Posttraumatic Elbow Stiffness
Lindenhovius, A.L.C.

Citation for published version (APA):

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CHAPTER 6

Correspondence between Perceived Disability and Objective Physical Impairment after Elbow Trauma
Lindenhovius AL, Buijze G, Kloen P, Ring D.
Abstract

Background: Substantial differences between disability and impairment are commonplace and puzzling. Subjective (psychosocial factors) may be paramount given that pain is a more important determinant of perceived overall arm-specific disability than objective elbow impairment. To further evaluate the relationship between impairment and disability, this study tested the hypothesis that objective loss of elbow motion predicts perceived elbow-related task-specific disability better than pain after elbow trauma.

Methods: One-hundred-and-fifty-eight patients were evaluated a median of 26 months after elbow trauma and completed the Disabilities of the Arm, Shoulder and Hand questionnaire (DASH). Predictors of total DASH score and responses to individual DASH items that were expected to relate to elbow function were evaluated by univariate and multivariable analyses.

Results: Motion accounted for 35% of the variability in total DASH scores, for 11% to 12% of the variability in responses to questions specific to hand-based activities, and 24% to 33% of the variability to tasks depending on elbow motion. Pain accounted for 41% of the variability in the total DASH score, and was a better predictor than motion for disability associated with three tasks: opening a tight jar, 24% vs. 11%; pushing open a door, 25% vs. 12%; and placing an object overhead, 28% vs. 25%. None of the multivariable models explained more than 53% of the variability in DASH.

Conclusion: Objective physical elbow impairment correlated with self-reported disability with respect to specific tasks, but a large proportion of disability remains unexplained. Further research is needed to better understand the differences between objective impairment and perceived disability.

Background

According to the International Classification of Functioning, Disability and Health (ICF), as published by the World Health Organization(1), impairments are the manifestations of an underlying pathology and represent objective, physical deviation or loss due to problems in bodily function or structure. Disability refers more generally to activity limitations, whether these are the result of objective physical impairments or psychosocial factors.

Prior work has documented wide variation in disability among patients with similar levels of hand or arm impairment.2-4 For instance, in patients with trigger finger2,3 or carpal tunnel syndrome2,4—diagnoses with relatively limited variation in objective measurable impairment—the range and standard deviations of perceived disability were large. When conditions with a broader range of objective physical impairment are considered, such impairment explains a relatively small percentage of perceived disability.5-10 For instance, the objective physical impairment in patients recovering from fracture of the distal radius explained only 25% of the reported disability.8
With respect to the elbow, Doornberg and colleagues\textsuperscript{10} found that only 17\% of the variation in disability after elbow trauma was explained by impairment. It is unclear if this relationship holds true when the relationship between impairment and disability is evaluated at the level of specific functional tasks. The current investigation addressed the hypothesis that elbow-related, task-specific disability is determined more by impairment of elbow motion than by pain. Better understanding of the relation between impairment, pain and disability may help to achieve better outcome of treatment in the future.

**Material and Methods**

**Patients**

During a four-year period, physical evaluations and health status data were collected during evaluation of patients at various stages of recovery after a complex elbow trauma as part of nine prospective and retrospective studies, all approved by the Human Research Committees at our institutions in the United States and in the Netherlands. A total of 324 eligible patients were invited for participation in these studies: 23 of these patients declined participation, 37 were deceased, and 38 could not be located, leaving 226 patients that were evaluated for inclusion in the current investigation. Inclusion criteria for this study were (1) operatively treated elbow fracture, (2) minimum 18 years of age at the time of injury, (3) date of evaluation more than four months following the most recent injury or surgery, and (4) a completed Disabilities of Arm, Shoulder and Hand questionnaire available in our research records. Patients with rheumatoid arthritis and elbow instability were excluded. One hundred-and-fifty-eight patients who met these criteria (96 males, 62 females) form the study cohort for the current investigation.

