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Research Article

Self-assessment of range of motion in patients undergoing surgery for a unilateral shoulder condition

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ABSTRACT

Objective: This study aimed to investigate the agreement of patient-assessed and researcher/physician-assessed measurements of the difference in range of motion between the unaffected and affected shoulders in 55 patients undergoing arthroscopic surgery for a unilateral shoulder condition.

Methods: The investigation included 55 patients (17 women and 38 men; median age = 53 years; range = 26–74) with a symptomatic unilateral shoulder condition and a surgically treatable diagnosis. Images of a model/researcher performing active shoulder abduction, flexion, external rotation, and internal rotation were created. Each image was paired with a degree diagram or a level system (for internal rotation) on the back for the patient to accurately self-evaluate and record. Each patient was instructed to attentively examine the figures and perform the movements with the same posture as depicted. On the day of surgery, prior to the procedure, 2 independent researchers who were not involved in the patient's care used a standard goniometer to assess the same active movements that the patient had previously self-assessed. For agreement analyses, the intraclass correlation coefficient and Bland-Altman plots were calculated for continuous data (abduction, flexion, and external rotation), and Cohen's weighted kappa was calculated for ordinal categorical data (internal rotation).

Results: The intraclass correlation coefficient for abduction, flexion, and external rotation was 0.93 (excellent) 95% CI (0.87, 0.96), 0.89 (good) 95% CI (0.81, 0.94), and 0.72 (moderate) 95% CI (0.52, 0.84), respectively. Cohen's kappa for internal rotation (measured as reaching levels on the back) was 0.63 (moderate).

Conclusion: We believe that patient-assessed measurements of abduction (intraclass correlation coefficient 0.93) and flexion (intraclass correlation coefficient 0.89) can be used as a valid substitute (for measurements by a clinician or researcher). Patient-assessed measurements for external rotation (intraclass correlation coefficient 0.72) and internal rotation (kappa 0.63) are in moderate agreement and should be used more cautiously as substitutes.

Level of Evidence: Level II, Diagnostic Study.

Introduction

Patient Reported Outcome Measures (PROMs) for various joints and various conditions are widely used both in clinical practice and in clinical studies. In both situations, it is common to register data sets from the same patients at various points of time. Such datasets of PROM are valuable, e.g., for gathering information about the natural development (of diseases) and the effect of any treatment.[1,2] Most PROMs include questions about symptoms and function of the limb or joint, e.g., the shoulder. Such questions are often related to the performance of activities of daily living (ADL), i.e., by asking the patient about his/her ability to conduct specific tasks, e.g., opening a new/tight jar or washing her/his back.[3] However, the patients' evaluation of their level of coping with ADL is highly subjective and influenced by many factors that may not necessarily be in high agreement with the objective measures of function, such as range of motion (ROM) or muscular strength.

Thus, health-care personnel and researchers have traditionally been left with a need to supplement the PROM with clinical examinations, e.g., to measure the ROM of the joint. Such visits lead to the use of time and funds by both the patient and the health-care provider that could possibly be allocated for other purposes. In addition, the COVID-19 pandemic has recently reduced face-to-face appointments with health-care providers to a minimum in an effort to halt the spread of the virus.[4,5] At the moment, much of the world is opening to a more normal situation, but we have reasons to believe that new pandemics will introduce new lockdowns.

Further, especially in follow-up situations that are not directly related to the treatment of the patient, i.e., in clinical studies where researchers who are not involved in the treatment conduct the examination, the patient may not be highly motivated to use time (and money) to attend the clinical examination. This may lead to dropouts (resulting in loss of statistical

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power in scientific studies). Bias may also be introduced as well-functioning patients are less likely to attend a clinical examination that they don't believe they need (especially if a precondition is taking time off from work and traveling a longer distance). Thus, the principle of self-assessment (patient-assessed) examination, e.g., of ROM of the shoulder has been introduced.[6-10]

The purpose of the present study was to compare the assessment of ROM of the shoulder by the patients versus the researchers in patients about to undergo arthroscopic surgery for a unilateral shoulder condition. We specifically wanted to address the difference in ROM (abduction, flexion, external rotation, and internal rotation) between the unaffected and affected shoulders. The patients were instructed, by the use of photos and diagrams, to report the results in the same way as the researchers would. Interobserver agreement between the 2 pairs of data was assessed by calculating intraclass correlation coefficient (ICC) and Bland–Altman plots for continuous data and Cohen's weighted kappa for ordinal categorical data (internal rotation). The *null hypothesis* was that there would be no statistical agreement between the self-assessed measurements and those by the researchers.

Materials and methods

Experimental protocol

All patients about to undergo an arthroscopic procedure for a unilateral shoulder condition at our institution, within a 6-week interval, were invited to participate in the study. The study was approved by Aleris Hospital Nesttun Institutional Ethical Committee (#TER-UIB-005). All patients gave their written informed consent before being enrolled in the study. It was made clear to all patients that neither their participation in the study nor the results of any study measurements would influence their treatment at the institution. All data were registered prospectively and stored in a local institutional database.

