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The assessment of grip strength after upper limb injuries in medico-legal practice

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Abstract

Four hundred adult claimants underwent medico-legal assessment following upper limb injuries. Dynamometry was performed on each using the Jamar five handle-position test. Injury causes loss of power and there is a significant relationship between the percentage loss of power and the measured whole limb impairment. This paper presents a new approach for the analysis of the tests. The normal physiological length–tension pattern of muscle is maintained in the majority of claimants albeit with modifications due to the specific effects of injury on hand function. This paper provides normative data for the analysis of dynamometry in this population and makes recommendations for parameters that suggest that a test is a true reflection of capacity and thus useable in court.

Keywords

Dynamometry, grip strength, Jamar, hand injury, medicolegal, assessment, disability, sub-maximal, malingering

Introduction

One of the purposes of a medico-legal report is to provide the court with an assessment of disability resulting from an injury. The mainstay of the assessment of functional outcome from a hand injury is clinical examination. This information is used by the expert to comment on the ability of the claimant to perform their normal daily activities, to care for themselves, to return to work and to compete on the open job market. This information is used to calculate the quantum of the claim.

Hand function is a product of sensation, movement and power. Loss of power is a common complaint amongst claimants. Measuring grip strength is a logical and seemingly objective approach to assessing this complaint. The most widely used method of assessing power is the measurement of grip strength using a Jamar dynamometer (Figure 1). This is an adjustable hand-held device that measures grip strength over five settings varying from $1\frac{3}{8}$ to $3\frac{3}{8}$ inches, in half-inch increments. It is isometric in use, with almost no perceptible motion of the handles, regardless of grip strength. A muscle contraction is described as isometric if the muscle tension changes but the muscle length remains the same.

Dynamometry is only valid when a patient exerts a maximal voluntary effort. It has been noted that

> It is a common misconception that all tests that generate numbers are necessarily objective. This is particularly true of grip and pinch measurements. These tests rely heavily on subject motivation and are therefore subjective.[1]

A number of technical approaches have been adopted to detect sub-maximal effort.[2] These include repetitive testing, the rapid exchange and the rapid simultaneous grip strength tests. Although these have been reported to detect feigned hand weakness, they are relatively time-consuming and rarely performed properly in the clinical setting.

Muscle contractions can be described based on two variables: length and tension. Muscles achieve their greatest active tension when close to an ideal length,

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which is usually their resting length. When stretched or shortened beyond this, whether due to the action of the muscle itself or by an outside force, the maximum active tension generated decreases. The power generated by a muscle plotted against length exhibits a skewed bell-shaped curve[3] (Figure 2). The physiological characteristics of muscle are paralleled by the varying power that can be applied over the five settings of the Jamar dynamometer; the maximum power being almost always achieved at either setting 2 or 3.

Different approaches have been used to analyse the data from the Jamar five-position test to allow more objective analysis. The visual analysis of the grip strength curves is subjective. As a result, a comparison of two curves with identical ratios but different power can suggest erroneously loss of the normal physiological relationship between muscle length and power. The effect of varying power is solved by normalisation of the data by expressing the relationship of power at the five settings as a ratio of either the maximum reading or the mean of the five settings. This approach negates the difference in power between curves and reveals that although an injury to a hand diminishes power, the normal physiological curve is maintained.[4,5]

The loss of the bell-shaped curve was proposed by Stokes[6] as a sign of feigning in his paper entitled 'The seriously uninjured hand'. In a subsequent paper, the same author showed flattening of the dynamometry power curves in patients suspected of being of 'low effort' and volunteers who were deliberately feigning weakness.[7] Subsequent studies in volunteers who had been instructed to feign weakness have not corroborated these findings.[8,9] Nevertheless, the concept of a 'flat curve' has gained traction as evidence of sub-maximal effort. Consequently, analytical techniques have focused exclusively on the issue of curve variation. It is, however, my experience that the curves obtained in clinical and medico-legal dynamometry are often atypical rather than flat.

I have previously alluded to the difficulty in relying on dynamometry results in medico-legal practice.[10] It has been long recognised that the interpretation of dynamometry results in clinical practice is hampered by the absence of objective criteria for analysis.[4] Much of the technical literature on dynamometry has involved studies on volunteers rather than patients. There are no publications on the use and interpretation of dynamometry in medico-legal practice. The purpose of this review is to analyse the results of dynamometry in a large group of patients undergoing medico-legal assessment, to improve the methodology of interpretation and to provide objective criteria of what is satisfactory test performance.

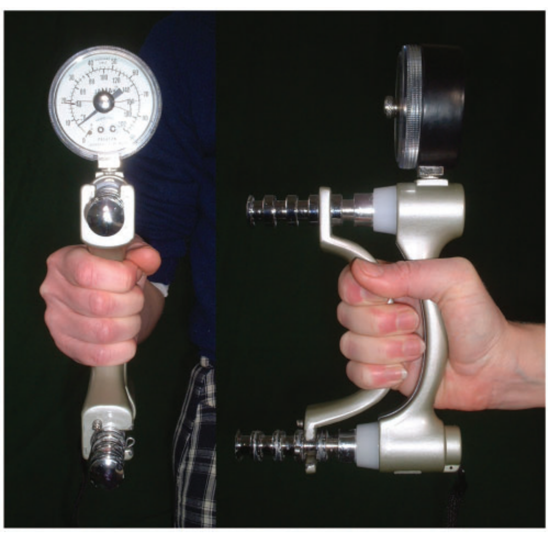

Figure 1. Front and side views of a Jamar dynamometer being used on position-2.

Methods

A consecutive and unselected group of adult claimants who had suffered unilateral upper limb injuries were assessed for the purpose of the preparation of

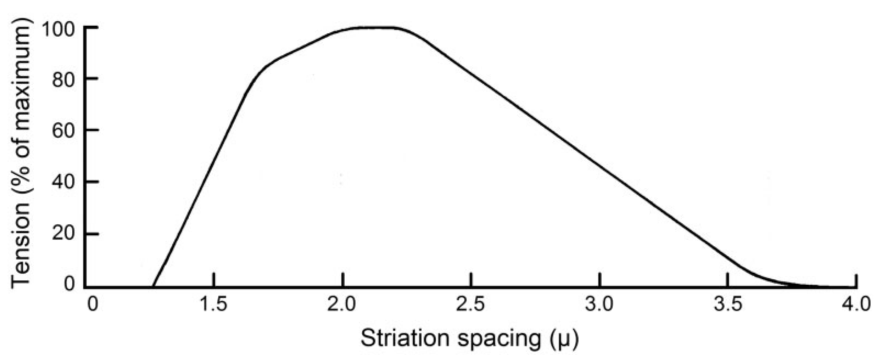

Figure 2. The length tension relationship of muscle fibres (Adapted from Gordon et al.[3]).

medico-legal reports. At the time of assessment, the information obtained from the claimants and their medical records included basic demographics, interval from injury (months) and hand dominance. The clinical examination was comprehensive and included the use of goniometers for range of movement, monofilament hair and static two-point discrimination for sensation as well as photography. Following examination, the whole limb impairment was calculated from these findings according to published guidelines.[11]

Power testing was performed with a Jamar dynamometer, utilising the five handle-position test (Figure 1). The tests were performed with the claimants seated with their arms at their sides, the elbows flexed to 90°, the forearms mid-prone and wrists in neutral. The test protocol comprised a single test at each Jamar position. The sequence started from the first and narrowest position on the uninjured hand, followed by the first position on the injured hand, the second position on the uninjured hand, etc. A number of calculations were performed on the data obtained.