**Evaluation**

An investigator that was not involved in patient care evaluated each patient a median of 38 months (average 101 months; range, 4 to 364 months) after the injury and a median of 26 months (average 64 months; range, 4 to 363 months) after the most recent surgery. Patients with incomplete recovery from injury were included in order to: 1) capture impairment and disability experienced by patients at various stages of recovery, and, 2) increase the variation in impairment, and 3) limit ceiling effects—(i.e. too many patients with limited impairment). The evaluation consisted of an interview, a physical examination (measurement of ulnohumeral and forearm motion), and administration of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. The DASH questionnaire was developed by the American Academy of Orthopaedic Surgeons in collaboration with the Council of Musculoskeletal Specialty Societies and the Institute for Work and Health as an outcomes instrument specific to the upper extremity, and applicable to a wide variety of problems.\textsuperscript{11} The questionnaire contains 30 items evaluated on five-point Likert scales: 21 items evaluate difficulty with
performance of certain activities (some ask about specific tasks like “turning a key” whereas others address difficulty with activities in general, for instance “managing transportation needs”), five evaluate symptoms (e.g. pain and stiffness), and one each evaluates social function, work function, sleep and confidence. The total DASH score is scaled from 0 to 100 points with higher scores indicating worse upper extremity function. We selected eight questions that measure a patient's ability to perform specific tasks that are likely to be affected by loss of elbow or forearm motion: (1) opening a tight or new jar, (2) turning a key, (3) pushing a heavy door, (4) placing an object on a shelf above the head, (5) changing a light bulb over head, (6) washing or blow-drying hair, (7) washing the back, (8) putting on a pullover sweater. Patients completing the DASH questionnaire are asked to rate the degree of their ability to perform the tasks on a Likert scale from one to five, with higher scores indicating more difficulty (1: none, 2: mild, 3: moderate, or 4: severe difficulty and 5: unable to perform activity). In addition, perception of pain and stiffness is rated on the DASH questionnaire (1: none, 2: mild, 3: moderate, 4: severe, and 5: extreme). Each of the eight tasks requires substantial elbow or forearm motion in one or more directions and represents an opportunity to evaluate discrepancies between objective impairment (measured motion) with perceived disability and perceived stiffness as rated on the DASH. As measures of pain and perceived stiffness, we felt that it would be more reliable to use the 5-point Likert scales for pain and stiffness from the DASH than to use a second, repeat question separate from the DASH score.

**Statistical Analysis**

**Univariate Analysis**

The dependent (or response) variables were the total DASH score, the scores on the 8 individual DASH questions that were felt likely to be affected by loss of elbow and forearm mobility, and the individual DASH question rating perceived stiffness. The independent (or explanatory) variables investigated included: flexion, extension, pronation, supination, age, number of surgeries, pain, arthrosis, time since last surgery, secondary gain, associated arm injuries, gender, limb dominance, distal humeral fracture, arthrosis, country of residence, ulnar neuropathy, and laborer occupation/heavy work. (Table 2)

Associations between continuous explanatory variables and the response variables were evaluated using Spearman correlations. Associations between dichotomous explanatory variables and the response variables were evaluate using the Mann Whitney U-test. Associations with a p-value less than 0.05 were considered statistically significant.
**Multivariable Analysis**

Multiple linear regression analysis was used to analyze the ability of the explanatory variables to account for variation in the response variables, accounting for any confounding between the explanatory variables. A multiple linear regression model produces a statistic called the adjusted R-squared, which reflects the percentage of the overall variability in the response variable that can be explained or accounted for by the explanatory variables included in the multiple linear regression model. (Table 3)

We ran several models including two backwards stepwise multiple linear regression models (a model that includes all the entered variables initially and then iteratively removes variables from the model until the best-fit model is achieved according to set criteria), one including pain and one excluding pain; a model with pain as the only explanatory variable; and a model with only those explanatory motion variables felt to be related to the specific task. Comparison of the variability accounted for by each model (the adjusted R-squared) provides a measure of the relative influence of each explanatory variable on the overall variation in the response variable.

The number of explanatory variables that can be included in a multivariable model is limited by the overall sample size of the study. Therefore, instead of entering all of our potential explanatory variables into the backwards stepwise models, we chose to enter only those variables that were either significant (p < 0.05) or nearly significant (p < 0.10) in the univariate analysis, a common cut off value for inclusion of variables in regression modelling. For each multivariable model, a multivariable analysis of variance (MANOVA) was performed to assess statistical significance, which indicates a linear relationship between at least one of the explanatory variables with the dependent variable. The statistical methodology has been summarized in a table (Table 1).

Power analysis indicated that a minimum sample size of 100 patients would provide 90% statistical power (β = 0.1, α = 0.05) to detect a moderate correlation (ρ ≥ 0.30) with excellent precision between flexion and pain with total DASH score.