We included patients with a symptomatic unilateral shoulder condition and a diagnosis amendable for surgery based on the patient's history, a clinical examination, and a recent magnetic resonance imaging (MRI) investigation (confirming the diagnosis). For chronic/degenerative conditions such as subacromial pain syndrome and/or non-traumatic rotator cuff tears, the positive determination of an indication for surgery required a history of pain negatively affecting the patient's ADL for at least 6 months and an unsuccessful non-operative treatment regime, including a rehabilitation program conducted by a physiotherapist, lasting for at least 3 months.

HIGHLIGHTS

- Most Patient Reported Outcome Measures (PROMs) include questions about function. However, the patients' evaluation of their level of coping is subjective and may not agree with the objective measures of function.
- Thus, there is generally a need to supplement the PROMs with clinical examinations, e.g., of range of motion (ROM). However, resources used for such visits could ideally be allocated for other purposes.
- It has been proposed that self-assessment of ROM could be substituted for a visit to the health provider. The current study aimed to examine the degree of agreement.
- Self-assessed measurements of abduction [intraclass correlation coefficient (ICC) 0.93] and flexion (ICC 0.89) in the shoulder can be safely used as a valid and accurate substitute for measurements by a clinician or researcher.
- Self-assessed measurements for external rotation (ICC 0.72) and internal rotation (kappa 0.63) are in moderate agreement and should probably be used more cautiously.

Exclusion criteria, at the time of surgery, were the following: patients not fluently reading and speaking the native language (of the instructions), patients with bilateral shoulder conditions, and patients failing to complete the self-assessment questionnaire prior to the surgery.

Design of self-assessment questionnaire

Black-and-white images of a model/researcher conducting active abduction, flexion, external rotation, and internal rotation of the shoulder were produced (the person in the images has signed a release for the images for use in the study and this publication) and included in a pamphlet together with text describing the procedures. Each image was combined with degree diagrams (abduction 0-180 degrees, flexion 0-180 degrees, and external rotation 0-120 degrees) or a level system on the back (for internal rotation) for the patient to self-assess and record precisely. Accordingly, in the same way, a researcher or health-care provider would conduct and record the same measurements of ROM (Figures 1-4).

Each patient was advised to study the figures closely and perform the movements in the same way, using the same posture, as in the images. For accurate measurements of ROM, we advised using a large mirror and/or seeking the help of a friend or member of the family. Sets of 2images/figures, 1 for each shoulder, were provided for each movement and the patient was required to mark the maximum ROM possible for each motion for each shoulder.

The questionnaire was sent to each patient about a week before the scheduled shoulder surgery. The patient (if willing to participate in the study) was asked to undergo the self-assessment evaluation close to the day before the surgery, ideally 1–3 days before.

Researcher-assessment of ROM

On the day of surgery, previous to the procedure, 2 independent researchers, not involved in the treatment, worked together assessing the same active movements, as the patient had previously self-assessed, using a standard goniometer.[11-13] For each measurement, one researcher made sure that the patient was positioned and carried out each movement correctly, while the other did the measurements. The same researcher conducted all the measurements. The researchers were blinded by the self/patient-assessed recordings, any recordings in the patient's medical files and the diagnosis of the patient's condition.

At a later moment, after the researcher-assessment measurements had been secured in an institutional database, the patient-assessed ROM measurements were measured as marked on the photo-diagrams using a goniometer (for abduction, flexion, and external rotation) and determined the level of internal rotation. At this time, the 2 researchers were blinded for the identity of the patient and the previously determined researcher assessments of ROM.

Statistical analyses

Statistical analyses and the creation of plots were performed with the use of Statistical Package for the Social Sciences, version 26.0 (IBM SPSS Corp.; Armonk, NY, USA)) on a personal computer. For the calculation of weighted Cohen's kappa, the Stats Weighted Kappa Version 2.0.0 extension to SPSS was downloaded and used. An a priori *P*-value less than .05 was considered statistically significant. For the pre-hoc calculation of the necessary sample size, we used the method by Bujang and Baharum.[14] We wanted to be able to demonstrate an ICC of 0.4 or higher at alfa 0.05 and a power of 90%. That