Maximum: The strongest result over the five positions was noted for each hand.

Position: The handle position of the maximum result was identified and if for example this same reading occurred at positions 2 and 3, the result has been recorded as 2.5.

Mean: The average of the five results was calculated for each hand.

Difference: The percentage difference of the maximum power between the injured and uninjured hands was calculated by the formula $(P_{injured} - P_{uninjured})/((P_{injured} + P_{uninjured})/2) \times 100$

Plotting: The grip strengths at the five positions were plotted on a graph to produce an power curve (Figure 3).

Normalisation: The curves obtained from the five results in each hand were normalised by division of each value by the calculated mean. Two further calculations were made from the normalised values.

Curve variation: The dynamism of the curves was assessed by calculation of the coefficient of variation between the five results for each hand (standard deviation/mean) which was multiplied by 100 to produce a percentage score (Figure 3). Statistical analysis is two-tailed as low scores indicate flattened curves and high scores indicate atypical and eccentric curves.

Curve deviation: The shape of the curves was assessed by calculating the percentage differences between each of the five normalised values and the mean normalised values in all uninjured hands for that handle position. The results were corrected for sex using the data presented below. The sum of the absolute percentage differences was divided by five to provide a mean percentage score (Figure 3). Statistical analysis is one-tailed as a score of zero indicates a perfect match. Increasing scores reflect increasing curve atypia.

Statistics: Comparisons between groups used the Student's t-test, Mann-Whitney, Chi-squared tests and analysis of variance; correlation calculations were performed by either the Pearson or Spearman tests as appropriate. Significance has been assessed at the 5% level. The results are presented as mean (standard deviation) or median (25% and 75% percentiles) for data that was not normally distributed.

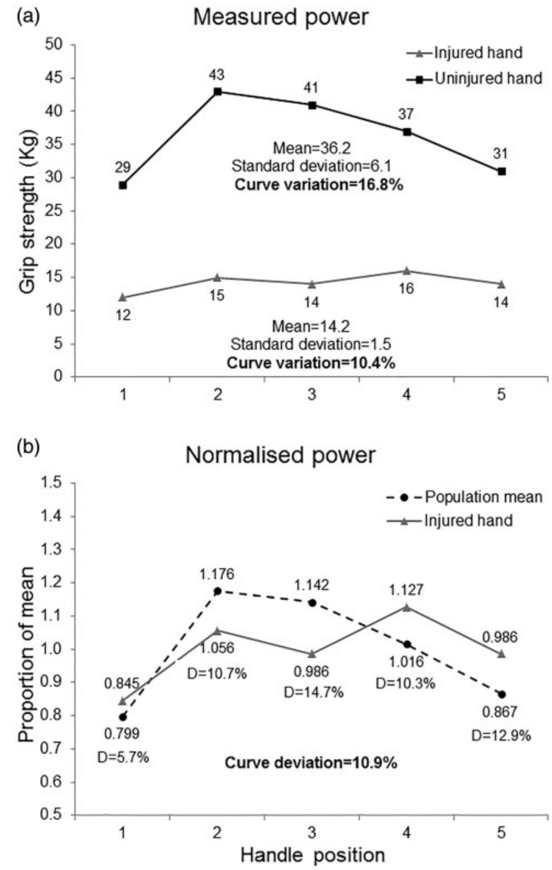

Figure 3. (a) The grip strength at the five positions of both hands of a male claimant plotted showing the power exerted at each handle position. The method of calculation of the curve variation score is shown. (b) The normalised curve for the injured hand is plotted and compared with the mean values for the male population. The method of calculation of the curve deviation score is shown.

Results

A total of 400 patients with a mean age of 39.1 (±13.9) years with a male to female ratio of precisely 3:1 were assessed at a mean of 21.4 (±15.4) months after injury. The median whole limb impairment score was 9(2–20)%.

The maximum grip strength was significantly reduced in injured hands compared with uninjured (all 30.5 ± 13.1 vs. 43.9 ± 11.8 kg, men 33.4 ± 13.3 vs. 48.5 ± 9.7 kg, women 21.9 ± 7.8 vs. 30.2 ± 5.3 kg). The median loss of grip strength in injured hands was 30(13–60)%. This was not affected by gender, age or hand dominance.

The normalised figures show a subtle and significant difference in the shape of the curves between uninjured and injured hands (Figure 4).

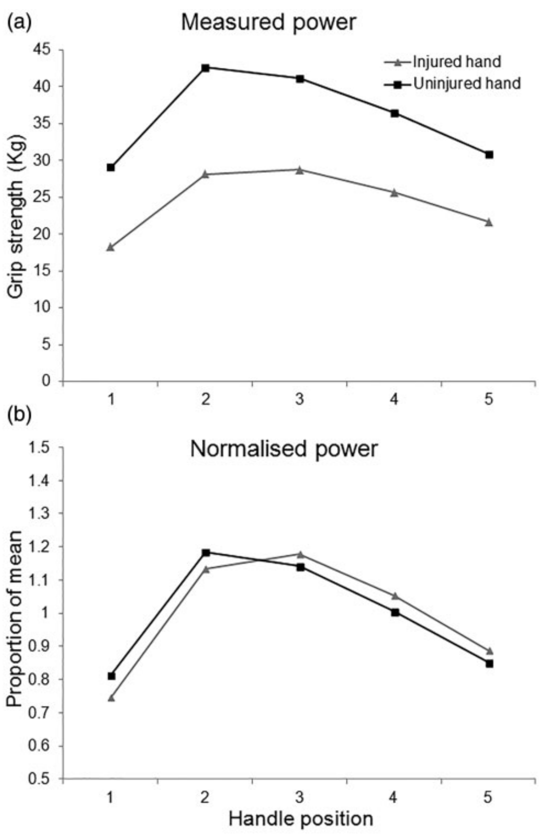

Figure 4. The mean measured and normalised grip strength for the entire population. Note the subtle shift in the curves caused by injury, which was significant at all points ($p < 0.001$).

Personal characteristics

There was a small but significant difference in shape of curves between the sexes. These figures were used as reference values for the calculation of the curve deviation scores to provide greater precision (Table 1).

The mean power varied across the age groups in both injured (<30 years 32.5 ± 13.4, 30–39 years 32.8 ± 13.1, 40–49 years 31.9 ± 14.5, 50 + years 24.9 ± 10.8 kg, $p < 0.001$) and uninjured hands (<30 years 45.3 ± 11.0, 30–39 years 48.2 ± 12.3, 40–49 years 45.1 ± 11.5, 50 + years 36.8 ± 9.3 kg, $p < 0.001$).

There were 364 right-handed claimants with injuries to 195 dominant and 169 non-dominant hands. The 36 left-handed claimants had injuries to 19 dominant and 17 non-dominant hands. There were no significant differences in any measures due to dominance in either injured or uninjured hands.

Injury type

Twelve injury groups were identified: amputation (71), burn/laceration (21), complex (14), contusion/crush (38), fingertip (27), fracture of fingers (26), fracture of hand (19), fracture of wrist (42), nerve alone (30), nerve and tendon (36), sprain (45) and tendon alone (31). The whole limb impairment percentages varied significantly between the injury groups (Figure 5). These differences were broadly paralleled by the dynamometry results (Figure 6).

