Role of pain in measuring shoulder strength abduction and flexion with the Constant–Murley score

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ABSTRACT

Objectives: The Constant–Murley score (CS) has been used for more than 25 years to assess shoulder function. Strength by itself accounts for 25% of the total score. The measurement at 90° abduction seems to be sometimes limited by pain, particularly with tendinopathy or subacromial impingement. We compared the assessment of isometric strength in anterior forward flexion and abduction and its effect on pain and total CS.

Methods: Strength was assessed by CS at both 90° forward flexion and abduction in the scapular plane by using an Isobex dynamometer, the first position tested being randomized. Pain was assessed on a 100-mm visual analog scale (VAS) and total CS was assessed.

Results: We included 54 patients with unilateral shoulder problems; 50% had rotator cuff injury. Mean strength on the affected side was 4.7 ± 2.5 kg in forward flexion and 4.6 ± 2.8 kg in abduction. Induced pain and total CS did not differ between the 2 positions.

Conclusions: Strength can be measured by the CS in forward flexion or abduction, because the measurement does not affect strength, pain intensity or total score. The choice of direction for measurement should be based on the underlying pathology, related contraindications and patient preference.

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1. Introduction

The Constant–Murley score (CS) has been used for more than 25 years to measure the function of the shoulder [1]. The score is divided into 2 parts: a subjective part assessing pain and activities of daily living, and a second part measuring strength and mobility of the shoulder. Strength by itself accounts for 25% of the total score.

The original method for evaluating strength was described by Moseley [2], who used an unsecured cable tensiometer or a spring balance in both 90° forward flexion and 90° abduction in the coronal plane. The use of a dynamometer was proposed by Gerber [3], with well-defined methodology [4], and normalized scores have been published [5–7]. Strength is assessed by measuring the maximal isometric strength at 90° abduction. Abduction was chosen because it was thought that the supraspinatus and deltoid (middle fasciculus) muscles were responsible for the greatest part of the shoulder power [2].

For a long time, whether the score should be assessed in the scapular or coronal plane was not specified. Bankes et al. proposed a standardized method in 1998 [4], but until recently, we had no precise description of the exact position to measure strength, which should be recorded at 90° abduction in the scapular plane, with the strap linked to the device and placed at the level of a pronated wrist [8].

The CS is routinely used in our hospital to assess shoulder function and helps determine improvement. The measurement at 90° abduction appears to be sometimes limited by pain, particularly with tendinopathy or subacromial impingement. Moreover, abduction is not the most common movement in everyday life as compared with forward flexion, which seems more functional. This latter position may induce less pain and is a usual movement in some early rehabilitation protocols [9].

Here we aimed to evaluate a modified CS by assessing isometric strength at 90° forward flexion (in the sagittal plane) and the usual measure at 90° abduction in the scapular plane. We aimed to assess

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whether strength in forward flexion induces less pain and if so, whether the measurement results in higher CS values and reliability than those measured in abduction in the scapular plane.

2. Material and methods

2.1. Context

The study took place between August 2008 and November 2009 at the “Clinique romande de réadaptation Suvacare” belonging to the Swiss accident insurance fund (SUVA), the main injury insurance fund in Switzerland. Patients are sent to our rehabilitation hospital when they exhibit persistent pain and functional limitations (median 9 months after an accident). The aim of the therapeutic program is care by a multidisciplinary approach (somatic and psychological) to improve quality of life, functional status and the chance to return to work. Most of our patients are blue collar workers and come to our clinic after work accidents or traffic accidents. At the end of the hospitalization (median duration 29 days), a program is defined to plan a return to the workplace, which may sometimes be adapted to the disability. If necessary, other care strategies (e.g., new surgery) are decided. If disabilities appear to limit a return to work, the goal of hospitalization is to determine functional limitations and engage vocational rehabilitation.

2.2. Population

Any patient 18–65 years old who was referred to our hospital for a shoulder problem was eligible for the study. Exclusion criteria were bilateral shoulder problems, associated elbow or wrist injury, central or peripheral neurological injury limiting the measurement of strength, unable to understand visual pain evaluation, somatoform disorder, and <3-month-old rotator cuff repair. Patients signed an informed consent form before entering the study. The protocol was approved by the ethics committee of the Canton of Valais local medical association (CCVEM No. 009/08).

