Journal of Orthopaedic & Sports Physical Therapy
Official Publication of the Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association

RESEARCH STUDY

Radial Epicondylalgia (Tennis Elbow): Measurement of Range of Motion of the Wrist and the Elbow

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The aim of the present investigation was to determine the range of motion (ROM) features of the elbow and wrist joints in patients with radial epicondylalgia (tennis elbow), since there have been contradictory statements in previous reports and apparently no accurate study has been published to establish these typical ROM values. The precision of the measuring technique and the active and passive ROMs of these joints were first evaluated in an intratester reliability study in 16 healthy individuals, 12 men and four women with a mean age of 46 years (range = 26–67). The clinical study consisted of 123 patients with unilateral symptoms, 75 men and 48 women with a mean age of 43 years (19–63) and a mean symptom duration of 11 months (0.5–72). All measurements were performed using a simple plastic goniometer. The precision of the measuring procedure, expressed as the standard deviation of the random error of the mean, was 1–6° depending on the actual ROM measured. In patients with unilateral radial epicondylalgia, almost all measured ROMs of the elbow and wrist were found to be limited in the affected arm. This could give a rationale to use stretching in the treatment of radial epicondylalgia.

Key Words: *radial epicondylalgia (tennis elbow), range of motion, reliability*

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In the long bibliography of radial epicondylalgia [lateral elbow pain, tennis elbow (21)], a paucity of data exists on the range of motion (ROM) of the elbow and wrist. Some authors, however, claim or have found that all movements are normal on clinical examination (1,7,23).

The cause of the ailment is often described as multifactorial or due to overuse (18). Nirschl (27) considered inadequate forearm muscle flexibility to be a contributory etiological factor, especially in patients with strong forearm muscles.

It is stated in a standard textbook about the elbow by Morrey (25) that perhaps no portion of the physical examination was more important than assessment of the range of motion, and apparently no accurate study had previously been performed to establish the typical ROM features in patients with tennis elbow (25).

This investigation was conducted to evaluate the ROM characteristics of the elbow and wrist joints in patients with radial epicondylalgia. The precision of the measurement technique and the active and passive ROMs of these joints was first established in an intratester reliability study (4,20,24).

MATERIALS AND METHODS

Subjects

The reliability study included a series of 16 healthy individuals, 12 men and four women with a mean age of 46 years (range = 26–67), without any history or sign of elbow or wrist disorder. All but two of the subjects were right handed. Different professions, eight blue-collar and eight white-collar workers, matching the clinical study below, were selected.

From an even larger series of patients with radial epicondylalgia, all 123 patients with unilateral symptoms treated at our institution were selected in a consecutive prospective series from February 1987 to June 1991. Diagnostic inclusion criteria for radial epicondylalgia were: *1)* typical history of lateral elbow pain [pain characteristically emanating from the outer aspect of the elbow, aggravated by repetitive use and effort of the arm (especially active wrist extension), and gripping (especially overhand grip), even leading to dropping things and often mitigated by rest]; *2)* tenderness at distinct palpation of the radial epicondyle of the humerus; and *3)* positive "tennis elbow pain test" (pain at the radial epicondyle when the elbow is actively moved from flexion to full extension with the forearm in pronation and the wrist in flexion) (11). Patients with a history of major trauma to the arms, ie., fracture, were excluded.

The sample included 75 men and 48 women with a mean age of 43 years (19–63). One hundred twelve patients (91%) were right handed

	Symptom-Giving Arm	
	Right	Left
Dominant arm		
Right	91	21
Left	1	10

TABLE 1. *The distribution between side dominance and symptom-giving arm in the clinical study of 123 patients.*

and 11 (9%) were left handed. Ninety-two patients (75%) had symptoms from the right arm while the remaining 31 (25%) had left-arm symptoms. Table 1 presents the full distribution between handedness and symptomatic limb. Almost all the left-handed patients had their symptoms in the left limb. On the other hand, among all with left-limb symptoms, the majority still were right handed. The mean symptom duration was 11 months (0.5–72), with a median of 6 months.

Procedure

The ROM measurements were performed using a 17-cm double arm plastic goniometer with a semicircular scale (Upjohn, Partille, Sweden), frequently used in ordinary clinical practice.