**Results**

The mean age at the time of injury was 44 years (range, 18 to 80). The left arm was involved in 84 patients and the right arm in 74. The dominant arm was affected in 88 patients (56%). Of the 120 patients employed outside the home at the time of the injury, 92 performed desk-based work and 28 were laborers. Five patients were students, and the remaining 36 patients did not have a job (16 retired, 14 unemployed, and 3 were disabled). Seven patients had a secondary gain: four patients filed a disability claim, one patient a workers’ compensation claim, and two patients had a narcotic addiction.
PART III  STIFFNESS AND DISABILITY

Outcome Measure

The percentage of variability in the scores of the response variable (adjusted R²): i.e. the degree to which the response variable is explained by the variables in the model.

Reason

To assess the degree to which certain explanatory variables explain the response variables. To do so, four backwards regression analyses were performed for each response variable:

(1) To determine the best predictors of the response variables (backwards multiple regression analysis removes the least important variables progressively until the best predicting model of variables remains)

Only variables that have significant or near-significant (p < 0.10) association will be entered in step 2 (multivariate analysis) to improve the quality of the multivariate model.

Table I. Statistical Methods

<table>
<thead>
<tr>
<th>Step</th>
<th>Analysis</th>
<th>Test</th>
<th>Reason</th>
<th>Outcome Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Univariate</strong></td>
<td><strong>Spearman correlation</strong> (continuous variables) &amp; <strong>Mann Whitney U-test</strong> (dichotomous variables)</td>
<td>To assess the association between each of the continuous and dichotomous explanatory variables with each of the response variables*</td>
<td>Significance of the association between the explanatory and response variable (p-value).</td>
</tr>
</tbody>
</table>
| 2A   | **Multivariate** | **Backwards multiple linear regression** | (1) To determine the best predictors of the response variables (backwards multiple regression analysis removes the least important variables progressively until the best predicting model of variables remains)
(2) To assess the degree to which certain explanatory variables explain the response variables. To do so, four backwards regression analyses were performed for each response variable: | The percentage of variability in the scores of the response variable (adjusted R²): i.e. the degree to which the response variable is explained by the variables in the model. |
**Model 1:** best model after regression analysis of all qualifying explanatory variables (p < 0.10) from the univariate analysis

**Model 2:** best model after regression analysis of all qualifying explanatory variables (p < 0.10) from the univariate analysis, except for pain

**Model 3:** model with pain alone

**Model 4:** model with motion variable(s) thought to be involved with the specific task entered

To determine the significance of each model

- **2B** Multivariate analysis of variance
- Significance of the model (p-value): significance indicates that at least one of the explanatory variables in the model has a linear relationship with the response variable

*Explanatory variables:* flexion, extension, pronation, supination, age, number of surgeries, pain, arthrosis, time since last surgery, gender, dominant limb, distal humeral fracture, ulnar neuropathy, country of residence, associated injuries, laborer vs. non-laborer occupation.

*Response variables:* total DASH score, the scores on the 8 individual DASH questions about tasks, and the perceived stiffness score
### Table 2. Results of Univariate Analysis (part 1)

<table>
<thead>
<tr>
<th></th>
<th>Total DASH Score</th>
<th>Opening Tight or New Jar</th>
<th>Turning Key</th>
<th>Pushing Open Heavy Door</th>
<th>Placing Object on Shelf Above Head</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spearman Correlation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Extension</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Pronation</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Supination</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Age at Follow-Up</td>
<td>NS</td>
<td>&lt; 0.05</td>
<td>&lt; 0.10</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Number of Operations</td>
<td>&lt; 0.05</td>
<td>&lt; 0.05</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Time since Last Surgery</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.01</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Pain</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td><strong>Mann-Whitney U-test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associated Injuries</td>
<td>&lt; 0.05</td>
<td>&lt; 0.01</td>
<td>&lt; 0.001</td>
<td>&lt; 0.05</td>
<td>&lt; 0.10</td>
</tr>
<tr>
<td>Country of Residence</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Dominant Side Affected</td>
<td>NS</td>
<td>&lt; 0.05</td>
<td>&lt; 0.01</td>
<td>&lt; 0.05</td>
<td>NS</td>
</tr>
<tr>
<td>Gender</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Distal Humerus Fracture</td>
<td>&lt; 0.05</td>
<td>&lt; 0.01</td>
<td>&lt; 0.10</td>
<td>&lt; 0.05</td>
<td>NS</td>
</tr>
<tr>
<td>Ulnar Neuropathy</td>
<td>NS</td>
<td>&lt; 0.10</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Arthrosis</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Occupation</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Secondary Gain</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>&lt; 0.05</td>
<td>NS</td>
</tr>
</tbody>
</table>