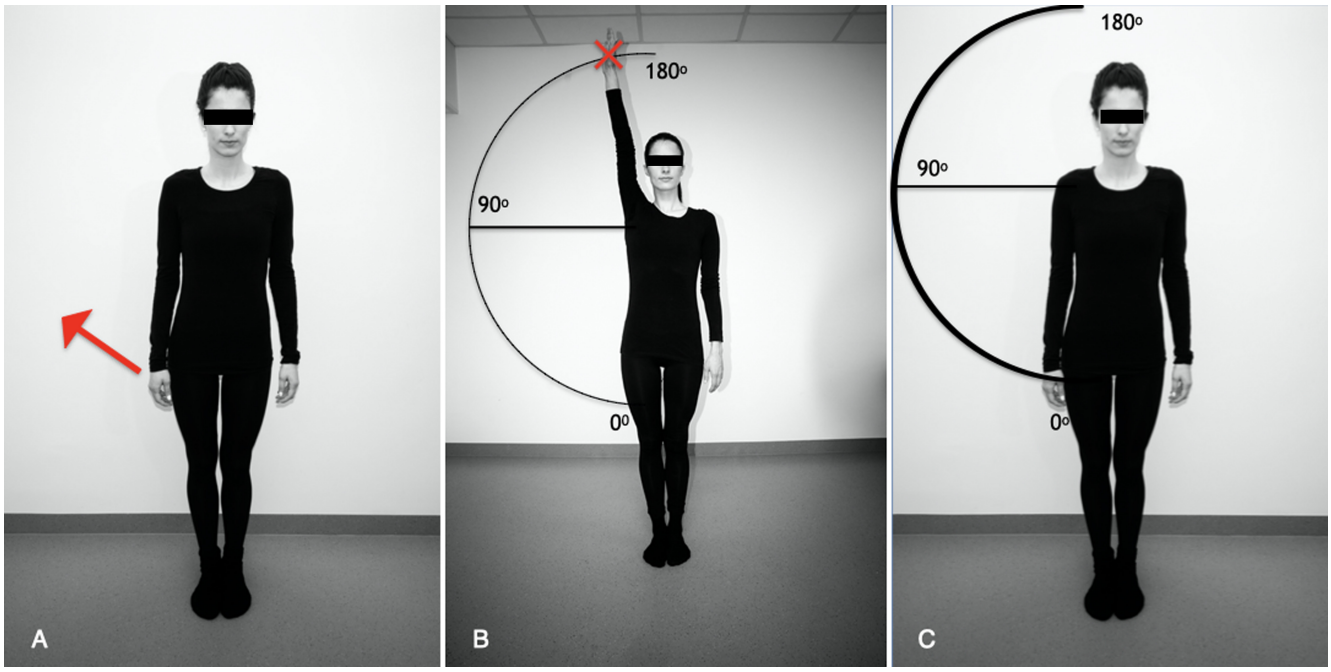

Figure 1. Images used for self-assessment of range of motion of abduction. (A) Shows the starting position and the direction of movement of the right arm. (B) Shows an example of self-assessment of the degree of active abduction marked by a cross on the included degrees diagram (from 0 to 180 degrees). (C) Invites the patient to mark his or her own result for the right arm.

required 45 subjects. Demonstrating ICC of 0.5 at the same alpha and power requires 30 subjects.

For continuous variables (abduction, flexion, and external rotation), inter-observer agreement between the (paired) observations by patients and researchers was calculated as ICCs with a 95% CI. Further, Bland–Altman plots (as part of the limits of agreement (LoA) method) of the means of measurement pairs were constructed.[15,16] For ordinal categorical data (internal rotation), interobserver agreement was calculated as Cohen's weighted kappa.[17]

Results

The self-assessment questionnaire of shoulder ROM was distributed to a total of 66 patients (with an invitation to participate in the study). Eleven patients declined to participate and/or did not present

