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Smartphone applications for the evaluation of pathologic shoulder range of motion and shoulder scores—a comparative study

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Hypothesis and background: Accurate measurement of range of motion (ROM) is important in evaluating a pathologic shoulder and calculating shoulder scores. The aim of this study was to establish the reliability and validity of different smartphone applications (apps) in assessing pathologic shoulder ROM and to determine whether differences in recorded ROM measurements affect calculated shoulder scores. The authors hypothesized that there is no difference between shoulder ROM assessment methods and calculated shoulder scores.

Methods: In this nonrandomized controlled clinical trial, ROM of 75 participants with a history of shoulder disease (21 women, 54 men) was assessed using a smartphone inclinometer and virtual goniometer, a standard goniometer, and clinicians' visual estimation. Shoulder strength was assessed, and Constant-Murley (CM) and University of California–Los Angeles (UCLA) shoulder scores were calculated.

Results: Independent of diagnosis or operation, all cases (except for passive glenohumeral abduction of unstable shoulders) showed excellent intraclass correlation coefficients (>0.84). Interobserver reliability was excellent for all ROM measures (intraclass correlation coefficient > 0.97). All modalities had excellent agreement to values attained with the universal goniometer. There were no differences for the calculated CM or UCLA scores between the modalities employed to measure ROM.

Conclusions: A smartphone inclinometer or virtual goniometer is comparable to other clinical methods of measuring pathologic shoulder ROM. Clinicians can employ smartphone applications with confidence to measure shoulder ROM and to calculate UCLA and CM scores. The apps are also available to patients and may be a useful adjunct to physiotherapy, especially in cases of limited access to health care services.

Accurate and reliable measurement of shoulder range of motion (ROM) is integral to the physical examination and functional evaluation of a pathologic shoulder. A universal goniometer (UG) is considered the "gold standard" for measuring shoulder ROM[1]; however, visual estimation is common in clinical practice as it is more time efficient, and a goniometer is often not available.[2,26,28] Other methods for measuring shoulder ROM include digital inclinometry, digital motion capture, and high-speed cinematography, but these require expensive, specialized equipment with limited availability.[9,10,13,16,24,28]

Smartphone applications (apps) have recently been proposed as an alternative method of measuring pathologic shoulder ROM.[15,21,22,26,29] Apps rely on an internal smartphone inclinometer[26] or a photographic virtual goniometer[21] to measure ROM. Several studies have demonstrated joint ROM measured with apps to be reliable and accurate compared with traditional methods,[7,14,15,19,21,23,25,26,29] but studies performed on the shoulder were limited by inclusion of only participants with no joint disease (for whom they have the most potential clinical application). In addition, no shoulder study considered the impact that ROM variability may have on shoulder scores with an objective ROM component.

The Constant-Murley (CM) score[5] and the University of California–Los Angeles[11] (UCLA) shoulder score are commonly used shoulder assessment tools that evaluate level of function and efficacy of

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surgical interventions and observe clinical change over time. These shoulder patient-reported outcome measures have the advantage over other scoring systems of including subjective patient-derived inputs as well as objective clinician-derived inputs, allowing a more balanced interpretation of shoulder function.[5]

Shoulder scores enhance communication during the physician-patient consultation[6,8] and aid in clinical decision-making. As shoulder ROM is an important component of these scores, measurements must be accurate and reliable for the scores to be of clinical use.

Apps have been shown to be accurate and reliable in measuring ROM in normal shoulders; however, their use in the pathologic shoulder is yet to be assessed. The authors hypothesized that smartphone ROM apps will provide accurate and reliable measurements when tested on pathologic shoulders.

Materials and methods

Patients were recruited from the outpatient department of 2 tertiary orthopedic units between February 2015 and February 2016. Inclusion criteria were being English speaking, older than 18 years, and willing to provide informed consent and having a documented current shoulder disease. Patients were excluded if they had cognitive impairment or were unable to follow the assessor's instructions. In cases of bilateral shoulder disease, both shoulders were assessed independently and included.