*All values are given as the p values. NS = not significant*

Injuries included a fracture-dislocation of the elbow in 69 patients, an intra-articular fracture of the distal part of the humerus in 49 patients, an isolated radial head fracture in 32, and an olecranon fracture in 8 patients. Seventeen patients had associated injuries of the same upper extremity; 9 had a distal radius fracture, 3 had diaphyseal forearm fractures, and 1 patient each had one of the following: a scaphoid fracture, a scaphoid and distal radius fracture, a distal ulnar fracture, a metacarpal fracture of the ring and long finger, and a scapula fracture. Eighty-six patients underwent an average of two subsequent operations on the affected elbow (range, 1 to 16 operations).

At the index evaluation, the mean flexion arc was $101 \pm 35$ degrees (range, 0 to 150 degrees) with an average flexion of $124 \pm 18$ degrees (range, 55 to 150 degrees) and an average flexion contracture of $23 \pm 21$ degrees (range, 10 to 100 degrees). The mean forearm rotation was $149 \pm 38$ degrees (range, 0 to 180 degrees), pronation $76 \pm 20$ degrees (range, 0 to 90 degrees) and supination was $72 \pm 25$ degrees (range, 0 to 90 degrees). Thirty patients had symptoms or signs of ulnar neuropathy at follow-up. Sixty-two patients showed radiographic signs of arthrosis; mild in thirty-six patients, moderate in sixteen, and severe in ten patients according
Table 2. Results of Univariate Analysis (part 2)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Flexion</th>
<th>Extension</th>
<th>Pronation</th>
<th>Supination</th>
<th>Age at Follow-Up</th>
<th>Number of Operations</th>
<th>Time since Last Surgery</th>
<th>Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing Light Bulb Overhead</td>
<td>&lt; 0.001</td>
<td>&lt; 0.01</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Washing or Blow-Drying Hair</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Washing the Back</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>NS</td>
<td>NS</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Putting on Pullover Sweater</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>NS</td>
<td>NS</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Spearman Correlation

- Flexion: < 0.001
- Extension: < 0.001
- Pronation: < 0.001
- Supination: < 0.001
- Age at Follow-Up: < 0.001
- Number of Operations: NS
- Time since Last Surgery: < 0.001
- Pain: < 0.001

Mann-Whitney U-test

- Associated Injuries: < 0.05
- Country of Residence: < 0.001
- Dominant Side Affected: < 0.10
- Gender: NS
- Distal Humerus Fracture: < 0.05
- Ulnar Neuropathy: NS
- Arthrosis: NS
- Occupation: NS
- Secondary Gain: NS

Total DASH scores averaged 20.0 ± 20.4 points (range, 0 to 93 points). Mean scores for individual item were 2.0 ± 1.2 for item 1, 1.5 ± 0.9 for item 2, 1.9 ± 1.1 for item 3, 2.1 ± 1.3 for item 4, 1.8 ± 1.2 for item 5, 1.7 ± 1.0 for item 6, 2.2 ± 1.3 for item 7, 1.7 ± 0.9 for item 8. Perceived stiffness and pain averaged 2.4 ± 1.2 and 2.2 ± 0.9, respectively.

Statistical Analysis

The details of the statistical analysis are presented in Appendix 1 online and in Tables 1, 2 and 3. By running each of the multivariable analysis with 4 distinct models, we were able to determine the relative ability of 1) all the explanatory variables, 2) all the explanatory variables except pain, 3) pain alone, and 4) motion alone to account for variance in the DASH scores. These analyses demonstrated that pain accounts for more of the variance than motion and other objective variables when considering the overall DASH score, but motion is more important than pain and the level of some of the specific tasks—primarily those that could be most directly related to the need for elbow motion. (Tables 1, 2, and 3)
### Table 3. Results of Multivariate Analysis (part 1)

<table>
<thead>
<tr>
<th></th>
<th>Total DASH Score</th>
<th>1. Opening a New or Tight Jar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variables in Best Model</td>
<td>Adjusted R²</td>
</tr>
<tr>
<td><strong>Model 1</strong></td>
<td>flexion, extension, pronation, pain, distal humerus fracture</td>
<td>53</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td>distal humerus fracture, flexion, pronation, time since surgery, extension</td>
<td>37</td>
</tr>
<tr>
<td><strong>Model 3</strong></td>
<td>pain</td>
<td>41</td>
</tr>
<tr>
<td><strong>Model 4</strong></td>
<td>flexion, extension, pronation, supination</td>
<td>35</td>
</tr>
</tbody>
</table>