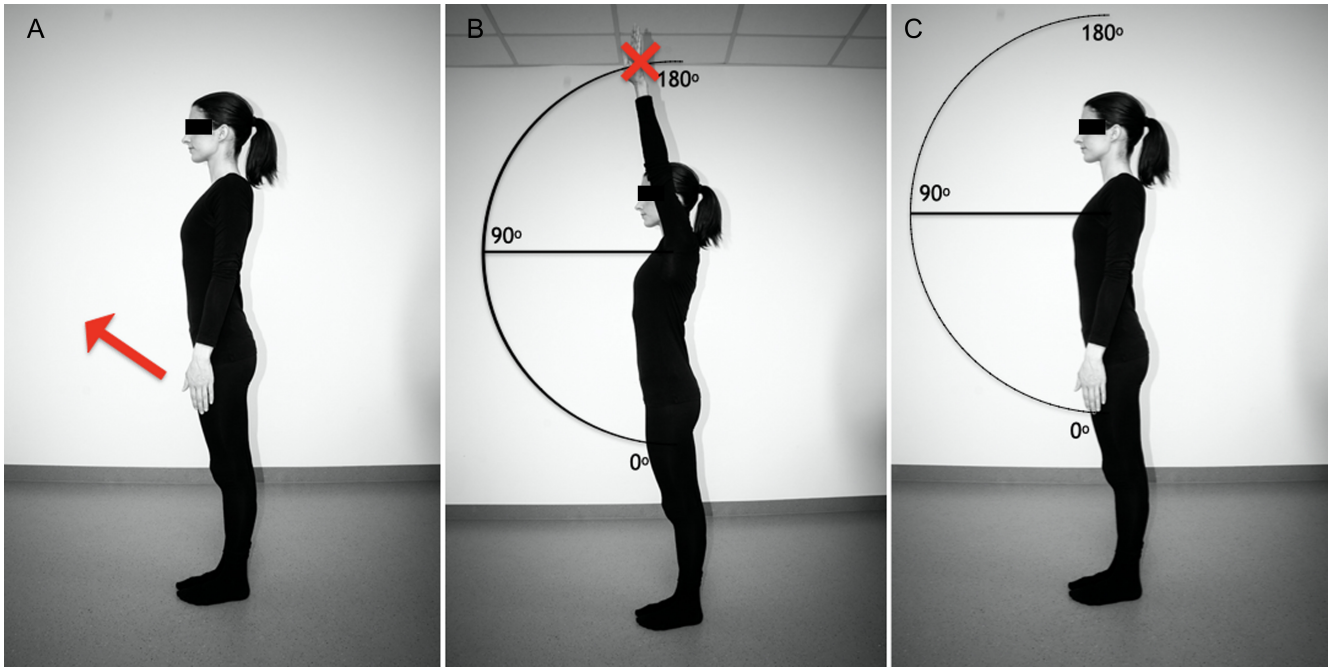

Figure 2. Images used for self-assessment of range of motion of flexion. (A) Shows the starting position and the direction of movement of the left arm. (B) Shows an example of self-assessment of the degree of active flexion marked by a cross on the included degrees diagram (from 0 to 180 degrees). (C) Invites the patient to mark his or her own result for the right arm.

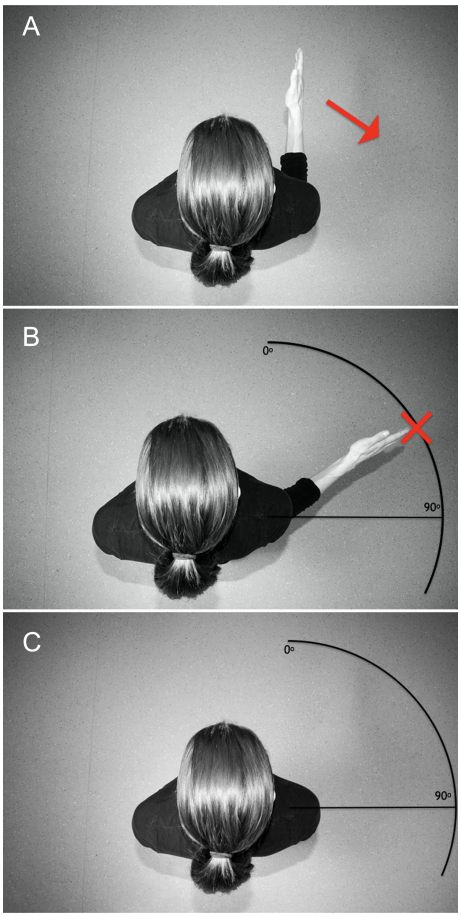

Figure 3. Images used for self-assessment of range of motion of external rotation. (A) Shows the starting position and the direction of movement of the right arm (into increasing external rotation). (B) Shows an example of self-assessment of the degree of active external rotation marked by a cross on the included degrees diagram (from 0 to 120 degrees). (C) Invites the patient to mark his or her own result for the right arm.

a completed questionnaire at the day of surgery. Thus, 55 patients (17 women and 38 men) were included in the study. The median age was 53 years (range 26-74). The right shoulder was involved in 29 patients, the left in 26.

The main diagnosis of the patients' disorders was subacromial pain syndrome (with MRI-verified cuff tendinopathy and often partial tears) with/without concomitant acromio-clavicular osteoarthritis (n = 32); full-thickness rotator cuff tear scheduled for repair (n = 13); SLAP lesion scheduled for repair (n=5); frozen shoulder/adhesive capsulitis scheduled for capsulotomy (n = 3); and anterior shoulder instability scheduled for Bankart repair (n = 2).

A statistically significant interobserver agreement (between self-assessed ROM and researcher-assessed ROM) was found for all 4 types of movement ($P < .001$ for comparisons). The ICC for (measured difference between involved and uninvolved shoulder in) abduction, flexion, and external rotation was 0.93 (excellent) 95% CI (0.87, 0.96), 0.89 (good) 95% CI (0.81, 0.94), and 0.72 (moderate) 95% CI (0.52, 0.84), respectively. For internal rotation, the weighted Cohen's kappa was 0.63 (moderate).

