Illness behavior in patients with musculoskeletal disease

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Determinants of grip strength in healthy subjects compared to that in patients recovering from a distal radius fracture

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Abstract

*Purpose:* Grip strength is influenced primarily by body mass index, sex, and age. It is also partly voluntary and correlates with symptoms of depression. This study examined whether psychological factors influence grip more in the setting of injury than in healthy volunteers.

*Methods:* Grip strength was evaluated in one hundred subjects, 50 healthy and 50 injured patients 6 weeks after a nonsurgically treated fracture of the distal radius. Grip strength was measured as the mean of three attempts and patients completed questionnaires for arm specific disability (Disabilities of the Arm, Shoulder and Hand), depression, pain anxiety, catastrophic thinking and negative thoughts in response to pain.

*Results:* The mean grip strength in the injured group was 55% of the uninjured side. Pain anxiety accounted for 9% of the variability in grip strength in injured wrists. Among healthy patients, sex was the only correlate of dominant side grip strength, and body mass index accounted for 8% of the variation in the grip strength of the nondominant side divided by the dominant side.

*Discussion:* The majority of the variation in grip strength remains unaccounted for, but physical factors correlate best with grip strength and percent grip strength of the nondominant side divided by the dominant side in healthy patients, and psychological factors correlate best with absolute grip in patients recovering from distal radius fractures.

*Clinical Relevance:* The influences on grip strength are complex, but the differences among recovering and healthy patients demonstrate a role for nonphysical factors in grip strength during recovery.
Introduction
Measurement of grip strength is often used to quantitatively assess upper extremity illness and the results of fracture treatment. Grip strength is influenced by age, sex, height, body mass index, and hand dominance. There is also a voluntary component of grip strength that can be influenced by psychological and sociological factors.
Studies of elderly men and individuals with clinical depression or anxiety disorders, found that depression is correlated with a decline in grip strength. Watson and Ring studied 134 patients with a variety of upper extremity diagnoses and found that grip strength of the involved arm correlated most strongly with the grip strength of the uninvolved arm, but symptoms of depression were a minor factor.
The objective of this study was to evaluate the effect of psychosocial factors on grip strength in two cohorts: a cohort of healthy volunteers and a cohort of patients evaluated six weeks after a nonoperatively treated distal radius fracture. Our primary null hypothesis was that there is no association between grip strength and symptoms of depression in uninjured subjects and those recovering from a distal radius fracture. Our secondary null hypotheses included no correlations between grip strength or disability and pain anxiety, catastrophic thinking or negative thoughts in response to pain.

Materials and Methods
Study design
We invited adult patients with a distal radius fracture treated nonoperatively in our institution and healthy individuals that accompanied patients being seen in the office to enroll in a study of the determinants of grip strength approved by our institutional review board. The criteria for nonsurgical treatment were stable fractures with less than 10° of dorsal angulation, for unstable fractures in low demand patients, or for patients who chose nonsurgical treatment. Only English-speaking people more than 18 years, not pregnant, and without a history of wrist or hand surgery, arthritis, muscular or peripheral neurologic disease (including effects of stroke on the hand) were recruited. Patients with fractures were enrolled during a regularly scheduled outpatient visit approximately six weeks after injury. Informed consent was obtained from all patients.

Subject Characteristics
Fifty participants were enrolled in the fracture group. There were 38 women and 12 men with an average age of 50 years (standard deviation=19, range 18 to 84 years). The dominant side was involved in 40 percent of fractures. The median Body Mass Index (BMI) was 25 (interquartile range 5.2, range 18 to 47). The BMI could not be calculated in 2 patients in the injured group because there was insufficient information. Fifteen patients had nondisplaced fractures, 25 had minimally displaced fractures, and 10 patients had unstable displaced fractures and declined operative treatment.
In the healthy group 50 participants were included. There were 31 women and 19 men with an average age of 49 years (standard deviation=16, range 18 to 78 years). The median BMI was 26 (interquartile range 7.5, range 20 to 60).