- **Model 1**: Best model after regression analysis of all qualifying (p < 0.10) variables
- **Model 2**: Best model after regression analysis of all qualifying (p < 0.10) except for pain
- **Model 3**: Model with pain alone
- **Model 4**: Model with motion variable(s) thought to be involved with the specific task
### Table 3. Results of Multivariate Analysis (part 2)

<table>
<thead>
<tr>
<th></th>
<th>2. Turning a Key</th>
<th>3. Pushing Open a Heavy Door</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variables in Best Model</td>
<td>Adjusted R2</td>
</tr>
<tr>
<td><strong>Model 1</strong></td>
<td>flexion, supination, pain, associated injuries, limb dominance</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>flexion, supination, associated injuries, limb dominance</td>
<td>27</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td>flexion, supination, associated injuries, limb dominance</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td><strong>Model 3</strong></td>
<td>supination</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 3. Results of Multivariate Analysis (part 3)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables in Best Model</td>
<td>extension, pain</td>
<td>extension, pronation, time since last surgery, associated injuries</td>
<td>pain</td>
<td>motion variable(s) thought to be involved with the specific task</td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>35</td>
<td>28</td>
<td>28</td>
<td>25</td>
</tr>
<tr>
<td>P Value</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
### Table 3. Results of Multivariate Analysis (part 4)

<table>
<thead>
<tr>
<th>Model 1</th>
<th>Variables in Best Model</th>
<th>Adjusted R²</th>
<th>P Value</th>
<th>Variables in Best Model</th>
<th>Adjusted R²</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best model after regression analysis of all qualifying (p &lt; 0.10) variables</td>
<td>flexion, extension, pain, age</td>
<td>41</td>
<td>&lt;0.001</td>
<td>flexion, extension, pain</td>
<td>39</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Model 2</td>
<td>flexion, extension, associated injuries, time since surgery</td>
<td>38</td>
<td>&lt;0.001</td>
<td>flexion, extension, associated injuries, time since surgery</td>
<td>35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Model 3</td>
<td>pain</td>
<td>21</td>
<td>&lt;0.001</td>
<td>pain</td>
<td>21</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Model 4</td>
<td>flexion</td>
<td>28</td>
<td>&lt;0.001</td>
<td>flexion, extension</td>
<td>33</td>
<td>&lt;0.001</td>
</tr>
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</table>
Table 3. Results of Multivariate Analysis (part 5)

<table>
<thead>
<tr>
<th>Model 1</th>
<th>Variables in Best Model</th>
<th>Adjusted R²</th>
<th>P Value</th>
<th>Variables in Best Model</th>
<th>Adjusted R²</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>flexion, extension, pain</td>
<td>39</td>
<td>&lt;0.001</td>
<td>flexion, pronation, pain, country of residence</td>
<td>48</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Model 2</td>
<td>flexion, extension, time since surgery</td>
<td>31</td>
<td>&lt;0.001</td>
<td>flexion, pronation, country of residence</td>
<td>33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Model 3</td>
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<td>&lt;0.001</td>
<td>pain</td>
<td>37</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Model 4</td>
<td>flexion, extension</td>
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<td>flexion, extension, pronation, supination</td>
<td>31</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

8. Put on Sweater

Model 1: Best model after regression analysis of all qualifying (p < 0.10) variables

Model 2: Best model after regression analysis of all qualifying (p < 0.10) except for pain

Model 3: Model with pain alone

Model 4: Model with motion variable(s) thought to be involved with the specific task
Discussion

Our hypothesis was confirmed in large part: disability correlated with objective physical impairment on specific tasks, and—for most of these tasks—impairment explained more of the variability in DASH scores than pain did. For instance, impairment in extension corresponded with difficulty inserting a light bulb overhead and placing an object above head and impairment in forearm rotation corresponded with difficulty turning a key or opening a tight jar. Flexion was among the strongest predictors in each model, except for those that clearly require extension. Furthermore, objective physical impairments of the elbow explained a larger proportion of the variability in disability associated with tasks dependent more on elbow motion (e.g. changing a light bulb overhead, blow drying hair) than hand based activities (e.g. opening a jar, turning a key). As expected, there was a strong relationship between objective physical motion impairments and perceived stiffness; however, complaints of pain accounted for more of the variability in perceived stiffness scores than did objective impairments in motion. Finally, for most specific tasks, physical impairments explained more of the variability in DASH scores than pain did.