2.3. Outcomes

The main outcome criteria were the CS and strength measurements. Secondary outcomes were pain before and after each measurement of strength, assessed by a 100-mm visual analog scale (VAS). Sociodemographic data were obtained at admission. At that time, patients completed the Disabilities of the Arm Shoulder and Hand (DASH) questionnaire in their native language [10], which was used as a measure of self-rated upper-extremity disability and symptoms.

2.4. Intervention

The CS was measured during the hospital stay. Pain was assessed by the mean score of the sum of the verbal scale evaluation followed by a VAS evaluation, with a maximum of 15 points. Activities of daily living were assessed by a 5-point Likert scale (from 0 to 4) asking patients how much they were limited by their shoulder problem at work or during activities of daily living; the total score was 20 points. The same scale was used for evaluating leisure or sports limitations. The presence of pain at night was assessed on a 3-point scale (0 to 2), and the ability to functionally use the arm up to a given level was assessed on a 0 to 10 scale.

Movement was assessed by measuring pain-free, active forward flexion, abduction in the scapular plane, and functional external and internal rotation; the total score was 40 points.

Strength was measured with use of an Isobex dynamometer (CURSOR AG, Bern, Switzerland) with the patient in a seated position, both in forward flexion and in abduction in the scapular plane, elbow in extension, forearm in pronation, with the device placed at the wrist. Patients were asked to give their maximal effort, without further encouragement. They were seated on the corner of a therapy table with the dynamometer placed on the floor, with a vertical vector, and the hand of the untested arm resting on the omolateral knee. The sequence of the measurement in forward flexion or abduction in the scapular plane was randomly determined. Strength was measured on both sides, first the healthy side, then the affected side. It was measured sequentially for each position (e.g., 2 measures in forward flexion followed by 2 measures in abduction) and the score was calculated following recommendations of the French version of the test [11]. Results of strength are in kilograms (kg).

We controlled intra- and inter-observer reliability of the measurements for 24 patients who were assessed twice (with an interval of 1–3 days) by the same 3 physiotherapists who conducted the study.

2.5. Statistical methods

Unless specified, results are presented as mean ± SD. Data not normally distributed are presented as median with interquartile range (IQR). Paired t test was used to compare measurements in abduction and forward flexion for normally distributed data and Wilcoxon signed-rank test for nonparametric data. The intraclass correlation coefficient (ICC) was calculated to assess reliability. ICC > 0.91 was considered very good and 0.71–0.9 good [12]. Agreement was assessed by the Bland–Altman method. We used Systat 13 for Windows (Cranes Software International, Bangalore, India. 2009) for analysis. Bland Altman plots were created with MedCalc for Windows, v14.12.0 (MedCalc Software, Ostend, Belgium). P < 0.05 was considered statistically significant.

3. Results

In total, 130 patients were eligible. After exclusions (Fig. 1), 54 patients had followed the correct protocol (measurements, randomization, etc.).

Except for the DASH score, which was available for 41 patients, other variables of interest were available for all 54 subjects tested. The mean age was 44 ± 10 years, with 91% males, who were blue collar workers. Median interval time from trauma was 309 days (IQR 91–2749). Half of the patients had a rotator cuff injury (24% underwent surgery and 26% not), 19% proximal humerus fracture, 9% adhesive capsulitis, 9% shoulder instability and 7% degenerative disease. Mean DASH score was 43 ± 21% for the 41 patients with data.
Table 1
Strength values (kg) and total Constant–Murley score (CS) on the affected side (AS) and healthy side (HS) overall and by sex.