In the 71 claimants who had sustained digital amputations, there was a significant relationship between the loss of power and number of phalanges removed (Figure 7). There were nine claimants who had lost complete fingers comprising two central fingers (2), index fingers (3), middle fingers (2) and ring fingers (2). The median loss of power for these four groups was 89%, 24%, 39% and 61%, respectively.

The claimants who had sustained nerve injuries included 27 who had divided their median (10), ulnar (14) or both median and ulnar nerves (3), principally at the wrist level. The median loss of power for these three groups was very uniform, being 47%, 42% and 43%, respectively.

Table 1. The mean normalised values for the five handle positions in the uninjured hands for men and women.

Handle position	1	2	3	4	5
Male	0.80 ± 0.14*	1.18 ± 0.09*	1.14 ± 0.1	1.02 ± 0.08*	0.87 ± 0.09*
Female	0.86 ± 0.16	1.21 ± 0.11	1.15 ± 0.09	0.98 ± 0.11	0.81 ± 0.11

The values are significantly different at all but one position (*$p < 0.001$). These provided the reference values for the calculation of the curve deviation in each sex.

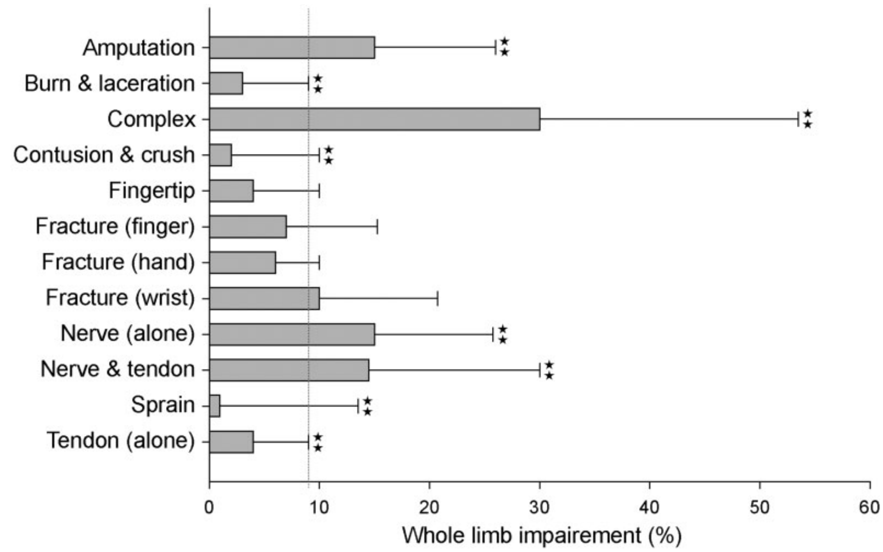

Figure 5. Median calculated functional impairment (+75% percentiles) in the 12 injury groups with the overall median value indicated by the vertical line (⋆⋆$p < 0.01$).

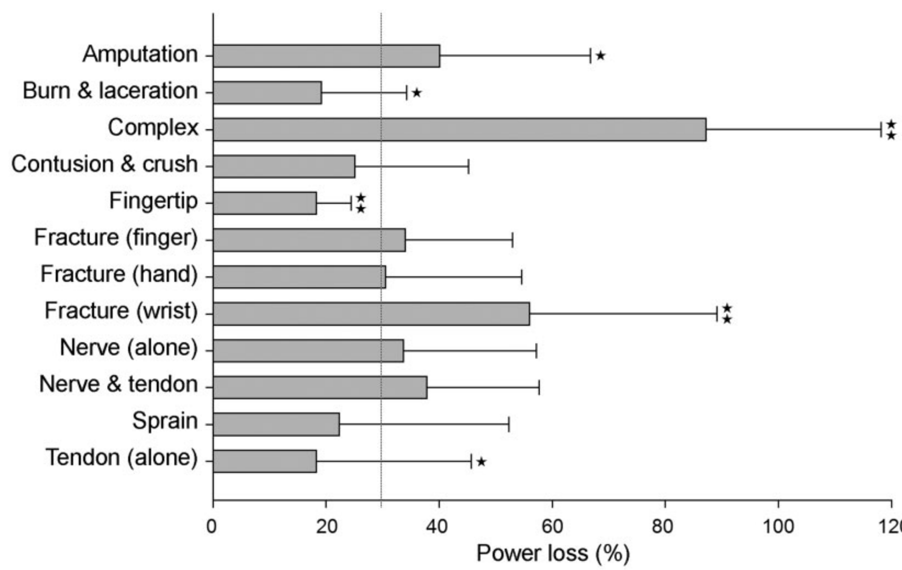

Figure 6. Median power loss (+75% percentiles) in the injured hands in the 12 injury groups with the overall median value indicated by the vertical line (⋆$p < 0.05$, ⋆⋆$p < 0.01$).

Handle position

The maximum grip was achieved at either position 2 or 3 in 99% of the uninjured hands. There was no difference between the sexes. The injured hands had significantly greater variation with peak grip strength occurring in handle positions other than 2 and 3 in 16% of cases (Table 2). Deviation from the positions 2 and 3 was significantly correlated with loss of grip strength in the injured hands (Figure 8).

Curve physiology

There was an increase in the curve variation observed in injured hands compared with uninjured hands overall (22.2(17.5–28.3)% vs. 19.0(15.4–23.0)%, $p < 0.001$). There also was a significant difference in the curve deviation between injured and uninjured hands (10.4(6.8–16.7)% vs. 7.1(5.0–10.2)%, $p < 0.001$). There was no difference in the curve variation and deviation scores between any of the injury groups. All groups exhibited physiological curves despite the variety

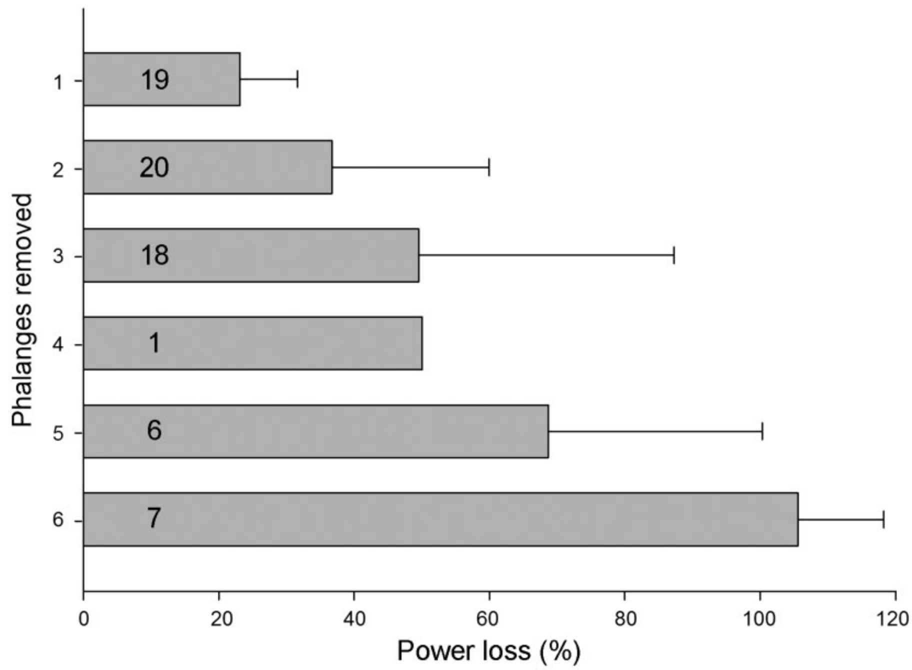

Figure 7. Median power loss (+75% percentiles) observed in the 71 injured hands compared with the number of phalanges lost (there are 14 phalanges in each hand; three for each finger and two for each thumb). The number of patients in each group is indicated within the columns ($p < 0.001$).

