Visual estimation of joint angles at the elbow

Rashid Barakat Abu-Rajab · A. Marsh · D. Young · L. A. Rymaszewski

Abstract The aim of this study was to assess the accuracy of visual estimation of elbow joint angles. A total of 116 observers (93 doctors and 23 physiotherapists) were shown 21 digital images of two arms in predefined degrees of elbow flexion on two separate occasions. They estimated the angle of flexion to the nearest 5°. Only 70.8% of estimates were within ±5°, although intra-observer agreement was good among all groups tested (ICC range 0.963–0.983). Orthopaedic consultants and registrars were equivalent and statistically better at estimating the angles compared to senior house officers and physiotherapists ($P < 0.001$). Compared to the angles of 85 and 90°, all other angles were significantly less likely to be estimated to within ±5° ($P < 0.001$). In conclusion, visual estimation of joint angles at the elbow may not be desirable in cases where accurate serial assessment is required for clinical decision making. The use of a goniometer by an agreed standardized protocol is advised.

Keywords Elbow · Visual estimation · Angles · Assessment

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Introduction

The main function of the elbow joint is to position the hand in space. Morrey et al. [5] showed that the functional range of motion is approximately 30–130°. Accurate measurement of elbow flexion/extension is therefore important to monitor disease progression and the response to treatment, as well to define the indications for surgery. Clinicians may be tempted to visually estimate these joint angles, although it is controversial whether this technique is reliable [1, 4, 7, 9, 10]. Goniometric readings at the elbow have been shown to have errors up to 6° [4]. Despite several studies reported in physiotherapy journals [4, 9, 10], only one paper has assessed orthopaedic surgeons' ability to accurately estimate joint angles [7], and this was not at the elbow. As this is common practice in orthopaedic clinics, the aim of this study was to determine whether visual estimation was an accurate method for assessing joint angles at the elbow.

Materials and methods

Two healthy volunteers, one overweight and one lean, were involved in the study. Each subjects' upper limb was positioned against a wooden board, and digital images were taken perpendicular to the board, with a camera mounted on a tripod (Fig. 1). The forearm was placed in neutral rotation with the palm of the hand flat on the board. The surface markings of the centre of the humeral head, the humeral lateral epicondyle (roughly the axis of elbow rotation) and the distal radio-ulnar joint were marked. The elbows were positioned at predetermined angles using a long-arm goniometer and validated using Scion Image (Scion Corporation, Maryland, USA) imaging software.

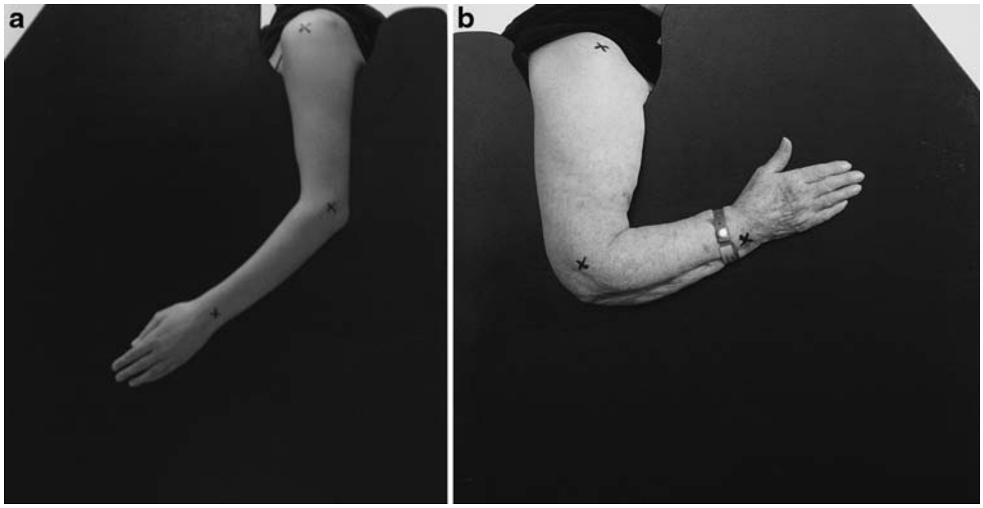

Fig. 1 **a** Digital photograph of lean arm showing a joint angle of 55°. **b** Digital photograph of overweight arm showing a joint angle of 105°

A total of 21 digital images (11 of the lean arm and 10 of the overweight arm) with the elbow in varying degrees of flexion were taken. The lean arms elbow was placed at 10, 25, 40, 55, 70, 85, 90, 105, 120, 135 and 150° of flexion. Those of the overweight arm were at 20, 35, 50, 65, 80, 90, 105, 120, 135 and 145°. One picture was shown twice, near the beginning and end (lean 55°).

