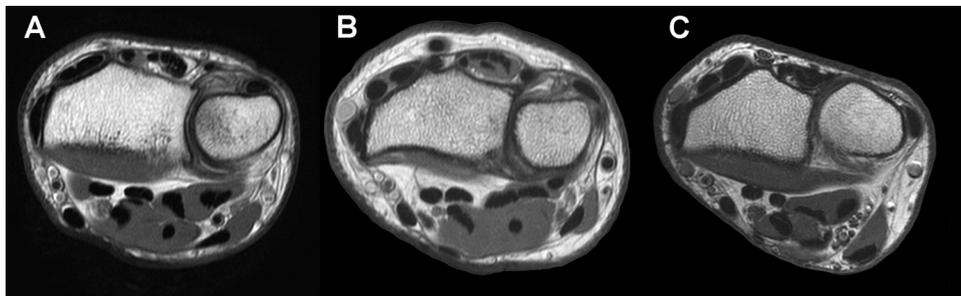


Fig. 7. Ulnar groove.

ECU within the ulnar groove (A), subluxed (B) and dislocated (C). The wrist is neutral in A and B and pronated in C.

sided symptoms may not always have been properly recorded by the clinician in the electronic patient data and/or the imaging referral form. Hence, the division into symptomatic and asymptomatic subjects is imperfect. However, we believe this reflects clinical practice and resembles the information that is normally available to a radiologist. Furthermore, despite this limitation a very similar distribution of wrist positions and subluxation was observed.

Wrist position itself was approximated by measuring the radioulnar angle and not directly measured with a goniometer. Although this method has not been validated previously, moving between pronation and supination anatomically requires rotation of the distal radioulnar joint and a corresponding change in radioulnar angle, which is what we have measured on imaging. Using this angle as a proxy for wrist position therefore meets face validity. The overall conclusion that ECU subluxation is independent from the anatomical wrist position is therefore thought to be valid.

Our study lacks data on the exact positioning of the arm in the MRI scanner. However, our analysis suggests the actual wrist positioning does not have a significant effect on the degree of ECU subluxation, either in the presence or absence of ulnar-sided symptoms.

Combining our own findings and those of previous studies ECU subluxation looks to be an aspecific finding that might be related to a person's symptoms, but may just as well be a coincidental finding.

Overall, the finding of a subluxed ECU on MRI is nonspecific and seems to be irrelevant.

Conflict of interest

None of the authors have a conflict of interest to declare.

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