Table 2. The handle position at which the maximum grip was observed in the injured and uninjured hands in the entire population showing dispersal from the central handle positions ($p < 0.0001$).

Handle position	1	1.5	2	2.5	3	3.5	4	4.5	5
Injured	6	1	148	38	149	10	33	5	10
Uninjured	0	1	233	56	101	5	4	0	0

of injuries. This was observed even in patients who had lost whole fingers or suffered nerve injury albeit with some alteration in curve profiles (Figure 9). Curve physiology was unaffected by gender, age or hand dominance.

Correlations

There was a strong correlation between the loss of grip strength in the injured hands and whole limb impairment (Table 3). Both the whole limb impairment and power loss were correlated with the curve physiology in the injured hands as measured by curve variation and deviation. Neither was correlated with curve physiology in the uninjured hands. There was, however, a significant relationship between curve physiology between the injured and uninjured hands.

Compliance

The 25% and 75% intervals for the curve variation and curve deviation scores in the uninjured hands provide the reference range for normality representing 50% of the population. In 108 injured hands, both scores were within the normal range. Scores lying outside the 5% statistical level identify significant outliers. At least one score was outside these limits in 108 injured hands. In the 69 hands that had abnormal curve variation, 8 exhibited flattened curves and 61 had a variety of atypical curves (Figure 10). Comparison of the types of injury between the claimants whose curve physiology was significantly abnormal with those whose scores were within the normal interquartile range revealed the two groups to be very well matched. However, the abnormal group were older (42 ± 15 years vs. 36 ± 13 years, $p = 0.002$), had a higher whole limb impairment (14(3–29)% vs. 6(0–14)%, $p < 0.001$) and had greater power loss (55(29–89)% vs. 17(9–38)%, $p < 0.001$) than those with normal curve physiology.

Discussion

This paper describes the use of dynamometry as part of the assessment of an unselected and heterogeneous

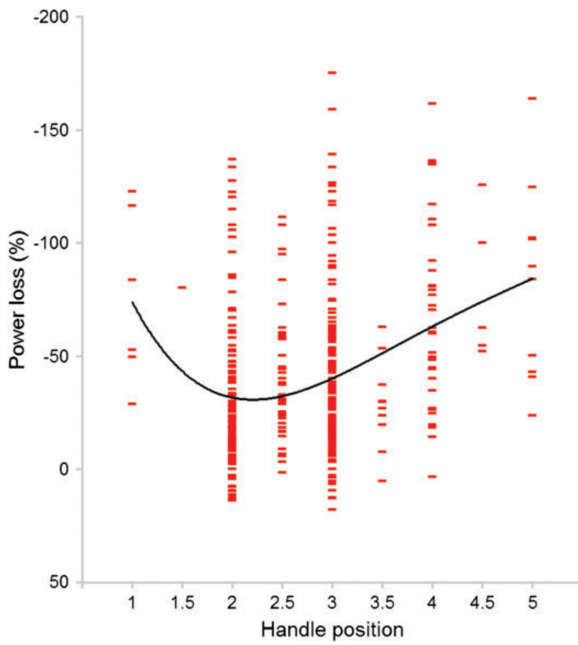

Figure 8. Power loss in all injured hands and the calculated polynomial trend line for each Jamar handle position demonstrating increased loss of power associated with maximum grip occurring at positions other than 2 and 3 ($R = 0.34$, $p < 0.001$).

group of adult patients who were engaged in litigation following both bony and soft tissue injuries of the upper limb. It demonstrates that injury causes loss of power and that there is a significant relationship between the percentage loss of power and the severity of injury as judged by calculation of the whole limb impairment. It has demonstrated the specific impact of amputation and nerve injury on power.

It has been shown that although injury causes loss of power, the physiological bell-shaped curve is maintained in the majority of claimants albeit with minor modifications due to the specific effects of injury on hand function. This information is consistent with previous studies after injury.[4,5] The subtle difference in curve shape between injured and uninjured hands has been observed previously[4] and may reflect the effects of denervation, the loss of digits, movement and tendon function.

An obvious effect of injury is the change in the handle position at which maximal grip strength was applied in some injured hands. The correlation between altered handle position and power loss can be explained by the loss of muscle efficiency at wide and narrow positions. It is unlikely that any test with maximum grip outside the central handle positions provides an

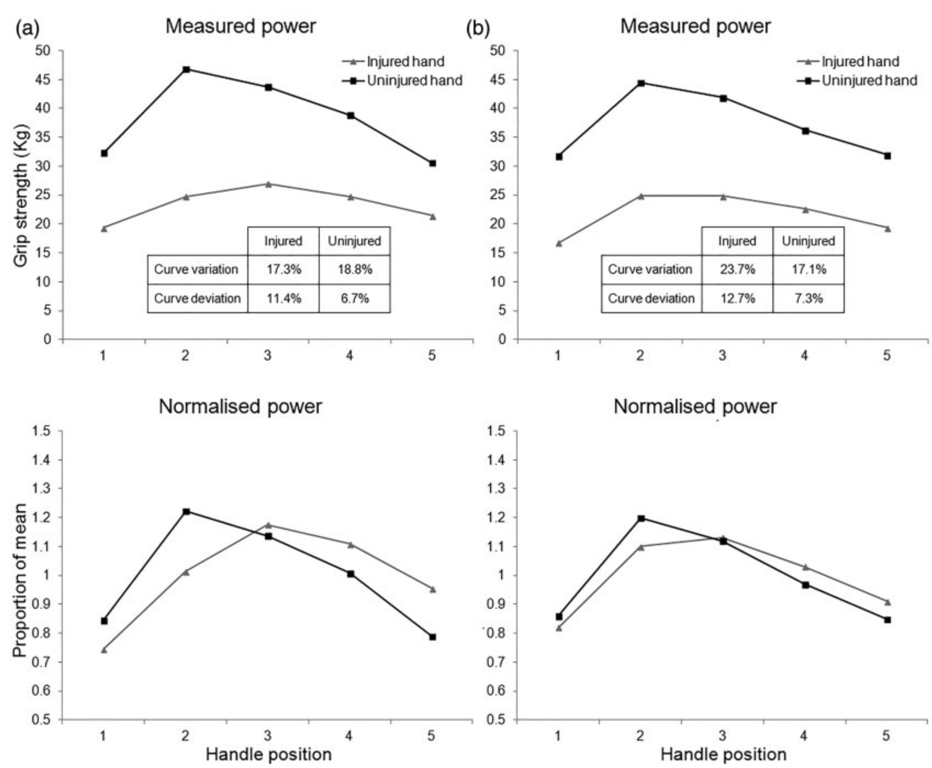

Figure 9. Mean measured and normalised power in the (a) 9 patients who had sustained amputation of one or more whole fingers and (b) 27 patients who had sustained divisions of their median, ulnar or both nerves. The median curve variation and deviation scores are provided for each population.

Table 3. Correlation between percentage power loss and the curve physiology measures in both injured and uninjured hands.