All measurements were performed by the same investigator at room temperature. No warm-up exercises were performed. The measurements were always executed in the same order according to the protocol. Both the active ROM (maximal joint angle reached by the subject's own force) and passive ROM (greatest joint angle reached with the assistance of the investigator) were registered (25,31). The passive ROM was measured at the angle where a distinct stop was felt and before any pain was experienced (or aggravated) by the patient. The investigator strived to apply the same pressure each time.

For the reliability study, the tests were carried out with one single measurement of each joint motion, repeated once a week for 4 (3–5) weeks. All tests were performed at the same time of day. When executing the repeated tests, the investigator did not have the previous results available nor could the subject observe the readings. In the clinical series, the ROMs were measured on one occasion for each patient—when they were seen for the first time by the investigator.

The terminology recommended by the American Academy of Orthopaedic Surgeons (2) was used, and the tests were performed as described by McRae (22). When performing tests 1–4 below, the active ROM was first measured. Immediately afterward, when the subject was told to relax, the passive ROM was measured. The right side was tested first, followed by the left side without delay. One registration for each actual joint angle was noted.

1. Wrist flexion With the elbow straight, the distal arm of the goniometer was placed along the third metacarpal and the proximal goniometer arm tight along the dorsal aspect of the distal forearm. The flexion angles were measured from a lateral view (Figure 1a and b).

2. Wrist extension The elbow and fingers were kept straight. The dorsal extension was measured from a lateral view with one goniometer arm parallel along the dorsal aspect of the third metacarpal and the other goniometer arm placed centrally on the distal forearm (Figure 2a and b).

3. Supination of the forearm The elbows were kept adjacent to the body and in 90° of flexion, the forearm unsupported. Supination was measured from "thumb up" position. The subject held a pen firmly in the hand parallel to the row of knuckles. The pen served as a guideline for one goniometer arm and the other was parallel in sight line to the central part of the upper arm. The subject actively rotated the forearm outward as far as possible (Figure 3a).

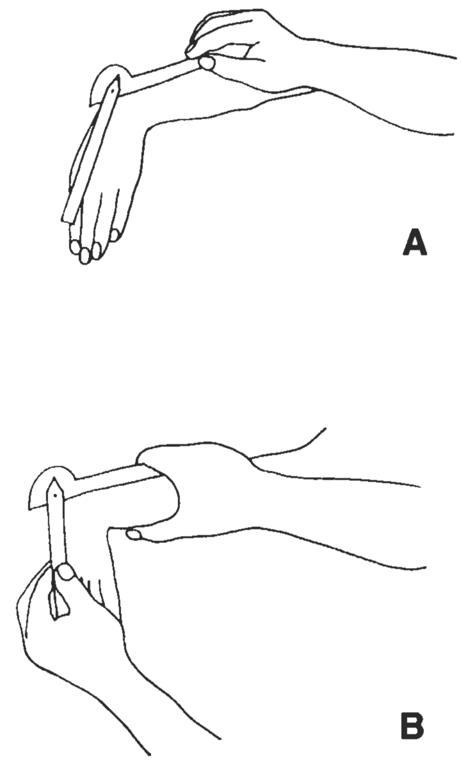

FIGURE 1. *A) Wrist flexion, active. B) Wrist flexion, passive.*

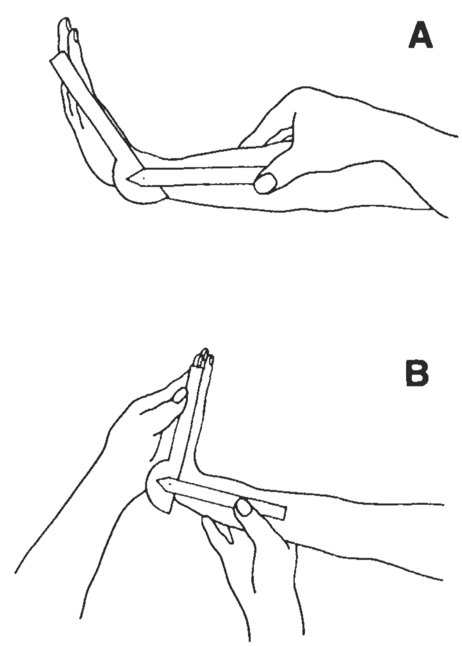

FIGURE 2. *A) Wrist extension, active. B) Wrist extension, passive.*

Then the passive "total" supination of the forearm, including the contribution from the wrist and the carpal joints, was measured as the examiner continued the rotation with mild force applied to the hand (Figure 3b).