The mean difference (in degrees) between the researcher and patient ROM was −1.7 [95% CI (−6.7, 3.3)] for abduction; −4.5 [95% CI (−10.4, 1.4)] for flexion; and −3.7 [95% CI (−8.1, 0.8)] for external rotation. The normality of the 3 sets of difference from mean data was confirmed by histogram and the Kolmogorov–Smirnov test (n.s.), and each data set was tested against the value 0 (n.s.) by the One-Sample *t*-test, thus validating the use of the LoA method. Bland–Altman plots (of difference on the vertical axis and mean on the horizontal axis with horizontal lines for mean and 95% limits of agreement) were constructed for abduction (Figure 5), flexion (Figure 6), and external rotation (Figure 7). Linear regression analyses of the difference and mean of each ROM demonstrated no proportional bias (n.s.).

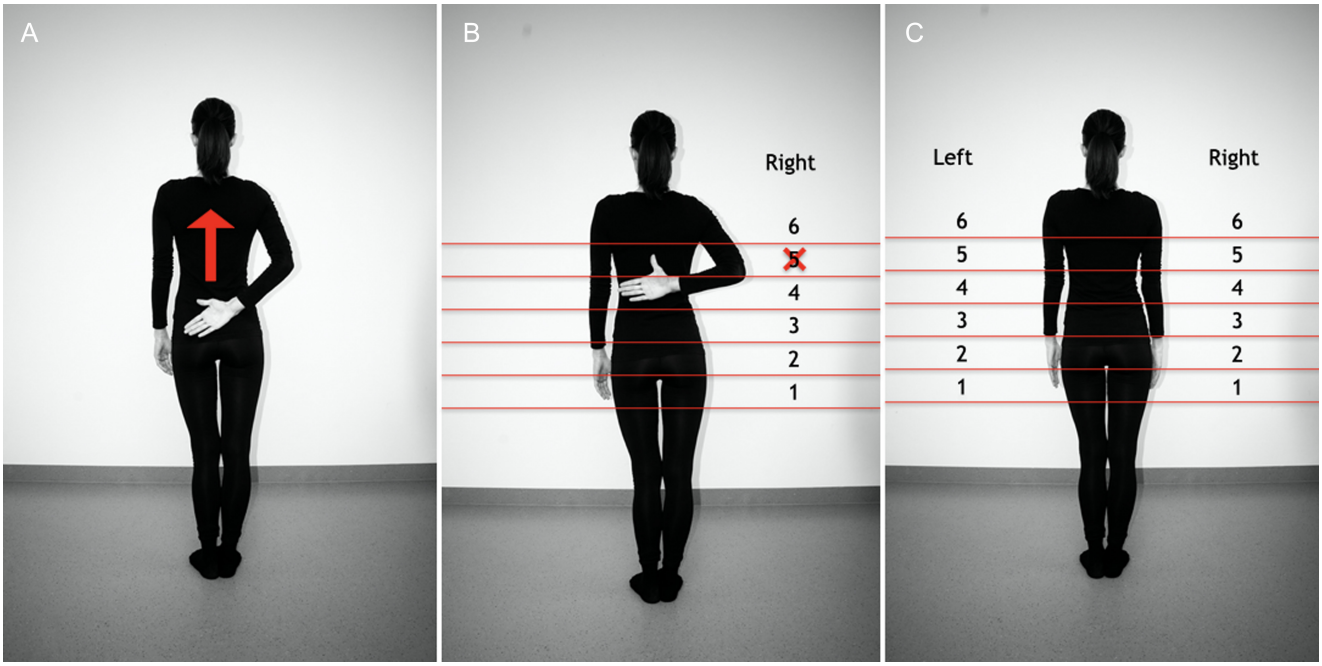

Figure 4. Images used for self-assessment of range of motion of internal rotation by recording the position of the hand with the thumb up along the middle of the back. (A) Shows the starting position and the direction of movement of the right arm (into increasing internal rotation). (B) Shows an example of self-assessment of the degree of active internal rotation marked by a cross on the included 6-level diagrams. (C) Invites the patient to mark his or her own result for the right arm.