R value significance	Power loss	Curve variation (injured)	Curve variation (uninjured)	Curve deviation (injured)	Curve deviation (uninjured)
Whole limb impairment	−0.46 $p < 0.0001$	0.22 $p < 0.0001$	0.04 NS	0.24 $p < 0.0001$	0.05 NS
Power loss		−0.13 $p < 0.01$	0.03 NS	−0.38 $p < 0.0001$	−0.02 NS
Curve variation (injured)			0.41 $p < 0.0001$	0.68 $p < 0.0001$	0.17 $p < 0.001$
Curve variation (uninjured)				0.30 $p < 0.0001$	0.41 $p < 0.0001$
Curve deviation (injured)					0.25 $p < 0.0001$

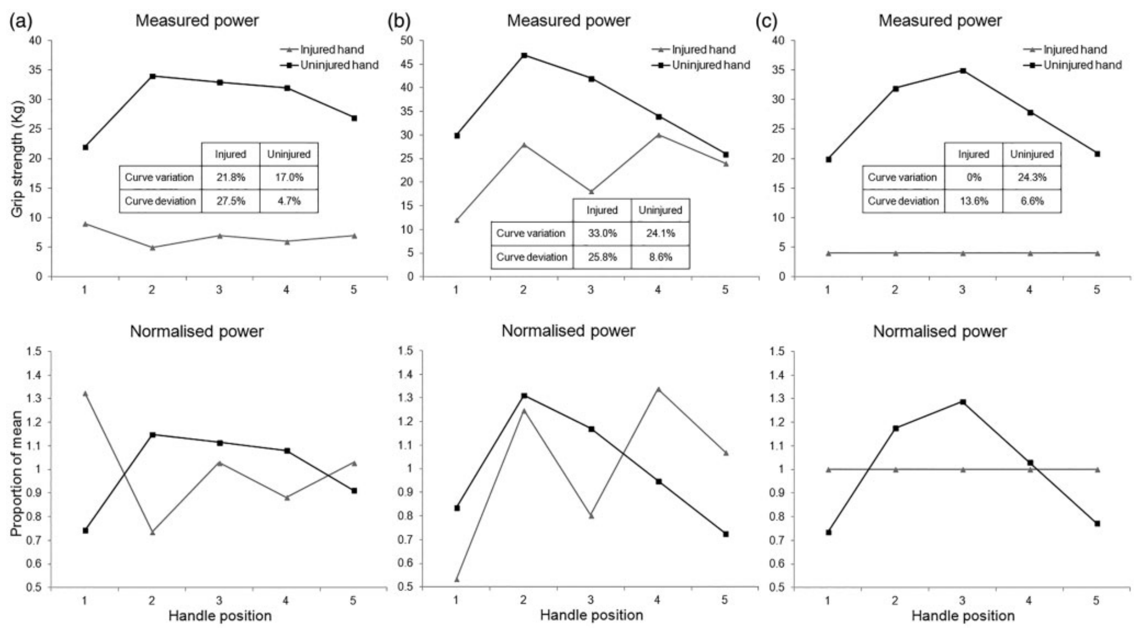

Figure 10. Three individual cases showing varieties of abnormal curves in injured hands. (a) A curve with normal dynamism but an inverse non-physiological profile. (b) An atypical non-physiological curve. (c) A classic and absolute "flat line".

accurate reflection of that claimant's true functional abilities. The same dispersal of maximal handle settings has also been observed in normal volunteers who were feigning weakness. It is suggested that the observation of maximum grip at handle positions 1 or 5 is indicative of feigning.[9]

The dynamometry data have been assessed by two further methods: one old and one new. The concept of measuring curve variation by one method or another has been previously described.[12] This measure is intended and is sensitive for the detection of a flat curve. However, it is not capable of detecting all atypical curves, which are the more common occurrence. The curve deviation measure has been created specifically to address this failing. The design of this measure is intuitive. It does not depend on sophisticated statistical methodology and its calculation is straightforward on widely available spreadsheet software.

Although very atypical curves are detectable by either measure, the curve deviation measure has proved capable of detecting atypia that would otherwise be unmeasurable (Figure 10(a) and (b)). Although this type of curve would be detected by visual inspection, the scoring system provides an objective method of identifying outliers.

The purpose of this paper is to broaden the repertoire for the assessment of dynamometry and to provide criteria by which a test result can be accepted as a valid result and thus useable in court. Apart from disability claims, I have in the past been asked to provide evidence in three cases where there was doubt about the ability of the defendants with a previous history of a hand injury to exert sufficient pressure to hold a knife, to pull a trigger and to strangle. It is therefore important for an expert to be confident that an assessment of strength is valid.

In scientific circles, the level of proof to test a hypothesis is generally set at a 5% chance that any observation would have happened by chance, equivalent to about two standard deviations from the mean. In legal circles, the level of evidence required is "the balance of probabilities" which is equivalent to a likelihood of over 50%. With this in mind, I have used measures that show the ranges that were observed in 50% of the normal hands. Therefore, the results in an injured hand whose curve physiology falls within this range can in my opinion be accepted. The results that fall outside the 50% levels cannot necessarily be relied upon. The results outside the 5% level should be disregarded and may indicate submaximal effort.

The results have shown that the dynamometry curves of only about a quarter of the injured hands fall within a normal range as defined by the data obtained from the uninjured hands. Furthermore, about one quarter of the injured hands had one or both scores that were outside the 5% range. Unintentional submaximal effort may be exerted as a result of pain, fear of re-injury or what I refer to as loss of confidence. Intentional submaximal effort may be exerted for secondary gain. It has been previously estimated that the incidence of illness deception in medicolegal practice and certain categories of benefit claims is between 20 and 50%. The manifestations include symptom exaggeration[10] and submaximal effort on testing.[13] The causes for curve atypia are multiple and will include the direct physical effects of an injury as well as psycho-social factors.

The majority of abnormal curves were eccentric rather than flat. Whilst some atypia is explicable due to the direct effects of injury such as stiffness or loss of tendon action, many of the curves obtained could not be explained on the basis of clinical examination or the injuries sustained. There was, within the 400 claimants, a group of 82 who had no measurable disability and whose median power loss was 14.6%. Twenty of these patients had significantly abnormal curve profiles. Although these patients may have had some residual symptoms, scarring, numbness in functionally unimportant areas and minor stiffness, it is more difficult to explain curve atypia in them than in those in whom there is obvious dysfunction or loss of a digit.

Eight claimants were identified who had flat lines with curve variations below the lower 5% limit. This group comprising seven men and one woman had a median whole limb impairment of 9%. Most had sustained significant injuries excepting one, who although complaining of ulnar nerve symptoms from a contusion to the elbow region, had no objective signs of dysfunction. This claimant, who is illustrated in Figure 10(c), had grip strengths of 4 kg at each handle position. I have no doubt that this particular claimant was feigning weakness. However, I am generally cautious about attributing abnormal test results to malingering. Although the "flat line" is apparently pathognomic of malingering, I would argue that there may be logical reasons for this type of pattern in some situations. If the dynamometer is in contact with a neuroma in the first web-space or there is a mechanical problem in the wrist joint, the exertion of a given force will cause a uniform amount of pain, irrespective of the handle position.

Test results have to be interpreted with regard to the clinical situation and pejorative labels avoided even if there is no other possible explanation for an atypical result. It is not the expert's role to determine motivation or label claimants but to give objective evidence to the court. If test results are inexplicable, it is sufficient to state that and to allow the court to draw its own conclusions.