Evaluation
Both groups of subjects completed 5 surveys to assess disability and psychological factors.
Arm-specific disability was evaluated with use of the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire. This questionnaire consists of 30 different questions; 21
questions about the ability to perform several activities over the past week, 2 questions specific to pain in social life and at work, 4 questions about specific symptoms at rest, 1 question related to tingling, 1 question related to sleeping and 1 question related to perceived capability. DASH scores are scaled from zero to one-hundred points, with higher scores indicating greater disability.

The Center for the Epidemiological Study of Depression Instrument (CES-D) questionnaire measures depressive symptoms during the previous week. CES-D scores range from 0 to 60, with a higher score indicating more symptoms of depression.

The Pain Anxiety Symptoms Scale (PASS) questionnaire was used to evaluate pain anxiety. This questionnaire investigates 4 dimensions; fear of pain (fearful thoughts when in pain), cognitive anxiety (insistent thoughts or impaired concentration), somatic anxiety (physical symptoms related to pain) and escape and avoidance (response to pain). Scores of each dimension range from 0 to 50, with a range of the total PASS score from 0 to 200. A higher score in a dimension is worse for the patient.

Catastrophic thinking was measured using the Pain Catastrophizing Scale (PCS) questionnaire. The PCS measures 3 components of catastrophic thinking: rumination, magnification and helplessness. Total scores range from 0 to 52 and higher scores indicate a more negative orientation toward pain.

The Negative Pain Thoughts (NPTQ) questionnaire was used to measure cognitions in response to pain and its treatment. It contains 11 questions and scores range from 0 to 55. Higher scores indicate more negative pain-related thoughts.

A few questionnaires were missing or invalid in 4 different patients in the distal radius fracture group: 1 DASH, 1 NTPQ, 1 PASS survey and 2 PCS surveys. In the healthy group a total of 10 questionnaires were missing (1 DASH, 2 CESD, 2 NPTQ, 3 PASS and 2 PCS surveys), in 3 different patients. We used mean imputation (substituted the mean of all patients with the cohort that completed the scale) for missing questionnaires.

**Grip Strength assessment**

Grip strength was measured on both sides with a Jamar dynamometer (Asimow Engineering, Santa Monica, CA) set at the third station with the arm of the patient to the side and the elbow at 90 degrees flexion. Patients were instructed to maximally squeeze the handle of the dynamometer a total of 3 times for each side. We did continuous rapid side-to-side measurements with no rest period. The average of 3 attempts was used for analysis.

We calculated grip strength as a percentage of the uninjured side for patients recovering from a distal radius fracture and grip as a percentage of the dominant side in the healthy group.

Grip strength of the uninjured side was inexplicably low in one of the injured patients and because of our suspicion of incomplete effort, device malfunction, or recording error, we did not calculate the grip strength as a percentage of the uninjured side in this patient.

One patient in the healthy group was ambidextrous. We decided to divide the right by the left hand for analysis of percentage grip. Information about hand dominance was missing in another patient in this group and we assumed the side with the highest grip strength to be the dominant side and used this for further analysis.

**Statistical Analysis**

Continuous data were presented as the mean when normally distributed. When data were not normally distributed we reported the median with interquartile range. Grip strength evaluation included grip of both sides and the percentage of the unaffected (for the injured group) or
dominant (for the healthy group) hand. An a priori power analysis showed that 100 patients
(50 in each group) would yield 80% statistical power ($\beta = 0.2$) to detect a significant
correlation between grip strength and depression of 0.5 or greater.

The Kolmogorov-Smirnov and Shapiro-Wilk test indicated a normal distribution for
DASH, NPTQ, PASS and grip strength in the injured group. CES-D, PCS, age and BMI were
not normally distributed. In the healthy group, NPTQ, PASS, age and grip strength were
normally distributed; DASH, CES-D, BMI and PCS were not normally distributed. Because
so many of the variables were not normally distributed, we used nonparametric tests.

To evaluate correlation between continuous variables we used Spearman correlations. The
Mann-Whitney U test was used to evaluate the association of dichotomous and continuous
variables. In the injured patients, the Kruskal-Wallis test was used for correlation of healthcare
provider (doctor) with outcome. When more than one explanatory variable had a $P$ value
less than .08 in bivariate analysis we entered them into a backwards, stepwise, multivariable
linear regression model. We did not enter the response (dependent) variables (DASH or grip
strength) as explanatory variables in the regression.