One iPhone (Model 5S) was used in the study and the software not updated during data collection. Two iPhone apps were used to measure shoulder range of movement (ROM): GetMyROM (version 1.0.3; Interactive Medical Productions, Hampton, NH, USA), an inclinometry-based app (Fig. 1, *A*); and DrGoniometer (version 1.2; CDM S.r.L, Milano, Italy), a photo capture–based application (Fig. 1, *B*). Visual ROM estimates were recorded for each subject, as were measurements made using a standard, manual goniometer as a control. A questionnaire recorded the subjective and functional questions of the UCLA and CM shoulder scores.

All participants were assessed with exposed shoulders. Two medical practitioner observers with experience in musculoskeletal disease collected the data independently with an assistant. Participants initially sat upright and straight on a fixed chair to stabilize the spine. In this position, the following measurements were observed: active forward flexion (Fig. 2, *A*), total abduction, active glenohumeral abduction (Fig. 2, *B*), and passive glenohumeral abduction. To assess glenohumeral joint abduction, the participants were asked to abduct the arm while the examiner stabilized the scapular. Commencement of scapula rotation was used to determine the limit of glenohumeral joint movement.

Rotation of the shoulder was measured with participants supine on a standard examination table. The shoulder was positioned in 90° of abduction with 90° of flexion at the elbow. With the forearm in neutral rotation and the proximal two-thirds of the humerus supported by the table, measurements were taken for active (Fig. 2, *C*) and passive external rotation and active (Fig. 2, *D*) and passive internal rotation. If shoulder disease prevented the participant from abducting the shoulder to 90°, supine external rotation was measured with the elbow in contact with the side of the body (0° abduction), and internal rotation measures were not recorded. With all ROM tests, care was taken to avoid compensatory movements, such as elbow extension or scapular elevation, and if these were observed, the measurement was repeated.

Shoulder ROM was first assessed using the smartphone inclinometer attached to the participant with a DualFit Armband (Belkin; Playa Vista, CA, USA). The armband was attached to the distal portion of the humerus for seated movements, then repositioned to the wrist for measurements performed with the participant supine. The inclinometer was positioned with the screen facing away from the observer. The assistant read and recorded the ROM value with the observer blinded to the reading. Next, the observer captured

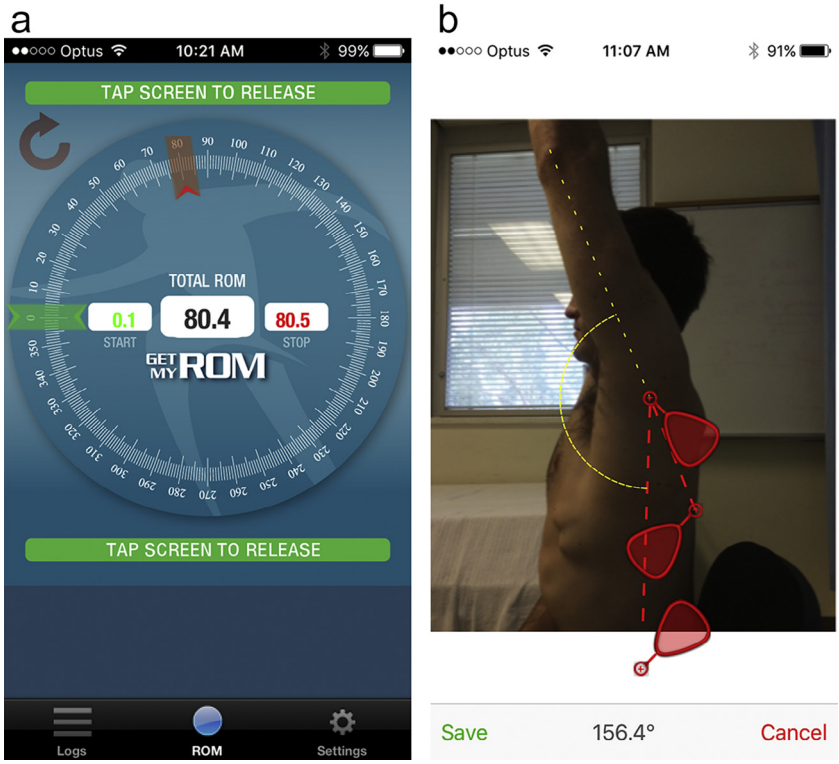

Figure 1 The iPhone applications. (**A**) GetMyROM. (**B**) DrGoniometer.