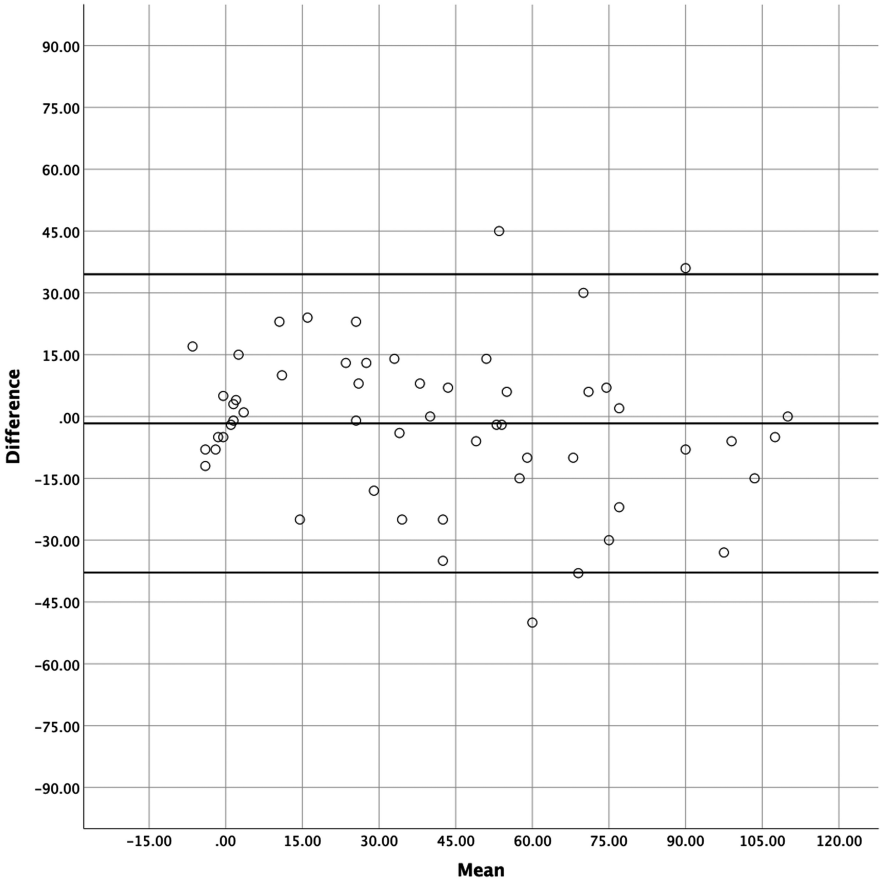

Figure 5. Bland–Altman plots of the difference between researcher-assessed and patient-assessed abduction on the vertical axis and mean on the horizontal axis with horizontal lines for mean and 95% limits of agreement.

Discussion

The most important finding of the present study was that we found a statistically significant agreement between the pairs of measurements by the patient and the researchers. For the difference in abduction between the 2 shoulders, a very high ICC of 0.93 (excellent) 95% CI (0.87, 0.96) ($P < .001$) was found. For flexion, the ICC was 0.89 (good) 95% CI (0.81, 0.94). Thus, we believe that patient-assessed measurements of abduction and flexion (at home) can be safely used as a valid and accurate substitute for measurements by a clinician or researcher during a clinical examination. For the other types of ROM, the agreement was somewhat less. For external rotation, we found an ICC 0.72 (moderate). For internal rotation (measured as reaching levels on the back), we found a Cohen's weighted kappa of 0.63 (moderate). Thus, patient-assessed measurements for external rotation and internal rotation seem to be somewhat less in agreement with that of a clinician/researcher and should probably be used more cautiously as substitutes, especially when a high degree of accuracy is needed.

The 3 Bland–Altman plots, too, point toward a significant agreement between patient- and researcher-assessed measurements, as almost all measured differences fall within a mean plus or minus 1.96 SD.[15,16] Generally, it may be tempting to view the researcher-assessed measurements as the "golden standard" (the truth) and consider any agreement less than perfect being caused by errors by the patient. However, this seems not to be true, as even seemingly simple physical measurements made by physicians and researchers are not without any error whatsoever.[18] Thus, multiple studies have found low-moderate intertester reliability (ICC) measuring ROM (by goniometer) in the shoulder and other joints.[13]

We strongly concur with the sound clinical principle that the difference in ROM between a joint suffering from a pathologic condition versus the contralateral unaffected one is more important than the absolute numbers (of ROM) of each shoulder, separately.[13] Therefore, it was decided pre-hoc to record the difference in ROM between the 2 shoulders and compare pairs of these measures (patient-assessed versus researcher-assessed data). Further, we believe comparing the ROM of the 2shoulders will reduce the effect of any systematic misconduct by the patient when performing the different motions (of each shoulder).

For measuring internal rotation, both by the patient and the researcher, we used the established level system by assessing how high the patient can reach with the back of the hand (with the thumb facing upwards).[19] Based on the reach, internal rotation is graded as 1 of 6 levels (1–6). Although commonly used, as well as reflecting the degree of ability to perform important ADL tasks, it is disputable to which degree the method precisely measures the internal rotation of the glenohumeral joint.[13] It has been documented that, in addition to the movement in the glenohumeral joint, scapulothoracic movement and flexion of the elbow both play great parts in internal rotation as measured by the level reached on the back.[20] Further, the type of data, ordinal categorical rather than continuous, precludes the use of Bland–Altman plots and calculation of ICC (and even