A Wilcoxon rank sum test was used to compare means between the fracture and healthy
control group for grip strength, DASH, NPTQ, PCS, CES-D and PASS scores.

Results

Injured Patients
Among injured patients, the mean grip strength of the affected side was 55% of the uninjured
side (Table 1). In bivariate analysis, lower grip strength of the injured side correlated with
higher PASS and CES-D score (Table 2). The best multivariable model for grip strength of the
injured side included PASS alone and accounted for 9% of the variability in grip strength of
the injured arm (Table 3).

The average DASH score among injured patients was 34 (Table 1). In bivariate analysis of
injured patients, DASH correlated in a statistically significant manner with age, grip strength as
a percentage of the uninjured side, CES-D and NPTQ (Table 2). The best multivariable model
(excluding the dependent variable grip strength) included NPTQ, age and sex and accounted
for 31% of the variability in arm specific disability (Table 3). Age had the greatest influence
on arm-specific disability (largest partial $R^2$).

Healthy Subjects
Among healthy subjects grip strength averaged 33 kg on the dominant side and 30 kg on the
nondominant side. Grip strength in the healthy cohort was significantly higher than in the
injured patients. Grip strength in the non-dominant hand averaged 92% of the dominant hand
(Table 1). In bivariate analysis, sex was the only factor associated with absolute grip strength
of the dominant side (Table 2). The only correlate of grip as a percentage of the nondominant
side was BMI (Table 2).

The average DASH score among healthy patients was 4 (Table 1). In bivariate analysis, only absolute grip of the dominant arm correlated with DASH in healthy patients (Table 2).

The DASH score in the injured patients was significantly higher than the DASH score of
the healthy patients. Differences in CES-D, NPTQ, PCS and PASS between the 2 cohorts were
not significant (Table 1).
### Table 1 Evaluation scores

<table>
<thead>
<tr>
<th></th>
<th>Total cohort</th>
<th>Fracture group</th>
<th>Control group</th>
<th>Differences Fracture and control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip strength dominant (kg)</td>
<td>Mean ± SD (range)</td>
<td>Mean ± SD (range)</td>
<td>Mean ± SD (range)</td>
<td>P</td>
</tr>
<tr>
<td>Injured hand divided by noninjured hand</td>
<td>27.0±12.3(0-57)</td>
<td>21±11(0-54)</td>
<td>4.1±6.8 (0-38)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Non-dominant hand divided by dominant hand</td>
<td>54.5%±47.5 (0-325)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDASH (total)</td>
<td>19.1±19.3(0-71)</td>
<td>34.0±15.9(3-71)</td>
<td>4.1±6.8 (0-38)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>CES-D</td>
<td>9.6±8.6(0-44)</td>
<td>10.4±9.1(0-44)</td>
<td>8.8±8.1(0-29)</td>
<td>0.26</td>
</tr>
<tr>
<td>NPTQ</td>
<td>21.4±7.5(11-41)</td>
<td>20±6.5(11-36)</td>
<td>22.8±8.2(11-41)</td>
<td>0.097</td>
</tr>
<tr>
<td>PCS (total)</td>
<td>5.5±7(0-35)</td>
<td>6.4±7.9(0-35)</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>DASH: Disabilities of the Arm, Shoulder and Hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CES-D: Center for Epidemiological Studies Depression Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPTQ: Negative Pain Thoughts Survey</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCS: Pain Catastrophizing Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PASS: Pain Anxiety Symptoms Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*statistically significant