Although the amount of variability explained by objective physical impairment was substantially higher in the current study (35% as compared to 17% in the prior study), the current findings are consistent with those of Doornberg and colleagues in that pain was the strongest predictor of total DASH scores (36% of variability explained by pain vs. 41% in our study). The important difference between the current study and our prior work is that we found that objective physical impairment has a greater influence than pain on disability when the relationship between task and impairment is more direct and specific. In other words, subjective factors such as pain have a greater influence when disability is measured with respect to the entire arm rather than with respect to the specific anatomical site involved. This is to some degree intuitive and leads to the more general hypothesis that less specific measures of disability are more easily influenced by factors other than objective physical impairment.

Although we were able to improve the relationship between impairment and disability by measuring disability at the level of specific tasks, the majority of variability in DASH scores could not be accounted for by our best multivariable models—even those including measures of pain. In other words, there is a substantial discrepancy between objective physical impairments and perceived disability in the injured elbow that remains unexplained. This is consistent with prior work by other investigators in the elbow and in the wrist and leg. For instance, MacDermid and colleagues found that physical impairment accounted for only 25% of perceived disability (and pain) after wrist fractures. In the leg, Mock et al found that 23% of perceived disability after lower extremity fractures was explained by range of motion and strength and 29% was explained by pain. Based upon current scientific analyses, health
status measures such as the DASH seem to be measuring something beyond and independent of a patient’s objective physical impairment or even their subjective experience such as pain. Discrepancies between impairment and disability have also been documented in other fields of medicine. Prior research regarding chronic pain has established that perception of pain, other symptoms, and perceived disability are extremely variable and strongly psychosocially mediated.\textsuperscript{16,17} Psychosocial factors influence the degree to which a variety of symptoms are perceived and expressed as disabling or painful.\textsuperscript{18-20} For instance, among several clinical and sociodemographic variables, depression was the best predictor of disability among over a thousand patients with osteoarthritis.\textsuperscript{21} The distress and illness behaviour that develop secondary to an underlying physical problem can be just as disabling as the original physical problem in some patients.\textsuperscript{9} In addition, secondary gain issues such as lawsuits, insurance claims, or claims for workman’s compensation may influence reported pain and disability.\textsuperscript{8,10} In a recent meta-analysis of 31 articles that reported associations between impairment with patient-rated disability and health status\textsuperscript{22}, only 36\% of the variability in disability scores and 13\% of health status scores were explained by impairment. The fact that 64\% of the variation in disability and 87\% of the variation in health status remains unexplained by objective disease factors and impairment implies that there are substantial, yet incompletely understood, opportunities for improvement in quality of life independent of physical impairment.

Recent data from the World Health Organization’s World Health Surveys identified that psychological distress (specifically depression) not only produced the greatest decrement in health compared to other chronic illnesses—depression was also responsible for incrementally worse health in association with other chronic diseases.\textsuperscript{23} Specific to arm illness, prior work has demonstrated that depression has a direct, moderate correlation with perceived disability, and the slope of the relationship is the same for several common diagnoses such as distal radius fracture, carpal tunnel syndrome and lateral elbow pain.\textsuperscript{2} This line of evidence supports the concept that discrepancies between impairment and perceived disability are explained, to a large degree, by psychosocial factors.

Among psychosocial factors, we were able to assess differences in culture since we had large numbers of patients from two different cultures. The country of residence was strongly correlated with each of the questions by univariate analysis where Dutch patients reported less disability than American patients; however, multivariable analyses determined that country of residence was not an important predictor of perceived disability after controlling for diagnosis, time since injury, objective physical impairments, and complaints of pain. This may be a result of the fact that most of the data from the Netherlands was derived from long-term studies. In any case, we feel that variations in perceived disability across cultures merit additional investigation. It has previously been reported, for instance, that complaints of pain may differ between cultures\textsuperscript{24-26}, and differences in perception of health status between populations have been described by others\textsuperscript{27,28}.
These data should be interpreted in the light of its limitations. First, we used a convenience sample of data from long-term retrospective studies and did not follow a prospective protocol. Second, some may question the use of Likert scales for pain and stiffness that were part of the DASH questionnaire, but our feeling was that to ask the same question outside the DASH questionnaire might be confusing, and would be unlikely to result in important differences. Third, the large number of individual comparisons should be not be overinterpreted: we did not correct the significance level for multiple comparisons because the purpose of the univariate analysis was simply to limit the number of variables entered into the multivariable statistical analyses.