One hundred and sixteen members of staff from four orthopaedic departments were recruited—28 consultant surgeons, 29 specialist registrars, 12 experienced senior house officers (SHO3), 24 first year senior house officers (SHO) and 23 physiotherapists. The observers were asked to visually estimate elbow flexion on each of the digital images on two separate occasions 1–5 weeks apart. They were instructed to record angles for each of the subjects to the nearest 5°, and only one measurement was allowed for each digital image.

Statistical analysis was performed grouping the errors into 5° levels of accuracy, and logistic regression analysis was used to determine the predictors of accuracy from grade, angle being estimated and thickness of arm, adjusted for time (i.e. first or second assessment). Backward selection was used to produce the final model and estimate odds ratios. Pairwise comparisons were done to compare the error rates for each profession with the performance of the consultants as the baseline with *P*-values adjusted for multiple comparisons using the Bonferroni correction factor. The reliability of the measurements over time was assessed for each professional group by computing the intra-class correlation coefficient. All analyses were done using Minitab Statistical Software for Windows (Minitab Inc., State College, USA) and STATA Statistical Software (StataCorp LP, Texas, USA) with a significance level of 5%.

Results

On only 3 out of 232 occasions were all 21 photos accurately estimated to within ±5°. However, the two specialist registrars, and one consultant, were unable to achieve this level of accuracy on both occasions.

All groups had high intra-class correlations (range 0.963–0.983) indicating good intra-observer variability, and repeatability of the measurements between the two time points (Table 1). The lean arm at 55° was shown twice and was estimated to within ±5° 44% of the time as photo 2 and 51% of the time as photo 17. This difference was not significant.

The measurement errors for each grade of profession are shown in Fig. 2. These are shown as the mean of both attempts and the statistics is described for all estimates taken as a whole and not each individual observer. A breakdown of these by attempt and a total for all observers can be seen in Table 2 and illustrates that taking all professions together an average accuracy to within ±5° was only seen 70.8% of the time. The magnitude of these measurement errors are illustrated in Fig. 3 that clearly demonstrates a wide variability of estimates. However, at angles close to 90° and at the extremes of flexion and extension observers

Table 1 Intra-class correlation coefficients for all professions

Profession	ICC	95% CI
Consultants	0.981	0.974, 0.986
Registrars	0.983	0.976, 0.988
SHO3s	0.970	0.956, 0.979
SHOs	0.963	0.948, 0.974
Physiotherapists	0.981	0.973, 0.986

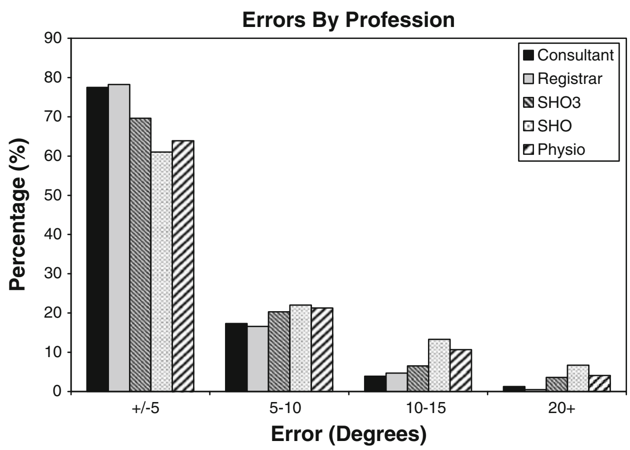

Fig. 2 Measurement errors for different profession—mean of both attempts

were more accurate. This was confirmed by logistic regression analysis when compared to an angle of 90°;all other angles, apart from 85°, were significantly less likely to be estimated within ±5° ($P < 0.001$).

There was no difference in the proportions of accurate estimates between the lean and overweight arms ($P = 0.141$). Results were more likely to be accurate on the second attempt ($P = 0.001$). Compared to consultants, SHOs and physiotherapists were significantly less likely to estimate the angles to within ±5° accuracy. These comparisons are shown in Table 3. Estimating angles to within ±10° highlighted a difference in the arm thickness

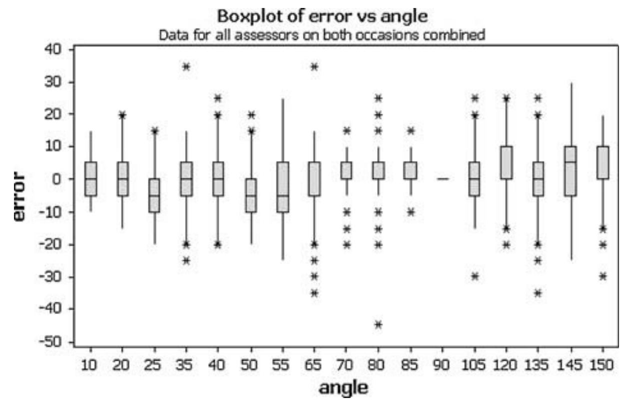

Fig. 3 *Boxplot* showing distribution of errors by angle

Table 3 Results of logistic regression analysis for comparison with consultants at level of estimation ±5°

Comparison with consultants	*P* value	OR	95% CI
Registrars	0.766	0.95	0.68, 1.32
SHO3s	0.071	1.58	0.96, 2.59
SHOs	<0.001	2.46	1.71, 3.54
Physiotherapists	<0.001	2.13	1.50, 3.03

($P = 0.007$), with the lean arm more likely to be estimated accurately [OR 2.04, 95% CI (1.21, 3.42)]. The corresponding table of results for comparison with consultants is shown in Table 4.

