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Upper limb kinematics after arthroscopic and open shoulder stabilization

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Background: Shoulder joint stability mediated by proprioception is often quantified by arm repositioning tests (i.e., static end-position accuracy), overlooking ongoing movement quality. This study assessed movement quality by adopting smoothness-related kinematic descriptors. We compared performance of healthy controls with that of patients in arthroscopic shoulder stabilization and open shoulder stabilization groups. We hypothesized that arm kinematics after arthroscopic intervention would more closely resemble healthy movements compared with patients after open shoulder stabilization surgery.
Methods: Healthy controls (N = 14) were compared with patients after arthroscopic shoulder stabilization (N = 10) and open shoulder stabilization (N = 12). Right-hand dominant subjects (the affected side in patients) performed 135 unconstrained 3-dimensional pointing movements toward visual targets (seen through pinhole goggles; i.e., no arm vision). Arm kinematic data were recorded and offline analyzed to obtain hand tangential velocity profiles further used to compute the acceleration-to-movement time ratio, peak-to-mean velocity ratio, and number of velocity peaks (“symmetry,” “proportion,” and “fragmentation” features, respectively). Parametric and nonparametric statistics were used for comparisons ($P \leq .05$).
Results: Control and arthroscopic shoulder stabilization groups presented similar acceleration-to-movement time ratio and peak-to-mean velocity ratio. Both groups differed from the open shoulder stabilization group ($P = .001$). Distributions of velocity peaks for control and arthroscopic shoulder stabilization groups were similar, whereas open shoulder stabilization and control subjects differed significantly ($P = .028$).
Conclusions: Movement quality mediated by proprioception in arthroscopic shoulder stabilization patients matches that of healthy controls, whereas performance in open shoulder stabilization patients seems inferior compared with that in healthy controls, as assessed by smoothness-related measures (less symmetrical, more fragmented movements).
Level of evidence: Basic Science, Kinesiology.

Keywords: Arm kinematics; shoulder stabilization; arthroscopic Bankart repair; open capsular shift

The study was conducted at the Sheba Medical Center, Tel Hashomer, Israel, and approved by the Sheba Medical Center’s Institutional Review Board–Israeli Ministry of Health (study reg. number SHEBA-09-7068-AO-CTIL; ClinicalTrials.gov identifier NCT00889109).

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The glenohumeral joint (GHJ) is inherently unstable and depends on complex interaction of static capsuloligamentous and dynamic tendinomuscular stabilizers to maintain its stability.[12,21,27] A reflexive feedback mechanism between afferent mechanoreceptors in the shoulder capsuloligamentous complex and the muscles surrounding the joint is believed to be responsible for the GHJ position sense (i.e., kinesthetic information conveyed through proprioception). Such a mechanism plays a substantive role in maintaining shoulder stability.[10,15,18,23] It has been shown that disruption of the shoulder capsuloligamentous complex after traumatic dislocation has a detrimental effect on proprioception,[4,22] which may recover after surgical restoration of the normal GHJ capsular tensioning.[25,29] Whereas open shoulder stabilization has been traditionally performed for this purpose, arthroscopic techniques for capsulolabral reconstruction gained popularity during the past decade with comparable clinical outcomes.[8,9]

Recovery of proprioception after different procedures of shoulder stabilization has been assessed in previous studies with static measures of accuracy at the end of the movement.[2,5,10,21,23,25,26] However, the quality of the ongoing movement has been overlooked and this motivated our investigation. In addition, baseline values for comparison in previous studies were obtained from the unaffected arm (regardless of hand dominance), which was later compared with the operated arm. It should be noted that bilateral comparisons may lead to inaccurate conclusions because the dominant and nondominant arms differ in terms of motor performance, haptic sense and nociception.[3,13,28]