### Table 2 Bivariate statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>Injured patients</th>
<th>Healthy controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman correlation</td>
<td>DASH</td>
<td>Grip strength</td>
</tr>
<tr>
<td>Age</td>
<td>0.48</td>
<td>0.001</td>
</tr>
<tr>
<td>Injured/noninjured</td>
<td>-0.28</td>
<td>0.046</td>
</tr>
<tr>
<td>Injured grip strength</td>
<td>NS</td>
<td>0.19</td>
</tr>
<tr>
<td>Dominant grip</td>
<td>NS</td>
<td>0.77</td>
</tr>
<tr>
<td>Non-dominant/dominant</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>TDASH</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>BMI</td>
<td>NS</td>
<td>0.33</td>
</tr>
<tr>
<td>CES-D</td>
<td>0.32</td>
<td>0.023</td>
</tr>
<tr>
<td>NPTQ</td>
<td>0.29</td>
<td>0.043</td>
</tr>
<tr>
<td>Mann-Whitney U</td>
<td>sex</td>
<td>0.075</td>
</tr>
<tr>
<td>Injured side</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Dominant</td>
<td>NS</td>
<td>0.094</td>
</tr>
<tr>
<td>Kruskall-Wallis</td>
<td>Doctor (1-6)</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS: non significant, x: comparison not made, †DASH: Disabilities of the Arm, Shoulder and Hand, ‡BMI: Body Mass Index, •CES-D: Center for Epidemiological Studies Depression Scale, †PCS: Pain Catastrophizing Scale, °PASS: Pain Anxiety Symptoms Scale
### Table 3 Multivariable statistical analysis

<table>
<thead>
<tr>
<th>DASH injured patients</th>
<th>Grip strength injured side</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Best model</strong></td>
<td>adjusted $R^2$</td>
</tr>
<tr>
<td>NPTQ</td>
<td>0.31</td>
</tr>
<tr>
<td>Age</td>
<td>0.180</td>
</tr>
<tr>
<td>Sex</td>
<td>0.094</td>
</tr>
</tbody>
</table>

* percentage of the overall variability in the dependent variable explained or accounted for by the independent variables in the model

* The percentage of the $R^2$ which can be accounted for by specific variable alone

### Discussion

Among healthy volunteers, sex was the only variable that was significantly associated with absolute grip strength. Grip as a percentage of the other arm has a slight correlation with BMI; and greater arm-specific disability correlated with lower grip strength. In contrast, in injured patients, absolute grip strength correlated slightly with pain anxiety, depression, and dominant limb grip (with only pain anxiety maintained in the multivariable model explaining 9% of the variation in grip strength). Disability correlated with age, depression and negative pain thoughts. Negative pain thoughts, age and sex were retained in the best multivariable model, explaining 31% of the variation in arm specific disability. However, only a small percentage of the variance of disability and grip was explained by these models. In other words physical make-up is important in healthy states but less important than anxiety or negative thoughts in response to pain in the context of recovery, but these are minor factors in the variation in grip strength overall. Although the limited amount of variability in grip strength that can be accounted for in these models demonstrate the complexity of the influences on grip strength, the differences among recovering and healthy patients seem to demonstrate the role of voluntary or subjective factors.

Watson and Ring found a slight correlation of depression with diminished grip strength in patients with various diagnoses. In the current study, psychological factors were an influence in patients recovering from injury, but not in healthy patients. The influence was again small, and it was pain anxiety and negative pain thoughts were retained in the final model. Depression, anxiety, pain catastrophizing, and negative pain thoughts usually correlate, but we did not detect excessive collinearity in our model.

Several potential shortcomings of the study should be kept in mind. Some prior studies adjusted the absolute values for hand dominance (by a factor of 1.07), but we elected not to do this. Questionnaires were missing for 4 patients and 3 control individuals, and the use of mean imputation to address this could have influenced the results. The highest value of grip strength was selected as the dominant side in 2 patients in the healthy group, which was an assumption. Because half of our data was not normally distributed, we decided to use non-parametric tests for further statistical analysis. This might have been too strict for the normally distributed questionnaires.

In the injured group, 1 patient had an inexplicably low value of grip strength on the dominant side and we decided to discard this value for assessment of percentage of the unaffected arm. However, we did use this value of grip strength for analysis of grip strength of the injured side, which could have reduced the mean grip strength in the healthy cohort because of the low value.

We powered our study sample size for our primary study question. Secondary study questions are hypothesis generating only and they may be underpowered.
This study suggests that psychological factors have less influence on grip strength if an individual is healthy. It seems to be a combination of pathophysiology (in this case, a healing fracture) and the human psychological response to the associated nociception (e.g. a sense of causing damage, or pessimism about future use of the hand) that decrease grip strength. These findings emphasize the importance of subjective factors in measures of grip strength, but they also highlight the small percentage of variation in grip strength that we can explain with current models, indicating that grip strength is a complex combination of physical and psychological factors.
References