4. Pronation of the forearm This was measured on the analogy of supination but instead the inward rotation was recorded (Figure 4a and b).

For tests 5–8 below, only active ROM was registered, since the passive moment does not add any notable gain in range of motion (30).

5. Radial deviation of the wrist Starting position was with the pronated forearm resting on a table, the elbow flexed to 90°, and the arm slightly abducted (30). One goniometer arm was placed along the third finger and the other along the radius in palpation contact (Figure 5). The ROM was registered with the fingers extended in adduction with the palm flat on the table and the hand deviated actively as far radially as possible.

6. Ulnar deviation of the wrist The test was performed on the analogy of radial deviation of the wrist (Figure 6).

7. Elbow extension The extension was measured from a lateral view, the forearm in supination, and the palm of the hand upward. The goniometer arms were positioned parallel to the upper arm and forearm centrally (Figure 7). The value 0° described full neutral extension. Hyperextension was attributed positive values, while an extension defect was attributed negative values.

8. Elbow flexion The test was performed on the analogy of elbow extension (Figure 8). The values were registered from the reference of 0° in full extension.

Data Analysis

In the reliability study, the precision of the ROM tests was determined using a one-way analysis of variance model (within groups) calculating the standard deviation of the random error $\sqrt{\sigma_\epsilon^2}$ by means of the sum of squares of deviations between measurement occasions within the individuals, estimated from the relation $\sigma_\epsilon^2 = \Sigma\Sigma(x_{ij} - \bar{x}_i)^2/n(k - 1)$, where x_{ij} denotes the measurement on individual i ($i = 1, 2, \ldots, n$) at occasion j ($j = 1, 2, \ldots, k$), and $\bar{x}_i$ is the mean value of the k measurements on individual number i (8).