The curve analysis is dependent on the data from the uninjured hands being representative of normality. The mean values obtained are a good match with those obtained by others in normal subjects.[14] The observation of minor but significant difference in curve shape between women and men almost certainly reflects differing hand size and has been accounted for in the calculation of the curve deviation scores. I have noted on many occasions that an erratic curve in an injured hand is associated with some atypia in the contralateral uninjured hand. This impression is supported by the significant correlation in curve physiology shown between injured and injured hands. It is therefore possible that the data from this population does not properly define normal physiology. Further studies in normal subjects are required either to verify or modify the reference ranges presented in this paper.

Dynamometry using the Jamar five-position technique is a quick, simple and low-cost method of assessing power. It is important that clinical examination provides valid information to allow calculation of quantum in civil claims and capacity in criminal cases. This paper has presented a new method for assessment and attempted to define criteria by which dynamometry can be judged to provide reliable results to the court.

Declaration of conflicting interests

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Functional and symptomatic assessment of medico-legal claims after upper limb injuries

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Abstract

A consecutive group of 250 patients underwent medico-legal assessment at a mean of 24 (±13) months following upper limb injuries. Each had completed questionnaires to assess function (Quick-DASH) and cold intolerance (CIQ36) before clinical assessment following which their whole limb impairment percentage was calculated. The mean(±SD) whole limb impairment, QDASH and CIQ36 scores were 9(±14)%, 43(±24) and 17(±10), respectively. There was a significant correlation between whole limb impairment and QDASH, although some patients reported surprisingly high disability levels despite minimal or no objective functional impairment. Whilst useful qualitative information can be obtained from questionnaires, the correlation between subjective and objective scores is weak albeit statistically significant. Individual patients can show marked discrepancies between objective and subjective functional scores. The results of questionnaires in individual medico-legal patients should be treated with caution.

Keywords

hand injury, medicolegal, assessment, disability, cold intolerance, questionnaires, PROM, QDASH, symptom exaggeration, malingering

Introduction

One of the purposes of a medico-legal report is to provide the court with an assessment of disability resulting from an injury. Whilst clinical assessment provides objective information on hand function, it is recognised that patient-reported outcome measures (PROM) can provide further insight into patients' symptoms and their abilities to perform activities of daily living. There are few publications that describe the assessment of upper limb function in patients engaged in medico-legal claims and none that describe the use of PROM. The present paper describes the practice and experience of one clinician over a three-year period.

Methods

A consecutive and unselected group of adult patients who had suffered upper limb injuries were assessed for the purpose of the preparation of medico-legal reports between June 2013 and June 2016. Each was sent and asked to fill out the Quick Disability of the Arm, Shoulder and Hand (QDASH)[1] and Cold Intolerance Questionnaires (CIQ36)[2] before the appointment. The completed forms were brought to the appointment for review, discussion and later analysis as part of the report process.

At the time of assessment, the information obtained from the patients and their medical records included basic demographics, interval from injury (months), hand dominance, smoking habit (non-smoker (0), <5 cigarettes/day (1), 5–10 cigarettes/day (2), >10 cigarettes/day (3)) and any history of complex regional pain syndrome (CRPS).

The clinical examination was comprehensive and included the use of goniometers for range of movement, monofilament and static two-point discrimination for sensation and ring-sizers for oedema as required. Power testing was performed in some patients with a Jamar dynamometer, utilising the five

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handle-position test.[3] The author has, however, found this to be an unreliable test in medico-legal claimants, and many results were discarded, because traces achieved were atypical or the results implausible. Following examination, the whole limb impairment (WLI) was calculated according to the guidelines of Swanson et al.[4]

The results are presented as mean (standard deviation) in the text and mean (standard error) in the graphs. Comparisons between groups used the Student's t-test, Mann-Whitney, Chi-squared tests and analysis of variance; correlation calculations were performed by either the Pearson or Spearman tests as appropriate.

Results

A total of 250 patients with a mean age of 42 ± 14 years with a male:female ratio of 163:87 were assessed at a mean of 24 ± 13 months after injury. The mean WLI, CIQ36 and QDASH scores were $9 \pm 14\%$, 17 ± 10 and 43 ± 24, respectively. There was no difference overall in demographics or outcomes between men and women. The WLI was weakly but significantly correlated with age and the interval between injury and assessment (Table 1). There was a significant trend towards heavier smoking in younger patients.

Function

The QDASH scores were significantly correlated with measured WLI and increased significantly with age (Table 1, Figure 1). They were not, however, correlated with hand dominance, smoking habit or interval from injury.

There were 77 patients who had no measurable limb impairment. These patients were slightly younger (38 ± 11 vs. 43 ± 15 years, $p < 0.05$) but their sex ratio and interval from injury were indistinguishable from patients with measurable functional deficits. Only two of these patients had experienced CRPS after injury. Their QDASH scores ranged from 0 to 89 but were significantly lower than patients with measurable limb impairment (32 ± 23 vs. 47 ± 23, $p < 0.001$).

Table 1. Correlations and probability values between the variables in the patient population (Rank-Spearman).

	Interval	Smoking	WLI	CIQ36	QDASH
Age	0.001, NS	−0.19, p < 0.005	0.14, p < 0.025	0.07, NS	0.20, p < 0.005
Interval		−0.03, NS	0.17, p < 0.01	0.08, NS	0.14, NS
Smoking			0.01, NS	0.06, NS	−0.04, NS
WLI				0.31, p < 0.0001	0.45, p < 0.0001
CIQ36					0.58, p < 0.0001

WLI: whole limb impairment; CIQ36: Cold Intolerance Questionnaires; NS: not significant; QDASH: Quick Disability of the Arm, Shoulder and Hand.

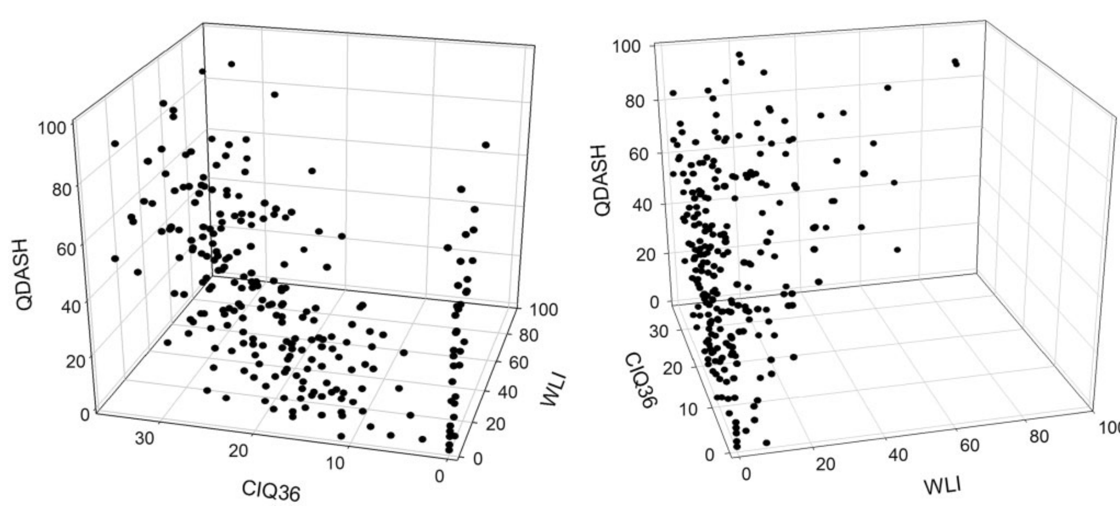

Figure 1. Two views showing the relationship between measured and subjective symptoms in all patients.

