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Movement control in patients with shoulder instability: a comparison between patients after open surgery and nonoperated patients

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Background: Open surgery to correct shoulder instability is deemed to facilitate recovery of static and dynamic motor functions. Postoperative assessments focus primarily on static outcomes (e.g., repositioning accuracy). We introduce kinematic measures of arm smoothness to assess shoulder patients after open surgery and compare them with nonoperated patients. Performance among both groups of patients was hypothesized to differ. Postsurgery patients were expected to match healthy controls.

Methods: All participants performed pointing movements with the affected/dominant arm fully extended at fast, preferred, and slow speeds (36 trials per subject). Kinematic data were collected (100 Hz, 3 seconds), and mixed-design analyses of variance (group, speed) were performed with movement time, movement amplitude, acceleration time, and model-observed similarities as dependent variables. Nonparametric tests were performed for number of velocity peaks.

Results: Nonoperated and postsurgery patients showed similarities at preferred and faster movement speeds but not at slower speed. Postsurgery patients were closer to maximally smoothed motion and differed from healthy controls mainly during slow arm movements (closer to maximal smoothness, larger movement amplitude, shorter movement time, and lower number of peaks; i.e., less movement fragmentation).

Conclusions: Arm kinematic analyses suggest that open surgery stabilizes the shoulder but does not necessarily restore normal movement quality. Patients with recurrent anterior shoulder instability (RASI) seem to implement a ''safe'' but nonadaptive mode of action whereby preplanned stereotypical movements may be executed without depending on feedback. Rehabilitation of RASI patients should focus on restoring feedback-based movement control. Clinical assessment of RASI patients should include higher order kinematic descriptors.

The study was conducted at the Movement Science Lab, Physical Therapy Department, University of Tel Aviv and the Sheba Medical Center, Tel Hashomer, Israel. It was approved by the Sheba Medical Center's Institutional Review Board, Israeli Ministry of Health (Approval Number 3-690183, Catalog Number 4062200811).

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Shoulder instability is the most common cause of joint dislocation in humans,[17] and 66.8% of all patients suffering from anterior shoulder dislocation will eventually develop recurrent anterior shoulder instability (RASI).[39] Because this is most prevalent in young adults (second to fourth decade of life), it has a significant impact on the quality of daily living, mainly in occupational and recreational activities.[11] Diagnosis of an unstable shoulder often relies on a patient's history and on physical examination.[42] The best diagnostic results have been reported with the apprehension and relocation tests, which have a sensitivity of 72% and 81%, and a specificity of 96% and 92%, respectively; other physical examinations and maneuvers have proved less accurate.[13]

First treatment procedures of RASI are commonly nonsurgical; failure of conventional physical therapy is eventually followed by surgical intervention. Open surgery has proved reliable in stabilizing the joint.[3,34] In terms of failure rate, open surgery is not significantly different from less invasive techniques,[7,8,12] but it may expose the shoulder to higher risks of structural damage, in particular damage to structures related to the kinesthetic sense in the capsule, labrum, ligaments, and muscles.[25,36] More specifically, open surgery may disrupt the sensory activity conveyed by Golgi, Ruffini, and Pacini corpuscles as well as free nerve endings, all of which provide information about joint position and muscle tension during ongoing movements.[9,16,33] Thus, whereas open shoulder surgery may be effective in stabilizing the joint, it may cause deterioration in the control of an ongoing movement and in reproducing static positioning accuracy of the arm at the end of the movement.[1,6,23,35] Yet, some authors argue otherwise and claim that shoulder surgery actually enhances the sense of arm positioning and motion by reactivating latent or uninjured neural structures underlying kinesthesia.[24,48] To explore this controversy, the current study includes measures of arm kinematics in two groups of patients with RASI. One subgroup of patients was not yet assigned to undergo surgical intervention, although patients showed signs of potential dislocation,[37] failure to use afferent feedback, and muscle weakness.[2,21,22,47] This nonoperated group was assigned to undergo conventional physical therapy for at least 3 months before a decision was made about surgical treatment. The second subgroup of patients was assigned to open surgical intervention as a last resource to stabilize the joint. All RASI patients were tested after recovering from treatment (surgery or a 3-month rehabilitation period) and compared with age-matched active controls who had no history of shoulder disease. Selected kinematic parameters were computed to describe and to compare shoulder motion during 3-dimensional point-to-point arm movements in the different groups.

We introduced a model-based approach whose validation comes from mathematical proof. A major assumption of the proposed model is that the motor system tends to optimize movement. In the current study, maximal smoothness is assumed as the optimization constraint. In line with this approach, we assess how close subjects are (healthy or RASI patients) to scores defined by model-based kinematic parameters. Comparisons are thus in terms of ''optimal'' values and not in terms of ''normal population'' values. A second assumption that stems from a model-based approach is that arm movements are planned for the entire path, from the start to the end of the movement before execution. The system only accesses the plan and activates it in a feedforward manner. Thus, online feedback is not critical for performance, in particular during fast movements.

We hypothesized that patients who did not undergo surgical intervention and were assigned to conventional physical therapy would fail to use intrinsic feedback. It was expected that such patients would use stereotyped slower movements to avoid joint pain. Failure to use feedback would be manifested as differences in the arm movement quality compared with healthy controls.

In addition, we hypothesized that open surgery patients would not significantly differ from healthy controls; that is, they were expected to move in an unconstrained manner, presenting arm kinematic features comparable to those observed in healthy subjects.

Throughout the study, it is assumed that under the constraints of the minimum jerk model,[14] linear motion of the elbow marker relative to the marker fixated on the acromion would correlate with the rotational motion of the shoulder joint. Smoothed arm motion in patients was assumed to reflect the intention to avoid sudden torques, unnecessary internal friction, and shoulder pain.

Materials and methods

Experimental design, participants, and procedures

This is a retrospective case-control study in which 14 healthy controls, 11 patients with RASI who had not been operated on, and 13 patients after open surgery volunteered to perform a series of point-to-point movements with the dominant/affected arm. A mixed experimental design was used to compare different