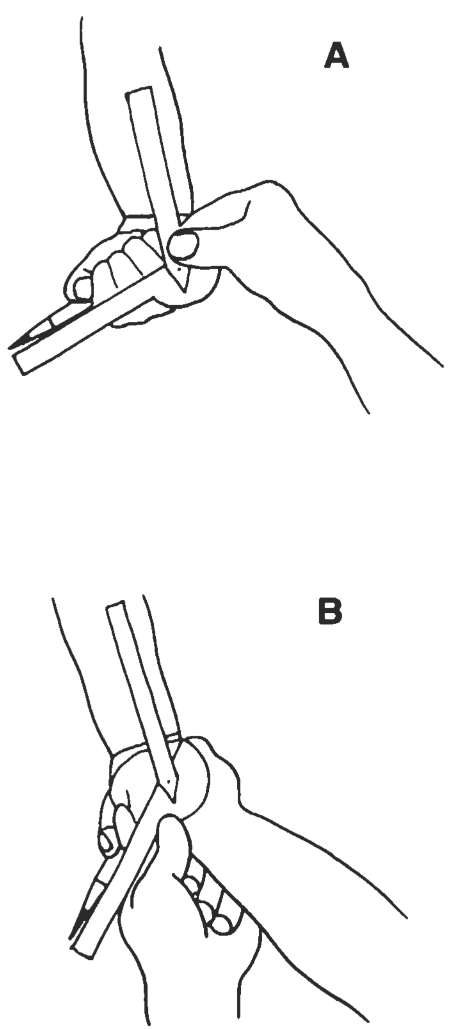

FIGURE 3. *A) Supination, active. B) Supination, passive.*

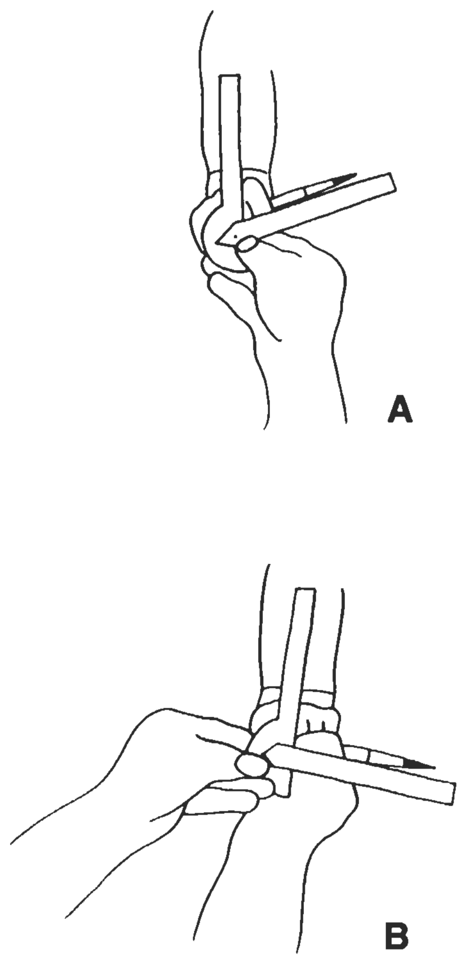

FIGURE 4. *A) Pronation, active. B) Pronation, passive.*

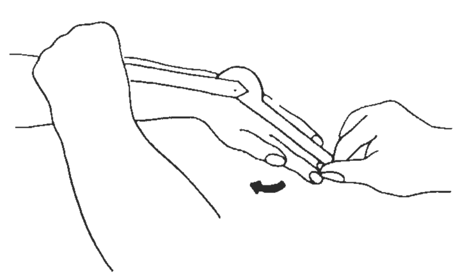

FIGURE 5. *Radial deviation.*

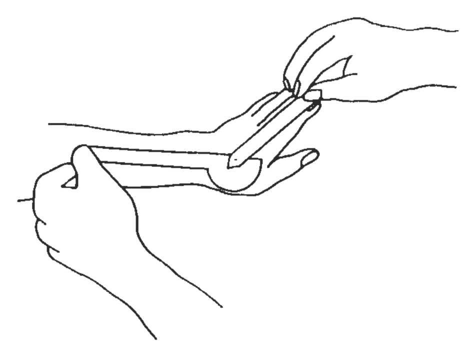

FIGURE 6. *Ulnar deviation.*

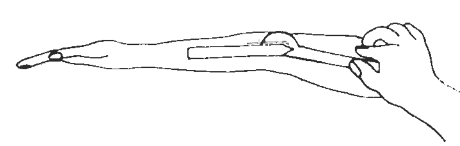

FIGURE 7. *Elbow extension.*

Before determining the ROM means and the 95% confidence intervals in the reliability study in Table 2, the individual average for each ROM category was calculated and then included in the statistical testing.

When calculating differences between certain ROMs, $d = x_1 - x_2$, eg., affected vs. healthy sides in the clinical study, the standard error of the mean differences ($\bar{d}$) is estimated by

$$\sigma_{\bar{d}} = \frac{\sigma_\epsilon}{\sqrt{\frac{n}{2}}}$$

because

$$\sqrt{\sigma_{\bar{d}}^2} = \frac{\sqrt{\sigma_1^2 + \sigma_2^2}}{\sqrt{n}} = \frac{\sqrt{2}\sigma_\epsilon}{\sqrt{n}}$$

since σ_1 is considered same as $\sigma_2 = \sigma_\epsilon$ for the same ROM and calculated in the reliability study above.

Thus, the greater the number of individuals, the smaller the variation of error, which in all instances were far below critical values in the calculations of the difference. Consequently, these differences were stated definitely true.

In the comparison between the healthy and the symptom limb side, a paired t test has been used for each separate variable. The sigma or any other value was not transferred from the reliability to the clinical study, since the calculations in the two groups were done entirely separately.

RESULTS

The Measuring Precision

The precision of the measurements (the standard deviation of the random error) varied in the reliability study from 1 to 6°. The most reliable measures were elbow extension, elbow flexion, and wrist flexion, while the greatest measurement error was found in pronation, supination, and wrist extension (Table 2).