Cold intolerance

The reported severity of cold intolerance was unrelated to age, sex ratio, hand dominance, smoking habit or interval from injury (Table 1). The CIQ36 score was strongly correlated with the QDASH score and less strongly with the calculated WLI (Figure 1).

Thirty-four patients reported no cold intolerance. Comparison of these patients with the 186 patients who reported some cold intolerance revealed no differences in their age, sex, hand dominance, smoking habit, interval from injury or WLI. However, their QDASH scores were significantly lower than in patients reporting cold intolerance (35 ± 5 vs. 45 ± 2, $p < 0.05$).

Correlation

The inter-relationship between WLI, QDASH and CIQ36 presented in Table 1 is illustrated in Figure 1. There is a close correlation between the CIQ36 and QDASH scores, excepting the 34 patients who reported no cold intolerance, which is best seen in the left projection of the figure. The right projection shows the weaker relationship between WLI and QDASH and illustrates the wide range of QDASH scores in patients with no or minimal measurable impairment.

CRPS

Twenty-six patients had been diagnosed with CRPS. Thirteen of these patients had sustained blunt injuries which is a significantly higher rate compared with the remaining patients or any of the other injury types ($p < 0.0001$). The CRPS patients were significantly older (51 ± 10 vs. 41 ± 15 years, $p < 0.001$) and had a lower male to female ratio than those without CRPS (15:11 vs. 152:72, $p < 0.01$). The CRPS group had higher WLI ($24 \pm 24\%$ vs. $8 \pm 12\%$, $p < 0.001$), CIQ36 (21 ± 12 vs. 17 ± 9, $p < 0.01$) and QDASH (67 ± 21 vs. 40 ± 23, $p < 0.001$) scores than patients without CRPS.

Injury type

The injuries could be divided into eight groups (Table 2). There were some differences in the demographic characteristics of the groups. There were proportionally more women in the patients with blunt injuries (contusion/crush/sprain) compared with the cohort overall. Patients with burn and tendon injures were younger and those with blunt injuries were older than the remaining patients. The interval between injury and assessment was significantly shorter in the patients who had suffered finger-tip/amputation injures and longer in these with wrist/carpal fractures. The differences in the assessment intervals between groups possibly reflect the differing complexity of their medico-legal journeys.

There were significant differences in measured and reported disability between injury groups (Figures 2 and 3). The WLI percentages were significantly higher in patients with wrist/carpal fractures and nerve injuries and lower in patients with simple lacerations and burns. These findings were broadly paralleled by the QDASH results.

The incidences and severity of cold intolerance varied between groups. Symptoms were significantly more common in patients who had suffered a finger-tip injury or amputation and those who had sustained a nerve injury. There were also significant differences in the reported severity of cold intolerance between injury groups (Figure 4). The lowest scores were observed in patients with burns injuries and the highest in patients who had suffered nerve injuries. Any other apparent differences between groups were not significant.

Table 2. The mean (±SD) results and numerical characteristics of the eight injury groups and their rates of reporting cold intolerance and experiencing CRPS.

Type of injury	N	M:F ratio	Age	Interval	Cold intolerance	CRPS
Burn	11	7:4	33 ± 12*	20 ± 19	45%†	0%
Contusion/crush/sprain	48	21:27†	47 ± 13**	25 ± 13	77%	27%†
Laceration only	20	14:6	39 ± 11	18 ± 8	85%	0%
Tendon injury	19	12:7	36 ± 13*	22 ± 12	91%	0%
Nerve (±tendon)	24	16:8	40 ± 18	24 ± 13	100%*	13%
Fingertip/amputation	51	39:12	43 ± 14	19 ± 10**	98%**	6%
Fracture (finger/hand)	28	18:10	42 ± 16	24 ± 12	72%	11%
Fracture (wrist/carpus)	49	36:13	41 ± 14	29 ± 12†	60%	8%

CRPS: complex regional pain syndrome.
*$p < 0.05$, **$p < 0.01$, †$p < 0.001$.

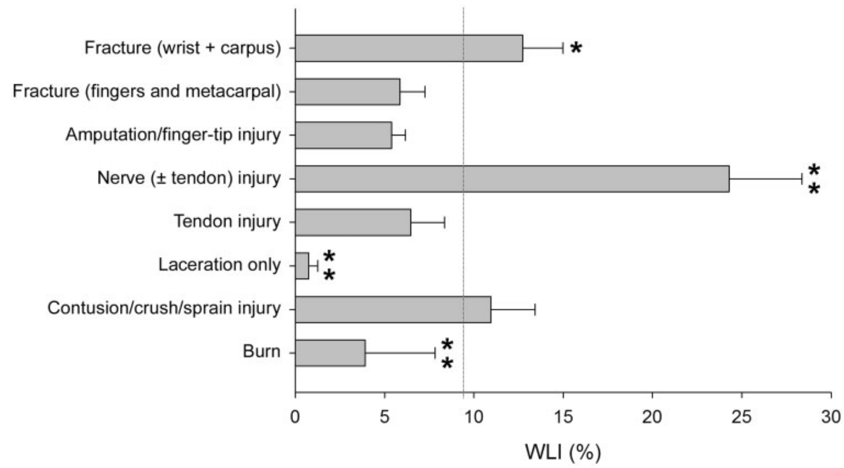

Figure 2. Measured disability percentages (±SE) in the eight injury groups with the overall mean value indicated by the vertical line (⋆$p < 0.05$, ⋆⋆$p < 0.01$).

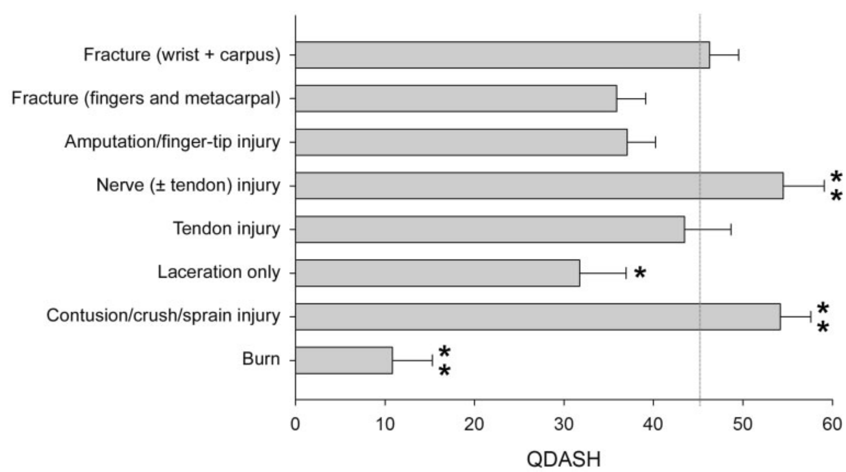

Figure 3. Reported disability scores (±SE) in the eight injury groups with the overall mean value (⋆$p < 0.05$, ⋆⋆$p < 0.01$).

Discussion

This paper describes the assessment of an unselected and heterogeneous group of adult patients who were engaged in litigation following both bony and soft tissue injuries of the upper limb. The severity of injury varied greatly. Some patients suffered only small burns or lacerations leaving them with no measureable functional deficit. Others sustained complex fractures or the division of multiple tendons and nerves leaving them with permanent and significant disability.