<table>
<thead>
<tr>
<th>Strength in</th>
<th>Overall</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>AS abduction</td>
<td>54</td>
<td>4.5</td>
<td>2.9</td>
</tr>
<tr>
<td>AS forward flexion</td>
<td>54</td>
<td>4.7</td>
<td>2.5</td>
</tr>
<tr>
<td>HS abduction</td>
<td>54</td>
<td>7.7</td>
<td>2.6</td>
</tr>
<tr>
<td>HS forward flexion</td>
<td>54</td>
<td>8.1</td>
<td>2.5</td>
</tr>
<tr>
<td>CS in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS abduction</td>
<td>54</td>
<td>59.8</td>
<td>14.7</td>
</tr>
<tr>
<td>AS forward flexion</td>
<td>54</td>
<td>60.2</td>
<td>14.4</td>
</tr>
<tr>
<td>HS abduction</td>
<td>54</td>
<td>88.8</td>
<td>5.8</td>
</tr>
<tr>
<td>HS forward flexion</td>
<td>54</td>
<td>89.6</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Table 2
Intra- and inter-observer reliability for strength measures and total Constant–Murley score in abduction and forward flexion and on the AS and HS.

<table>
<thead>
<tr>
<th>Strength</th>
<th>Intra-observer reliability</th>
<th>Inter-observer reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC</td>
<td>95% CI</td>
</tr>
<tr>
<td>AS abduction</td>
<td>0.93</td>
<td>0.84–0.97</td>
</tr>
<tr>
<td>AS forward flexion</td>
<td>0.95</td>
<td>0.88–0.98</td>
</tr>
<tr>
<td>HS abduction</td>
<td>0.94</td>
<td>0.87–0.97</td>
</tr>
<tr>
<td>HS forward flexion</td>
<td>0.95</td>
<td>0.89–0.98</td>
</tr>
<tr>
<td>Total score after</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS abduction</td>
<td>0.90</td>
<td>0.79–0.96</td>
</tr>
<tr>
<td>AS forward flexion</td>
<td>0.90</td>
<td>0.79–0.96</td>
</tr>
<tr>
<td>HS abduction</td>
<td>0.96</td>
<td>0.92–0.98</td>
</tr>
<tr>
<td>HS forward flexion</td>
<td>0.97</td>
<td>0.94–0.99</td>
</tr>
</tbody>
</table>

3.1. Reliability
Reliability was measured for 24 patients. ICC and 95% limits of agreement are detailed in Table 2 for the 2 directions tested and for the healthy and affected shoulder. Differences between measurements were stable, even with extreme values on Bland–Altman plots.

3.2. Strength
On the affected side, mean strength was 4.7 ± 2.5 kg in forward flexion and 4.5 ± 2.9 kg in abduction (P = 0.754). On the healthy side, mean strength was 8.1 ± 2.5 kg in forward flexion and 7.7 ± 2.6 kg in abduction (P = 0.386). Results by gender are in Table 1.

3.3. Pain
On the affected side, mean pain before strength measurement in abduction was 26.7 ± 25.2 mm and 26.6 ± 24.4 mm before strength measurement in forward flexion (P = 0.691). Mean pain after strength measurement was 46.1 ± 30.8 mm after abduction and 44.0 ± 29.7 mm after forward flexion (P = 0.262). The mean increase in pain intensity was 19.3 ± 20.6 mm after strength measurement in abduction versus 17.4 ± 20.5 mm after the measure in forward flexion (P = 0.749). On the healthy side, we found no significant difference between measurements.
Among 54 patients, 10 declared that forward flexion induced less pain (pain difference on a VAS ≥ 10/100 as compared with the other direction on the affected side), and 5 patients declared less pain in abduction. Because of this low number of patients, results are not presented.

3.4. Total score
We found no difference between both methods of strength measurement in total CS measured on the affected side [i.e., forward flexion 60.2 ± 14.4 points and abduction 59.8 ± 14.7 points (P = 0.896)]. On the healthy side, the total score was 89.6 ± 5.8 after forward flexion and 88.8 ± 5.8 after abduction (P = 0.426). Fig. 2 shows measurements in both directions, on the affected side and healthy side, for strength, pain changes after strength measurement, and total CS. Results for gender are in Table 1.

4. Discussion
Our study is the first to assess strength of the CS in forward flexion and the induced pain after shoulder strength measurement. We found no difference in pain between measurements of maximal isometric strength in abduction in the scapular plane or in forward flexion for the 54 patients tested. In both directions, strength measurement increased pain by nearly 20 mm on the 100-mm VAS on the affected side. The total CS did not differ by direction tested, which suggests that we could use either direction based on the favored one.