Joint Motion	Variation of Error	ROM	
		$\bar{X}$	95% CI
Wrist flexion active right	3	66	62–71
Wrist flexion active left	2	68	63–73
Wrist flexion passive right	2	83	78–88
Wrist flexion passive left	3	85	80–91
Wrist extension active right	4	50	44–57
Wrist extension active left	6	57	51–64
Wrist extension passive right	3	77	71–83
Wrist extension passive left	3	82	76–88
Supination active right	5	115	107–123
Supination active left	6	113	105–121
Supination passive right	5	144	137–150
Supination passive left	5	137	129–145
Pronation active right	6	69	65–72
Pronation active left	5	74	70–79
Pronation passive right	6	101	95–106
Pronation passive left	5	113	108–118
Radial deviation right	5	29	26–33
Radial deviation left	4	31	28–35
Ulnar deviation right	4	49	44–54
Ulnar deviation left	4	50	46–55
Elbow flexion right	2	143	141–145
Elbow flexion left	2	144	142–146
Elbow extension right	1	4	1–6
Elbow extension left	2	4	1–7

95% CI = 95% confidence interval for the mean.

TABLE 2. *Reliability measurements of range of motion (ROM) in the elbow and wrist in 16 healthy individuals in degrees (rounded values).*

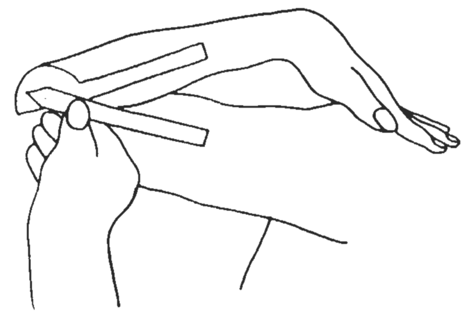

FIGURE 8. *Elbow flexion.*

The Magnitude of the ROMs

The mean ROMs and the 95% confidence interval for the mean (95% CI) of the various joint motions are listed in Table 2. In all joint measurements except supination, a slightly better ROM was found on the left compared with the right side (1–12°). The difference was statistically significant for wrist flexion, wrist extension, pronation (both active and passive), and elbow flexion. The passive ROM generally exceeded the active ROM by 17 to 39°. This difference was greatest for pronation: 32° on the right and 39° on the left side, respectively, followed by supination (24 and 29°), wrist extension (25 and 27°), and wrist flexion (17° on both sides).

The Effect of Radial Epicondylalgia on the ROM of the Elbow and Wrist

The differences in ROM between the healthy and the affected arm are illustrated in Tables 3 and 4. For the 92 patients with right-arm symptoms, all measured ROMs were restricted on the involved limb except passive supination. The greatest differences were seen in wrist extension, wrist flexion, and pronation. For the 31 patients with left-arm symptoms, the ROMs for wrist flexion, supination, and elbow extension were restricted. Tables 2, 3, and 4 indicate consistency between measurement of the ROMs in the healthy subjects in the reliability study and the ROMs on the

Joint Motion	Difference			ROM Healthy Side	
	$\bar{X}$	95% CI	p	$\bar{X}$	95% CI
Wrist flexion active	7	5.3–8.4	3×10^{-7}	70	68–72
Wrist flexion passive	8	6.4–9.6	1×10^{-15}	85	83–87
Wrist extension active	11	8.3–13	3×10^{-7}	63	60–65
Wrist extension passive	8	6.3–10	2×10^{-7}	85	83–87
Supination active	3	0.1–5.5	0.04	110	107–112
Supination passive	NS			129	125–132
Pronation active	7	5.2–9.0	4×10^{-11}	79	77–81
Pronation passive	12	9.9–15	1×10^{-15}	109	106–112
Radial deviation	4	2.8–5.3	1×10^{-8}	31	30–33
Ulnar deviation	4	2.3–6.1	4×10^{-5}	53	51–55
Elbow flexion	3	1.5–3.8	1×10^{-5}	146	145–147
Elbow extension	4	3.1–5.4	2×10^{-7}	6	4–7

95% CI = 95% confidence interval for the mean.
NS = Nonsignificant difference.