While the current study suggests that impairment is a better predictor of disability with respect to specific functional tasks than with respect to overall arm-specific disability, there is still a substantial discrepancy between impairment and disability that is not accounted for neither by pain nor by objective physical impairments. Because some research suggests that the influence of psychosocial factors (depression in particular) may best explain the discrepancy between impairment and disability, additional research along these lines is merited since many psychosocial factors are amenable to treatment.

Acknowledgement

We are grateful to the AO Documentation Center in Davos, Switzerland, for managing the fracture database for the departments of orthopaedic surgery and general surgery at the Academic Medical Center in Amsterdam, the Netherlands, over the last decades. All Dutch cases included in the study were identified through this database. We kindly thank the departments of surgery and traumatology for the permission to use the data of their patients.

References

Appendix 1

Total DASH Score

Univariate analysis revealed significant associations between total DASH scores and flexion, extension, pronation, supination, time since the most recent operation, pain, country of residence (all \( p < 0.001 \)), and the number of operations, associated injuries, and distal humerus fracture (\( p < 0.05 \)).

The best multivariate model based on all variables found to be significant or near-significant by univariate analysis included flexion, extension, pronation, pain, presence of a distal humerus fracture and accounted for 53% of the variability in the DASH scores. The model without pain included flexion, extension, pronation, time since surgery and presence of a distal humerus fracture and accounted for 37% of the variation in total DASH scores. The model with pain alone accounted for 41% of the variability in total DASH scores. A model with the four motion variables alone accounted for 35% of the variability in DASH scores. MANOVA indicated significance of \( p < 0.001 \) for each of the four models.

Question 1: Opening a tight or new jar

Univariate analysis showed significant relationships between difficulty opening a tight or new jar and flexion, extension, pronation, supination, time since the last surgery, pain, and country of residence (all \( p < 0.001 \)), associated injuries and presence of a distal humerus fracture (\( p < 0.01 \)), age at follow-up, number of operations, and dominance (\( p < 0.05 \)), and a nearly significant relationship with ulnar neuropathy (\( p < 0.10 \)).

The multivariate model based on all significant and near-significant predictors from the univariate analysis included pronation, supination, pain and limb dominance and accounted for 35% of the variability in the outcomes of question one. The model without pain included flexion, supination, the number of operations and associated injuries and accounted for 26% of the variability for outcomes on question one. The model with pain alone accounted for 24% of variability in outcome scores. A model with pronation alone accounted for 11% of the variability in outcome scores. MANOVA indicated significance of \( p < 0.001 \) for each of the four models.

Question 2: Turning a key

Univariate analysis showed significant correlation of difficulty turning a key with flexion, extension, pronation, supination, time since the last surgery, pain, and associated injuries (all \( p < 0.001 \)), country of residence and involvement of the dominant limb (\( p < 0.01 \)), and near-significant correlation with age and presence of a distal humerus fracture (\( p < 0.10 \)).

The multivariate model based on all significant and near-significant predictors included flexion, supination, pain, associated injuries and limb dominance and accounted for 27% of
the variability in outcome scores. The model without pain included flexion, supination, associated injuries and limb dominance and accounted for 25% of the variability in the outcomes on question two. The model with pain alone accounted for 10% in variability in outcome scores on this question. The model with supination alone accounted for 12% of the variability in outcomes scores on this question. MANOVA indicated significance of $p < 0.001$ for each of the four models.

**Question 3: Pushing open a heavy door**

Univariate analysis demonstrated significant correlation of pushing open a heavy door with flexion, extension, supination, and pain (all $p < 0.001$), pronation, time since last surgery, and country of residence ($p < 0.01$), limb dominance, associated injuries, presence of a distal humerus fracture, and secondary gain ($p < 0.05$).

The multivariate model based on all significant predictors included flexion, pain, limb dominance and this model accounted for 35% of the variability in outcomes on question three. The model without pain included flexion, extension, limb dominance, distal humerus fracture and secondary gain and accounted for 24% of the variability. The model with pain alone accounted for 25% of the variability in outcome scores on this question. A model with extension alone accounted for 12% of the variability in scores for this question. MANOVA indicated significance of $p < 0.001$ for each of the four models.