Empirical observations in healthy humans show that upper limb movements from one location to another are characterized by the intention to move the hand as smooth as possible by imposing on the arm a "minimum-jerk constraint."[11] Maximally smoothed arm movements show symmetrical bell-shaped, unimodal (i.e., one peak) tangential velocity profiles with an acceleration phase during 50% of the movement time followed by a deceleration phase in the remaining 50% (Fig. 1).[1,2,11] Empirical validation for the use of a minimum-jerk constraint is reported for horizontal point-to-point hand movements[11,24] as well as for curved movements in 2 dimensions[19] and 3 dimensions.[6,7]

The same evidence that supports the assumption that accuracy at the end of the movement is affected by proprioceptive feedback[5,10,21,23,25,26] justifies our assumption that movement smoothness is under control of proprioception, particularly when vision of the arm is occluded. Therefore, the parameters of arm motion smoothness in the current study may serve as clinical markers of deterioration of proprioceptive feedback.

Our goal was to evaluate the movement quality of the dominant arm in patients after arthroscopic and open shoulder stabilization compared with healthy age-matched controls. We used smoothness-related variables (temporal kinematics) to compare between groups and hypothesized that arm motion smoothness after arthroscopic shoulder stabilization would more closely resemble that of healthy subjects compared with patients after open surgery.

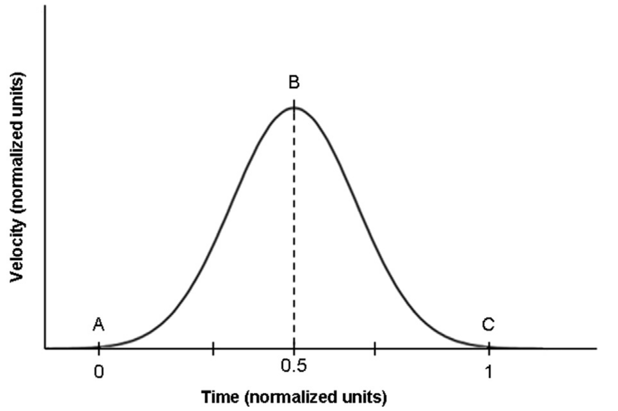

Figure 1 Bell-shaped velocity profile of the arm derived from a maximal smoothness model as expected in healthy individuals. The model predicts a profile that starts and ends at a zero velocity level. It is characterized by a single peak (i.e., it is unimodal) at 50% of the movement time, whereas the durations for the acceleration and deceleration phases are equal (i.e., the profile is symmetrical). *A*, movement start; *AB*, acceleration phase; *B*, peak velocity; *BC*, deceleration phase; *C*, movement end; *AC*, total movement; time.

Materials and methods

Experimental design, participants, and procedures

A between-subjects experimental design was used in which 3 levels of the group factor were compared (controls, arthroscopic, and open surgery).

Subjects were selected from a cohort of 276 patients who underwent anterior shoulder stabilization between 2003 and 2008 (134 patients underwent open stabilization and 142 patients arthroscopic stabilization). Surgical procedures were performed by 1 of 2 senior shoulder surgeons (A.O. and M.P.), who decided which procedure to perform on an individual basis, considering the specific shoulder disease and the patient's lifestyle and expectations. Patients with basic shoulder pathologic processes leading to instability (e.g., an isolated anterior-inferior lesion) and less demanding lifestyle were routinely treated in our institution with arthroscopic stabilization, whereas patients with more complex pathologic processes (e.g., revisions, joint hyperlaxity, glenohumeral ligaments avulsion) and high physical demand (e.g., regular involvement in contact sports, manual workers) were routinely treated with open surgery. Both interventions included anterior-inferior labrum repair with suture anchors and anterior-inferior glenoid-sided capsular shift. The open approach involved complete detachment (and later repair) of the subscapularis tendon from its lesser tuberosity insertion. For the purpose of the study, to match patients' characteristics of both surgical groups, we excluded patients who underwent open surgery because of the nature of their disease, and included only those who underwent