The lack of difference in strength between the 2 directions may be explained by pain and motor control adaptations in the pattern of recruitments of rotator cuff, deltoid or scapulothoracic muscles during forward flexion or abduction in the scapular plane. Electromyography studies of healthy shoulders have indeed found that maximum activity is required to provide dynamic stability by maintaining optimal humeral head and scapular alignment [13–15]. In a healthy shoulder, deltoid and rotator cuff muscles provide significant abduction torque, with an estimated contribution of up to 35% to 65% by the middle deltoid, 30% by the subscapularis, 25% by the supraspinatus, 10% by the infraspinatus and 2% by the anterior deltoid [16]. Boettcher et al. studied electromyographic activation of shoulder muscles in healthy subjects during isometric testing in different positions. Abduction in the scapular plane ("empty can") and forward flexion at 90° showed maximal activation of rotator cuff muscles and also deltoid, trapezius and serratus anterior muscles in both positions [13]. To our knowledge, similar electromyography analyses have not been performed in pathological shoulders where patterns of movement...
and recruitment of rotator cuff muscles are modified because of pain or muscle failure [17–19].

The strength values we found were comparable with those in other studies involving the Isobex. Yian et al. [7] found a mean strength in abduction of 9.2 ± 1.9 kg for males and 4.7 ± 1.0 kg for females among 115 healthy volunteers 11–69 years old. We found no data with use of the Isobex for mean strength in forward flexion, but data from a study testing strength in forward flexion with another dynamometer [20] found a mean strength of 5.3 kg for healthy female subjects and 9.7 kg for healthy male subjects, which is comparable to

![Graphs showing mean strength, change in pain score after testing, and total Constant–Murley score.](image)

**Fig. 2.** Mean strength, change in pain score after testing and total Constant–Murley score.
data we found (i.e., 5.4 and 8.4 kg for the healthy side of female and male patients, respectively). Mean CS on the healthy side of our patients was comparable to that for the Yan et al. control subjects [7] (87 ± 5.91 ± 4 for males and 83 ± 3 for females).

We could not determine whether the CS measurement in forward flexion results in higher values and reliability than that measured in abduction in the scapular plane because of lack of power, with 10 and 5 patients who found testing less painful in forward flexion and in abduction in the scapular plane, respectively. Preliminary analysis (results not shown) suggests a higher reliability of the 2 measures of strength needed for the CS when performed in the less painful direction but needs confirmation.

Intra-observer reliability for strength measurement in forward flexion and in abduction with the isobex dynamometer was good to excellent, which was also found by other groups, with a higher intra-observer than inter-observer reliability, as it is usually seen [21–23].

From the original strength measurement description of the CS, adaptations have been made over the years. Abduction was chosen to test shoulder power and particularly supraspinatus and anterior deltoid muscles [2]. In the last recommendations of the European Society of Shoulder and Elbow Surgery (2008), pain and strength measurements were detailed to improve inter-observatory reliability [5]. In these recommendations, the measurement of strength at 90° is described in abduction in the scapular plane. From electromyography studies [13–16] and our results, we think strength could be measured at 90° in abduction in the scapular plane or in forward flexion.

The limitations of our study are the low number of patients included, in part because some patients did not follow the randomization protocol. Thus, we were not able to further analyze results based on diagnosis and confirm our second hypothesis. Measurements were not standardized for the time of the day they were done, so we cannot exclude differences when comparing results of strength measurements at the end of the day with measurements done earlier in the day.

5. Conclusions

Our results suggest that strength can be measured with the CS in forward flexion or in abduction in the scapular plane, because the direction of measurement does not appear to induce differences in strength, pain intensity or total score. The variability of strength measurements when performed in a less painful direction needs further analysis. In clinical practice, the induced pain after strength measures might be disturbing for some patients. The less painful direction between forward flexion and abduction in the scapular plane before testing could be determined by asking the patient to move in both directions without weight. The decision should then be based on the patient's preference, the underlying pathology, and related contraindications.

Authors’ contributions

OD and MK participated in the design of the study. MK and CB participated in the acquisition of data and had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. CB, OD, FL and MK helped draft the manuscript. All authors read and approved the final manuscript.

Disclosure of interest

The authors declare that they have no competing interest.

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