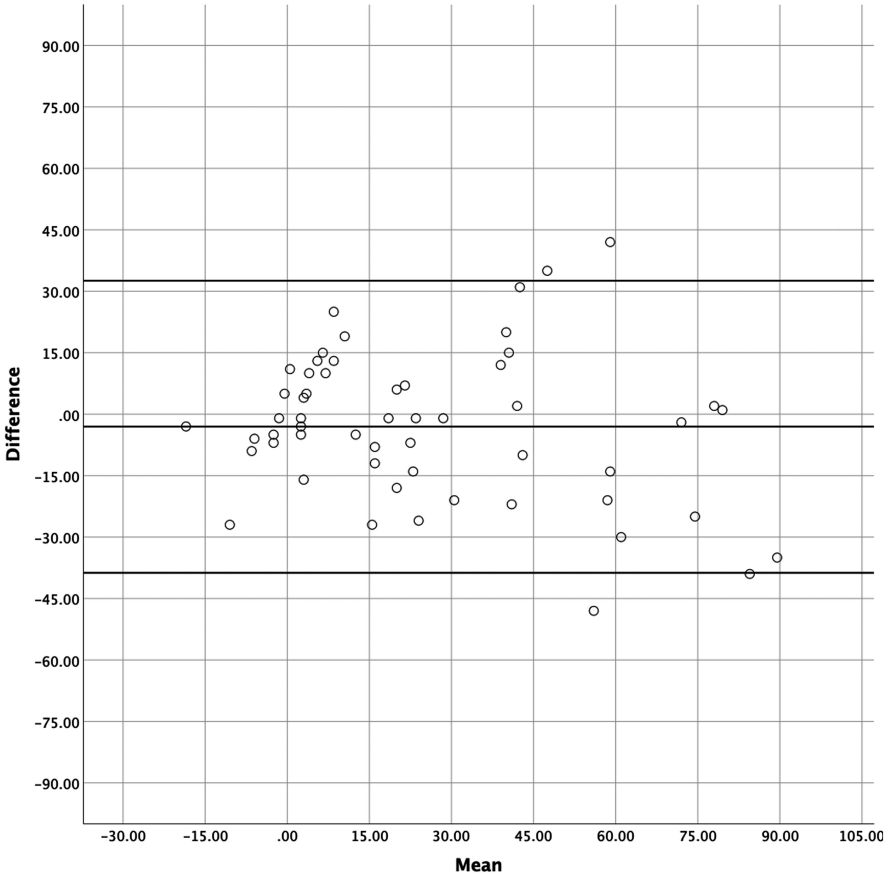

Figure 6. Bland–Altman plots of the difference between researcher-assessed and patient-assessed flexion on the vertical axis and mean on the horizontal axis with horizontal lines for mean and 95% limits of agreement.

makes it difficult to compare external and internal rotation in the same patient). Thus, we suggest incorporating a method for measuring internal rotation on a degree scale/by a goniometer, e.g., at 90 degrees abduction.[13]

The current study is based on the innovative work of Cordelia W. Carter and co-workers published in 2008.[6] Carter et al used a diagram-based questionnaire that included photos of models performing flexion, external rotation, and internal rotation, at different levels of ROM, of each shoulder. For flexion, 5 photos were presented showing 0, 45, 90, 135, and 180 degrees of motion. For external rotation (in 90 degrees of abduction), 4 photos were presented showing 0, 30, 60, and 90 degrees. For internal rotation, 4 photos were presented showing the arm/hand at the back pocket, lower back, mid-back, and upper back. For each set of photos, the patient was asked to circle the picture that most closely matched the patient's ROM. The authors found that the patients matched the physician's ROM assessment in 85% of the cases. A match was declared when the patient circled an image showing a ROM that was within halfway to the next step in either direction compared to the physician's measurement. Thus, e.g., if the physician measured 45 degrees external rotation, a circle by the patient on either 30 or 60 degrees would have to be considered a match.[6]

By reducing the patient's degree of accuracy of answering about shoulder ROM from that of the continuous data (0-360 degrees determined by a goniometer) to ordinal categorical data of 4 or 5 levels, a great loss of potential useful information is lost. Further, as the patient-assessed data are categorical and the physician-assessed data are continuous, it is not possible to statistically test the degree of agreement between them (without converting the physician-assessed data into the same categories). Thus, we decided to produce a new diagram-based questionnaire that allowed the patient to assess the ROM of the shoulder in the same way as the physician does. By collecting the same type of data from the patient and physician/researcher, we were able to use correct/relevant statistical tests for determining the degree of agreement between patient-assessed and physician-assessed data.[18]

We included abduction, in addition to flexion, external rotation, and internal rotation[6,19] as a motion to be measured and analyzed for agreement between patient- and physician-assessed data. This movement is particularly reduced in many common shoulder conditions, e.g., subacromial impingement syndrome/cuff tendinopathy and rotator cuff tears (in which the supraspinatus tendon is most commonly involved) and pathology (including osteoarthritis) of the acromioclavicular joint and frozen shoulder/adhesive capsulitis.[13] The current study shows an excellent agreement between patient- and physician-assessed data with an ICC of 0.93. As patient-assessed abduction agrees highly with that of physician-assessed and is a motion that is commonly negatively affected in common shoulder conditions, we advocate the use of a diagram questionnaire similar to ours in addition to a PROM when evaluating shoulder function.