Table 2 Measurement errors for all professions on both occasions

Grade	Time	Proportion accurate to within ±5° (%)	Proportion accurate to within ±10° (%)	Proportion accurate to within ±15° (%)
Consultant	First	75.2	93.7	98.3
	Second	79.8	95.9	99.2
	Both	77.5	94.8	98.7
Registrar	First	74.1	92.8	99.5
	Second	82.4	96.9	99.5
	Both	78.2	94.8	99.5
SHO3	First	65.9	88.9	96.8
	Second	73.4	90.9	96.0
	Both	69.6	89.9	96.4
SHO	First	62.1	82.1	92.5
	Second	59.9	83.9	94.1
	Both	61.0	83.0	93.3
Physiotherapist	First	63.2	84.5	95.9
	Second	64.6	85.9	95.9
	Both	63.9	85.2	95.9
All	First	68.8	88.8	96.8
	Second	72.7	91.2	97.2
	Both	70.8	90.0	97.0

Table 4 Results of logistic regression analysis for comparison with consultants at level of estimation ±10°

Comparison with consultants	*P* value	OR	95% CI
Registrars	0.992	1.00	0.56, 1.78
SHO3s	0.106	2.16	0.85, 5.47
SHOs	<0.001	4.19	2.35, 7.48
Physiotherapists	<0.001	3.49	1.93, 6.29

When validating all photos using Scion Image (Scion Corporation, Maryland, USA) imaging software, all angles measured with the long-arm goniometer, using a standardized protocol, were found to be within a mean difference of 1.56° (range 0.04–2.59°) from the value measured on the computer.

Discussion

This study demonstrated the inaccuracy of visual estimation of joint angles at the elbow, with only 70.8% of estimates overall being within ±5°. Low [4] showed a mean error of 5° (SD 6°) when using a goniometer to measure elbow angles, but a mean error of 9.3° (SD 12.5°) when visually estimating. Watkins et al. [9] have shown similar results for the knee, and Rose et al. [7] for the small joints in the hand. However, these findings have been disputed by others. Williams et al. [10] compared the different types of goniometer with visual estimation for shoulder flexion and concluded that visual estimation was as reliable and consistent as goniometry. However, they only looked at one angle, which was 100°, and as our study has shown angles closer to 90° are more likely to be estimated correctly so one could question their bold conclusion.

The reliability of goniometers has also been questioned with reported standard deviations varying from 2.1° to 6.0° for the elbow [1, 2, 4], but with values as high as 11.48° reported for other joints [10]. Standardisation of the patient's position and stabilization of the proximal segment of the joint during the measurement process have been shown to minimize error and increase interobserver reliability [6, 9]. Fish and Wingate [2] reported that improper alignment of the goniometer, misidentification of bony landmarks and variations in manual force, all contributed to goniometric error at the elbow. Thus, unless bony landmarks are accurately identified, correct application of the instrumentation cannot be guaranteed. In our study, the bony landmarks were clearly marked for reference, allowing all subjects to see these points for measurement. This may have been a source of potential error as it may have forced the observers to estimate angles in an unfamiliar way, but it did standardize what everyone was measuring.

During the study, some test observers complained of "fatigue" while estimating the angles and felt they may not have performed as well at the end as at the beginning. We believe that this mimics the clinical environment, as fatigue will be experienced towards the end of a busy clinic. These concerns were not borne out in the results; however, as when the same photo was shown twice, it was more accurately estimated on the later of the two occasions, though this was not statistically significant, suggesting the "fatigue" they felt made little difference.

Experience did, in our study, seem to play a role in the accuracy of visual assessment being significantly better in consultants and specialist registrars. Interestingly, physiotherapists, despite familiarity with assessing joint angles with a goniometer, had significantly poorer results. This may simply be due to a lack of experience with the techniques of visual estimation. These findings are similar to the findings of Rose et al. [7], who looked at estimation of MCP and IP flexion in a resin hand model, and Williams and Callaghan [10] who hypothesised that visual estimation is a level of skill that is acquired through practice.

Our study demonstrated good intra-observer reliability for all different groups (range 0.963–0.983). These results are in agreement with previously published studies [1, 3, 8, 9], emphasizing the importance of continuity when serially assessing joint angles.

In conclusion, we would suggest that visual estimation of joint angles at the elbow is not advisable in cases where accurate serial assessment is required for clinical decision making and would recommend the use of a goniometer by an agreed standardized technique in clinical practice.

Conflict of interest statement No funds were received in support of this study. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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