TABLE 3. *Differences in degrees between affected and healthy arm in range of motion (ROM) in the elbow and wrist in 92 patients with radial epicondylalgia and right arm symptoms (rounded values). The difference was considered significant if $p < 0.05$ in the used paired t test.*

symptom-free limb in the subjects in the clinical series.

DISCUSSION

The total variation of measurement consists of the sum of errors from several sources. The error from the measuring device itself (goniometer error) is negligible (29). The two major contributors of measuring error are, instead, the error between different observers (intertester variation) and the error between different measurement recordings by the same observer (intratester variation) (4). The intertester error for repetitive measurements was excluded in this study by allowing one investigator to execute all the measurements since the main interest was focused on the intratester variation. The procedure was, moreover, standardized in other aspects, such as time of the day and registrated test order at each time.

The applied test design was performed using only one measurement for each joint motion repeated once weekly instead of the traditional test routine for statistical calculations where several recordings are taken on the same occasion (4). A single measurement for each test session was chosen to eliminate the risk of receiving a gradual increase of the actual ROM, related to the so-called creep phenomena (14). Such a stretching effect, when performing repeated ROM recordings of the same joint motion at the same occasion, was thus avoided. An ordinary clinical situation with usually one measurement was also imitated in this way.

The precision of the joint motion tests were expressed as the standard deviation of the random error. This calculation was judged more appropriate than using the coefficient of variation (the ratio, standard deviation/mean value), which has been used in previous studies for other joints (10). First, no correlation was found between the size of the measured angle and the standard deviation. Secondly, the ROMs varied from 0° for elbow extension up to 144° for elbow flexion and passive supination. Because the coefficients of variation are influenced by the ROM for each joint motion, a comparison of the precision of the tests between various joint motions may not be possible when the precision is expressed as a coefficient of variation (5).

Some joints can be measured more accurately than others (20). The precision of the measurements in this study had a satisfyingly small variation from only 1–6° for the different motions. The most accurate measurements were elbow extension, elbow flexion, and active and passive wrist flexion, which possibly could be a function of a more distinct skeletal stop at the end point of the joint motion. The greatest variation was shown for pronation, supination, and active wrist extension. The reason for this may perhaps be due to softer end-feel. The use of a pen as a guideline and the use of sight lines may also add a greater element of unreliability in determining reference points.

Joint Motion	Difference			ROM Healthy Side	
	$\bar{X}$	95% CI	p	$\bar{X}$	95% CI
Wrist flexion active	5	0.8–8.4	0.02	66	63–69
Wrist flexion passive	4	0.9–7.7	0.01	80	77–83
Wrist extension active	NS			57	52–61
Wrist extension passive	NS			78	74–82
Supination active	9	4.8–12.7	9×10^{-5}	107	102–113
Supination passive	8	5.1–11.3	8×10^{-6}	127	122–133
Pronation active	NS			69	64–73
Pronation passive	NS			92	88–96
Radial deviation	NS			29	25–32
Ulnar deviation	NS			48	45–52
Elbow flexion	NS			143	141–145
Elbow extension	4	0.8–5.7	0.01	5	3–7

95% CI = 95% confidence interval for the mean.
NS = Nonsignificant difference.

TABLE 4. *Differences in degrees between affected and healthy arm in range of motion (ROM) in the elbow and wrist in 31 patients with radial epicondylalgia and left arm symptoms (rounded values). The difference was considered significant if $p < 0.05$ in the used paired t test.*

Joint Motion	AAOS	Boone and Azen
Wrist flexion	73	76
Wrist extension	71	75
Supination	84	82
Pronation	71	76
Radial deviation	19	22
Ulnar deviation	33	36
Elbow flexion	146	143
Elbow extension	0	1

TABLE 5. *Normal active range of motion of joints (male subjects) according to Boone and Azen (3) (rounded values) and means of estimates from the four sources used by the American Academy of Orthopaedic Surgeons (AAOS) (2).*

The greater ROM on the left limb compared with the right is perhaps a consequence of the higher frequency of dexterity in the population. The dominant arm is usually stronger than the nondominant, and greater muscle strength tends to be associated with more tightness as has been proven for athletes (9). However, from a functional standpoint, the ROMs of the right and left arm are essentially equal; in our study, the difference was only a minor number of degrees. As a consequence of this minor difference, we have in the present clinical study followed the recommendations of Boone and Azen (3) that joint motions of a patient's healthy limb can routinely be used for comparison with the affected side in the presence of disease or lesion.