In the future, smartphones with installed applications for analyzing motion directly (as a digital goniometer) or by interpretation of

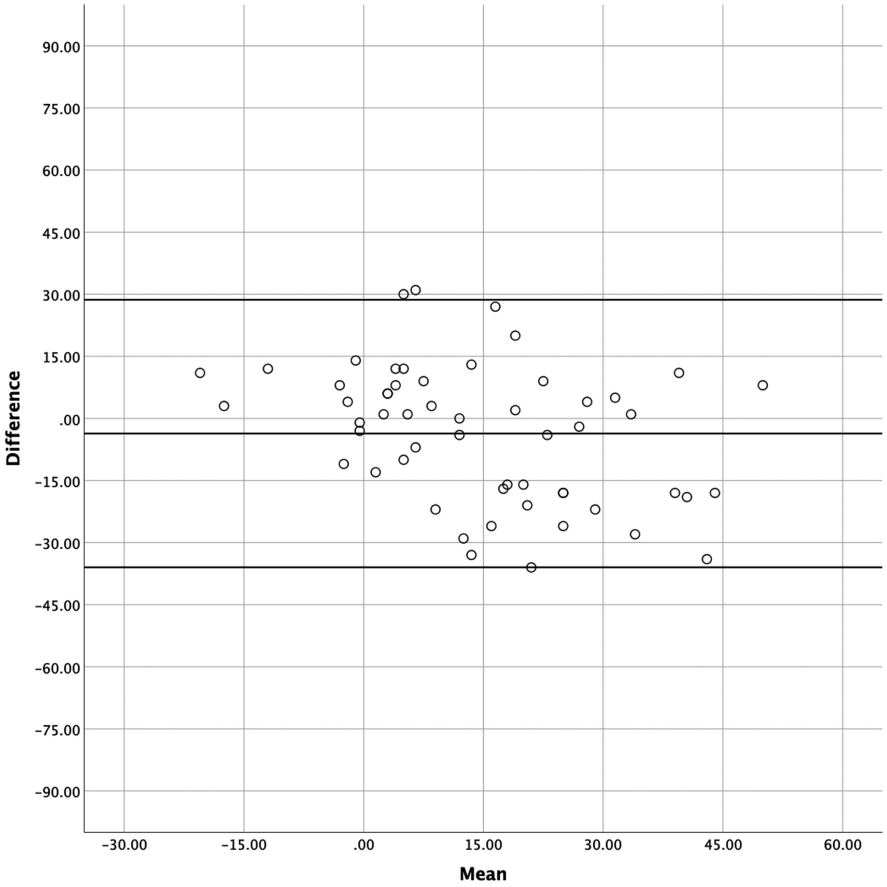

Figure 7. Bland–Altman plots of the difference between researcher-assessed and patient-assessed external rotation on the vertical axis and mean on the horizontal axis with horizontal lines for mean and 95% limits of agreement.

images and videos may come into wider use.[21] This type of solution may prove to be more accurate and more practical/convenient for the patient and researchers/clinicians. However, as long as the measurement of ROM is only a (small) part of a PROM questionnaire, we would argue that adding an extra page with diagrams for the patient to mark the ROM is a convenient, accurate (especially for measurement of abduction and flexion) and inexpensive alternative. This may be distributed/collected by postal mail, e-mail, or on a dedicated secure website.

The strengths of the current study include the inclusion of a rather large group of consecutive prospectively registered patients; recording identical data for patient assessment and researcher assessment; and using correct statistical measures for agreement between tests. The weaknesses include examining only patients with a unilateral shoulder condition having failed non-operative management and about to undergo arthroscopic surgery. Thus, our findings may not apply to the general population.

We believe that patient-assessed measurements of abduction (ICC 0.93) and flexion (ICC 0.89) can be used as a valid substitute for measurements by a clinician or researcher. Patient-assessed measurements for external rotation (ICC 0.72) and internal rotation (kappa 0.63) are in moderate agreement and should probably be used more cautiously as substitutes.

Ethics Committee Approval: The study was approved by the Institutional Ethical Committee of Aleris Hospital Nesttun, Bergen, Norway (Approval no: #TER-UIB-005).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – E.S.; Design – E.S., M.R., K.R. ; Supervision – E.S.; Resources – E.S.; Materials – E.S., M.R., K.U.; Data Collection and/or Processing – E.S., M.R., K.U., A.P.; Analysis and/or Interpretation – E.S., M.R., K.U., A.P.; Literature Search – E.S., M.R., K.U.; Writing – E.S., M.R., K.U.; Critical Review – A.P.

Declaration of Interests: The authors have no conflict of interest to declare.

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