INTRODUCTION: The shoulder is the most mobile joint in the human body. Restriction of shoulder girdle motion can lead to serious functional impairment. The internal-external rotation component of shoulder motion is often impaired by traumatic injury and is related to chronic instability. Clinical assessments of internal and external rotation in abduction suffer poor intra- and inter-rater reproducibility [1, 2], perhaps, in part, because they are not conducted under known load. Before progress can be made in understanding the role of internal-external rotation in instability and in surgical and rehabilitation outcomes, a reliable technique is needed to accurately and non-invasively assess rotational range of motion (ROM) and flexibility in vivo. We have been developing such a method, which focuses on rotational laxity in response to controlled torque application, and we hypothesized that in normal subjects, these parameters would be relatively invariant over three testing periods.

METHODS: Twelve (6 male, 6 female) subjects with no history of shoulder surgery were recruited for the study (Age: 24.7 ± 4.8, Body Mass Index: 25.2 ± 4.4 kg/m²). For analysis, each shoulder was considered independently. Clinical assessment of function was documented using the American Shoulder and Elbow Surgeons (ASES) form [4]. Each subject was tested during three separate sessions. During each test session, the system was configured, applied, evaluated, and then removed. After a brief warm up, electromagnetic position sensors (MiniBIRD 800, Ascension, Milton, VT) were secured to the skin above the spinal column (C7/T1), the lateral aspect of the scapular spine, and the distal humerus. Subjects were seated in the beach chair position and their back and shoulders were supported with a vacuum pack (Olympic Medical, Seattle, WA) and strapping. The arm was held in a position of approximately 55-60° of abduction in the scapular plane. Digitization with the subject in neutral position referenced the electromagnetic position sensors to the bony anatomy. The proximal end of the humerus was located by the center of rotation method [5]. The arm was secured in a custom-molded thermoplastic brace with the elbow at 90°. The brace interfaced with a 6 DOF load cell (ATI, Apex, NC) through which a couple was applied to induce maximum internal rotation followed by maximum external rotation. An additional motion tracker recorded the position and orientation of the load cell throughout testing. During analysis, force and torque components were transformed into the local (moving) coordinate axis of the humerus. Four repetitions of internal-external rotation were completed under prescribed torque at each session. The Euler angle sequence describing glenohumeral joint motions followed the standard set by the International Shoulder Group [6]. Range of motion was defined as the rotation occurring between 4 Nm of internal rotation moment and 4 Nm of external rotation moment [3]. Flexibility was computed as the slope of the curve between 1 and 4 Nm. Flexibility and ROM were compared across trials using repeated-measures ANOVA.

RESULTS: Across all trials of all arms the mean ROM was 194.2 ± 22.7°. Mean internal rotation flexibility was 14.3 ± 4.5 °/Nm, whereas external rotation flexibility was slightly higher (18.6 ± 11.1 °/Nm). (r² >0.8 for all regressions) A typical series of test curves is shown in Fig. 1. Variation in the defined ROM over three trials on average was reproducible to within 13.4% (± 5.2%) or 26.0°. This ranged from 3.7% to 23.5% of the total range of motion. No statistically significant difference was detected among the three trials in ROM (p = 0.74), internal rotation flexibility (p = 0.91) or external rotation flexibility (p=0.86).

DISCUSSION: Some of the internal-external rotation ROM measured was facilitated by scapulo-thoracic motion, which did occur. In a previous study at our institution, an attempt was made to evaluate torque-rotation response strictly at the glenohumeral joint by immobilizing the shoulder girdle and measuring humeral rotation with similar electromagnetic position sensors [3]. This approach produced ROM data over three trials that were, on average, reproducible to within 24.7% (± 19.6%). The lower value of 13.4% found in the current study (variability of both internal and external flexibility data was likewise lower than with the previous protocol) underscores the importance of monitoring the position and orientation of the entire shoulder complex in combination with the humerus when measuring internal-external rotation biomechanics.

Loss of internal or external rotation can lead to negative functional consequences. Optimization of shoulder joint surgical procedures and rehabilitative protocols has been thwarted by the lack of quantitative outcome measures. A reproducible method of quantitatively shoulder joint function will allow comparisons to be made between patients and normal subjects. Rehabilitation progress can also be monitored with such a technique. Clinically, ROM is measured with a goniometer. External rotation of the shoulder from neutral, for example, has only intertester reliability and varies ± 11.7° when measured and remeasured in the same individual with a goniometer [1]. Flexibility cannot be measured at all with a goniometer. The question remains as to how much of a change in rotational ROM is clinically significant. Our study has revealed that changes in ROM less than 13.4% between visits cannot be determined reliably.

All subjects were right-handed. Dominant arm results did not differ from non-dominant. As previous biomechanical studies of other joints have shown, females had greater ROM than males.

In using electromagnetic motion tracking devices, the assumption is made that the motion measured at the skin is an acceptable surrogate for the rigid body motions of the underlying bone. A requisite next step for future studies will involve comparison of results obtained using this method to those obtained simultaneously using uniplanar radiostereometric analysis in vivo.


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