**Question 4: Placing object on shelf above head**

In univariate analysis, placing an object on an overhead shelf was associated with flexion, extension, pronation, time since the most recent surgery, pain, and country of residence (all $p < 0.001$), supination ($p < 0.01$), associated injuries ($p < 0.10$).

The multivariate model based on all significant predictors included extension and pain and accounted for 40% of the variability in the question four scores. The model without pain included extension, pronation and time since the last surgery and this model accounted for 28% of the variability in outcome scores. A model with pain alone accounted for 28% in variability of outcome scores. The model with extension alone accounted for 25% of the variability in outcomes on question four. MANOVA indicated significance of $p < 0.001$ for each of the four models.

**Question 5: Changing a light bulb overhead**

The univariate analysis showed that difficulty changing a light bulb overhead correlates with flexion, extension, pronation, supination, time since the most recent surgery, pain, country of residence (all $p < 0.001$), associated injuries, dominance, and presence of a distal humerus fracture ($p < 0.05$).
The multivariate model based on all significant predictors included extension, pain and limb dominance and accounted for 35% of the variability in outcomes on this question. The model without pain included extension, time since the most recent surgery and associated injuries and this model accounted for 28% of the variability in outcomes on this question. The model with pain alone accounted for 19% in variability of scores on this question and the model with extension alone accounted for 24% of the variability in outcomes. MANOVA indicated significance of p < 0.001 for each of the four models.

**Question 6: Blow-drying hair**

The univariate analysis demonstrated significant correlation of difficulty blow-drying hair with flexion, extension, supination, time since the most recent surgery, pain, and country of residence (all p < 0.001), pronation (p < 0.01), age and associated injuries (p < 0.05). Based on all significant predictors the multivariate model included flexion, extension, pain and age and this model accounted for 41% of the variability in outcomes on question six. The model without pain included flexion, extension, associated injuries and time since the last surgery and accounted for 38% of the variability in outcome on question six. The model with pain alone accounted for 21% of variability in outcome scores on question six. A model with flexion alone accounted for 28% of the variability in scores on question six. MANOVA indicated significance of p < 0.001 for each of the four models.

**Question 7: Washing back**

The univariate analysis demonstrated significant correlation of difficulty with washing of the back with flexion, extension, pronation, supination, time since the last surgery, pain, and country of residence (all p < 0.001), number of operations and associated injuries (p < 0.05), and near-significant correlation with gender and ulnar neuropathy (p < 0.10). Based on all significant and near-significant predictors the multivariate model included pain, flexion and extension and accounted for 39% of the variability. The model without pain included flexion, extension, associated injuries and time since the most recent surgery accounted for 35% of the variability in outcome scores for question seven. A model with pain alone accounted for 21% of the variability in outcome scores on this question. The model with flexion and extension accounted for 33% of variability in scores on this question. MANOVA indicated significance of p < 0.001 for each of the four models.

**Question 8: Putting on a sweater**

The univariate analysis showed correlation of question eight outcomes with flexion, extension, pronation, supination, time since the most recent surgery, pain, and country of residence (all p < 0.001), and associated injuries (p < 0.05).
Based on all significant predictors the multivariate model included flexion, extension and pain and this model accounted for 39% of the variability of the outcomes on question eight. The model without pain included flexion, extension and time since the last surgery accounted for 31% of the variability of the outcomes on this question. The model with pain alone accounted for 27% of variability in outcome scores on question eight. The model with flexion and extension accounted for 28% of the variability on outcomes on question eight. MANOVA indicated significance of $p < 0.001$ for each of the four models.

**Question 9: Perceived stiffness**

The univariate analysis showed significant or near-significant correlation of outcomes on question nine with flexion, extension, pronation, supination, pain and country of residence (all $p < 0.001$), and time since the most recent surgery, associated injuries, and presence of a distal humerus fracture ($p < 0.10$).

The multivariate model based on all significant and near-significant predictors included flexion, pronation, pain and country of residence and accounted for 48% of the variability of outcomes on this question. The model without pain included flexion, pronation and country of residence and accounted for 33% of the variability in outcomes on question nine. The model with pain alone accounted for 37% of the variability, whereas the model with flexion, extension, pronation and supination accounted for 31% of the variability in perceived stiffness scores. MANOVA indicated significance of $p < 0.001$ for each of the four models.
PART IV

Treatment

Nonoperative Management
Operative Management
Postoperative Management