The width of the 95% CI for the different ROMs, in spite of the great variation in age and professions for the individuals, allows comparison of the ROMs in the present study for this particular age group with those of Boone and Azen (3) and mean estimates from four different sources used by the American Academy of Orthopaedic Surgeons (2). In these sources, where all reported ROM measurements were done only actively, elbow extension, elbow flexion, and pronation correspond well with the current study (Table 5). Also, the values for wrist flexion differ little between the different studies. The present study has, however, greater ROMs for wrist extension, ulnar deviation, radial deviation, and supination. The latter finding could at least partly be explained by the technique of recording that allowed a certain contribution from the wrist and carpal joints in the "total" passive supination. However, since this additional contribution is reasonably constant in the measurements, any such differences between left and right arms in the clinical study is interpreted as due to the actual condition at the elbow. Furthermore, our study contains both men and women, while Boone and Azen only examined men.

For radial epicondylalgia patients, Mills (23) wrote that on superficial examination, all movements were complete. However, he added that when wrist and fingers were flexed during forearm pronation, the patient could not attain full elbow extension and had a painful feeling of resistance in contrast to the unaffected elbow which had full and painless extension and pronation. Similarly, Chard and Hazleman (6) stated that the ROM of the elbow usually was normal, but loss of a few degrees of extension was found in some chronic cases. Lehman and Kushner (19) also expressed that measurement of the elbow usually showed no restriction of elbow extension. According to Leach and Miller (17), the flexion and extension of the elbow joint were complete, but in some instances of chronic tennis elbow, the patients did lack 5 to 15° of wrist extension. A slight loss of passive wrist flexion could also be seen. Gunn and Milbrandt (12), however, stated that there was full passive motion of the actual joints. Albers et al (1) mentioned that the ROM was normal. Halle et al (13) also pointed out that examination generally reveals complete elbow ROM with little or no discomfort with passive ROM of the wrist and elbow.

In contrast to these references, the ROM of the elbow and wrist in the present clinical series was restricted. A possible and rational explanation as to why more significant differences were found in those with symptoms in the right limb than for the left could be the size of the patient material: there are almost three times as many patients with right limb symptoms as with left. The most affected ROMs were elbow extension, pronation, and wrist flexion, all of which involve the forearm extensor muscles, with their common origin at or close to the radial epicondyle.

The most affected range of motions were elbow extension, pronation, and wrist flexion, all of which involve the forearm extensor muscles, with their common origin at or close to the radial epicondyle.

These findings indicate that stretching of the forearm muscles could be of therapeutic value as was recommended by such authors as Kulund et al (15), LaFreniere (16), Leach and Miller (17), Nirschl and Sobel (28), and Murtagh (26). This fact still requires more thorough investigation in future controlled studies.

CONCLUSIONS

The reliability of the measuring procedure with a simple goniometer for active and passive ROM of the elbow and wrist was found to be good, giving high measurement precision. The standard deviation of the random error varied between 1 and 6° for the different joint motions, being best for elbow extension, elbow flexion, and wrist flexion. The greatest variation was found for pronation, supination, and wrist extension.

Practically all measured ROMs of the elbow and wrist were found to be limited in patients with unilateral radial epicondylalgia. The restriction of the ROM in the patients with right-arm symptoms was most evident for active and passive wrist flexion, active and passive wrist extension, and passive pronation. Patients with left-arm symptoms had significant restriction of the ROM for active and passive wrist flexion and pronation and for elbow extension. JOSPT

ACKNOWLEDGMENT

We wish to express our gratitude to Professor Adam Taube, Institution of Statistics, Uppsala University, Uppsala, Sweden, for the statistical guidance.

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