The mainstay of assessing the functional outcome from a hand injury is clinical examination. This information is used by the expert to comment on the ability of the Claimant to perform their normal daily activities, to care for themselves, to return to work and to compete on the open job market. This information is used to calculate the quantum of the claim.

It is recognized that perceived and actual levels of disability do not necessarily only reflect the direct structural and neurological effects of an injury. The presence of symptoms such as tenderness, pain and cold sensitivity affect use of a hand. The impact of the injury is also significantly influenced by psychosocial factors, personal circumstances and employment issues. It is therefore evident that examination alone

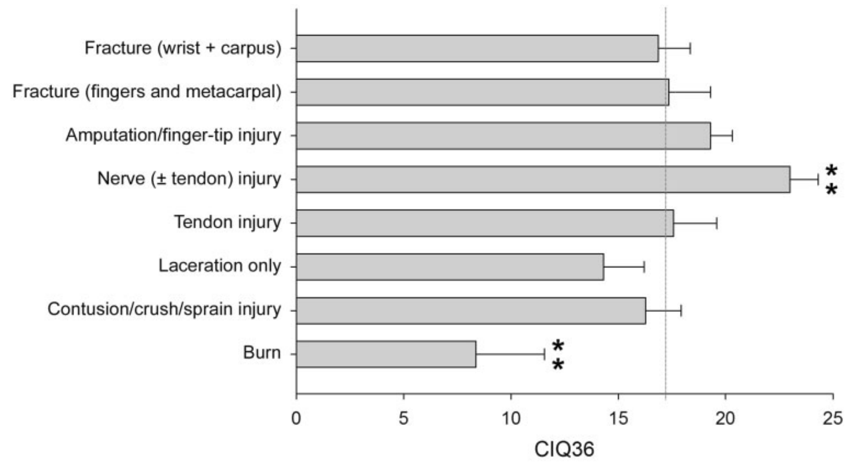

Figure 4. Reported cold intolerance scores ($\pm$SE) in the eight injury groups with the overall mean value ($\star\star p < 0.01$).

does not necessarily provide a complete assessment of the effect of an injury on a patient's functional abilities.

There has been an increased emphasis on the use of PROM to assess symptoms, disability and recovery after injury. The DASH and its shortened version the QDASH are widely used for assessing function in patients who have sustained injuries to their upper limbs. These questionnaires can provide a measure of function and are responsive to effects of recovery. PROM are widely used in fields such as pain and psychology, where it is difficult if not impossible to assess objectively the effects of injury. Cold intolerance is a well-recognized sequel to hand injuries, which can be an impediment to the return to some forms of work and recreational activities. Objective measures of this problem are complex and unreliable and thus subjective measures are more widely used.

Ten percent of the patients assessed had developed CRPS after injury. This is a poorly understood phenomenon, the aetiology of which is uncertain. Its occurrence is not specific to type or severity of injury. However, my data would suggest an association with blunt injuries without fractures although this may be due to the preponderance of women in this group who are recognised to have a greater susceptibility to the development of CRPS. The severity of the condition can vary considerably. Milder examples are self-limiting and merely slow progress after injury or surgery. Most patients are left with some disability including cold intolerance.[5] Severe forms are fortunately very rare but can cause significant and permanent dysfunction in the whole limb. As would be expected, this group of patients was left with higher levels of cold intolerance as well as both subjective and measured disability compared with the remaining patients.

Eighty-five per cent of patients reported cold intolerance, a rate comparable to previous reports after hand injury.[6,7] The incidence and severity were significantly less in patients who had suffered burn injuries compared with the population overall. The highest incidence occurred in patients who had suffered finger-tip or amputation injuries and those who had sustained nerve injuries. Cold intolerance was significantly but relatively weakly correlated with the WLI. This is consistent with studies that have shown an association between the severity of cold intolerance and the hand injury severity score.[8]

The present data have shown a correlation between the measured WLI and subjective QDASH. Although statistically significant, the relationship is relatively weak. This is exemplified by the wide variation in scores observed in the 77 patients with no measurable functional impairment when applying the published criteria as fairly and objectively as possible.[4] This is not to deny that these patients may have had some residual symptoms, some scarring, numbness in functionally unimportant areas, minor stiffness but retention of a functional range of movement, cold intolerance, etc. Although unsurprisingly, the overall QDASH score in these patients was less than those with measurable disability, 10 of them had QDASH scores in excess of 60, which has been suggested represents severe disability. Others have observed that there is not always a close relationship between either estimated severity of injury or measured recovery and QDASH scores.[9,10]

The assessment of WLI, although an apparently exact process, in reality requires judgment and a degree of intuition. Even if it is accepted that there is some margin for error in assessing WLI, the sometimes wide discrepancies between objective and subjective measures of disability suggests exaggeration of reported symptoms and, in some eyes, malingering. It is notable that in the patients assessed, the strongest correlation was between QDASH and the CIQ36 score. This may reflect a true association or merely indicate that patients who report high scores on one questionnaire will tend to do so on others.

The concept of symptom exaggeration embraces a number of overlapping concepts including conversion disorder, compensation neurosis, factitious disorder and malingering. The term compensation neurosis has been defined as

> an exaggeration of symptoms that occur as a result of the unique stressor of seeking legally awarded compensation. It is brought about primarily by internal motivators coupled with a lesser degree of anticipation of secondary gain. Financial reward can clearly be a component in the condition and may influence the course, but the overall constellation of symptoms is due to more than just the pursuit of money.[11]

It is recognized that the label of compensation neurosis gives no insight into prognosis as not everyone improves after settlement. It is notable that the mean PROM scores in the present patients are virtually identical to those obtained in the group of hand trauma patients I have previously assessed in a clinical rather than medico-legal setting ($QDASH = 43 \pm 23$, $CIQ36 = 18 \pm 9$).[2] This appears to refute any suggestion that the majority of scores are driven by litigation.

Malingering can be defined as the 'intentional simulation or exaggeration of psychological or physical symptoms for secondary gain'. This, however, should be a diagnosis of exclusion as the drivers for symptom exaggeration are more subtle and diverse than this pejorative label suggests. When malingering is raised in legal context, it becomes an allegation of fact. The party who makes an allegation of malingering has the burden to adduce evidence of it at trial. In determining whether the allegation of malingering is or is not sustainable, the court will consider legal facts rather than the opinions formed by a medical witness.[12]

It is my experience that whilst many patients exaggerate their symptoms in a medico-legal setting, few are malingerers. Expert witnesses should be cautious about alleging that a patient is malingering. Guy Pulvertaft[13] reasonably suggested

> I have avoided the term when composing a medical report and have used a phrase such as ''I am unable to find a satisfactory explanation for this man's complaints''. When a remark of this kind follows an examination which clearly has been thoroughly performed, the reader of the report or the Judge may safely be left to draw his own conclusions.

PROM questionnaires provide useful qualitative information about symptoms and function in patients who have suffered hand injuries. Review of individual questions can identify issues for discussion. The scores provide insight into the perceived impact of an injury on a patient, but their absolute values do not necessarily provide a precise measure of physical disability. It is my experience that patients who are not litigating can record high PROM scores following relatively minor injuries. It is likely that the PROM scores reflect a combination of factors that include the physical effects of an injury, the need of a patient to demonstrate injury or distress, the psychological and socio-economic effects of the injury, as well as anger about the circumstances of the injury. I believe that although individual PROM scores recorded by a patient should be regarded with caution in a medico-legal context, the use of questionnaires can be helpful.

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