Open and Closed Kinetic Chain Exercises Improve Shoulder Joint Reposition Sense Equally in Healthy Subjects

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Abstract:

Objective: To compare the effects of open and closed kinetic chain exercise on shoulder joint reposition sense.

Design and Setting: Subjects with no previous upper extremity injury participated in a 6-week exercise program consisting of 3 sessions per week.

Subjects: Thirty-nine healthy male military cadets: 13 each in the open, closed, and control groups.

Measurements: Each subject was pretested and posttested for both active and passive joint reposition sense at 30° external rotation, 30° internal rotation, and 10° from full external rotation.

Results: The open and closed kinetic chain groups decreased in reposition sense error scores in comparison with the control group, but no difference was found between the 2 training groups.

Conclusion: Our findings suggest that shoulder joint reposition sense can be enhanced with training in healthy subjects. Also, open and closed kinetic chain exercises appear to be equally effective in improving shoulder joint reposition sense.

Key Words: proprioception, glenohumeral, strength

Article:

Proprioception, the combined functions of joint position sense and kinesthesia, has been identified as an important aspect of athletic injury rehabilitation.[1-6] Joint injury can affect proprioception, disrupting the normal neuromuscular reflexes that serve to protect the joint. Much of the early proprioceptive research focused on ankle and knee instability and produced recommendations on how to treat these proprioceptive deficits.[3,4,7-11] As such, proprioceptive exercises are commonly prescribed for rehabilitation from lower extremity injury.

More recently, shoulder proprioception has gained attention, especially in instability of the shoulder. Smith and Brunolli[12] demonstrated that subjects with anterior shoulder instability performed more poorly on joint reposition sense testing with the involved shoulder than the uninvolved shoulder. Lephart et al[5] also found proprioceptive deficits in unstable shoulders. After surgical reconstruction, shoulder proprioception returned to the same level as that of the uninvolved side.[5]

Proprioceptive exercises have been recommended to improve neuromuscular control in individuals with shoulder instability.[5,13-I5] Proprioceptive training may improve the musculoskeletal system's ability to give appropriate feedback to the central nervous system, optimizing joint stability and function. Proprioceptive rehabilitation also enhances cognitive awareness relative to position, motion, and muscular stabilization in the absence of structural restraints. Additional research is needed to determine what types of exercise are optimal for enhancement of shoulder joint proprioception.

Shoulder rehabilitation exercises have been classified as open or closed kinetic chain. In open kinetic chain (OKC) exercise, the terminal segment of the extremity moves freely without any external resistance.[16] The sequential activation of muscles in OKC exercise from proximal to distal allows rapid acceleration and speed of the distal segment.[13,16,17] Because the upper extremity often functions in an OKC position, this type of exercise is frequently used in rehabilitation settings. In closed kinetic chain (CKC) exercise, the distal segment of the extremity is fixed, and proximal motion takes place in multiple planes.[13,16] Closed kinetic chain exercise is thought to establish early proximal stability of the joint, providing a stable base for the upper extremity to function.[13] Furthermore, CKC exercise may train the shoulder girdle musculature to appreciate its own static and dynamic functions.[13] A shortfall of CKC exercise is that minimal acceleration of the distal extremity is allowed, and this is a key component of upper extremity athletic performance.

Recent reports in the literature have recommended various exercise programs to enhance proprioceptive reposition sense.I3.18-20 The purpose of our study was to compare the effects of OKC versus CKC exercises on joint reposition sense of the shoulder in adolescent athletes.

METHODS

Subjects

The dominant, injury-free shoulder of 39 volunteer male cadets (age = 16.31 ± 1.54 years; ht = 177.47 ± 4.2 cm; and wt = 78.70 ± 17.42 kg) was studied. The subjects participated in multiple sports at a military academy but engaged in no active weight training during the study. There was no change in routine activities, including military duties, except for the exercise protocol. We randomly assigned the subjects in equal numbers to 3 groups (n = 13). Subjects in group 1 performed an OKC exercise, while subjects in group 2 participated in a CKC exercise. Subjects in group 3, the control group, did no upper extremity exercise for the duration of the study. None of the subjects were familiar with the testing protocol or the testing device. The University of Virginia Committee for the Protection of Human Subjects approved the study, and each subject and his parent or guardian signed a statement of informed consent before participation.

Instrumentation

We used a Cybex II isokinetic dynamometer (Lumex, Ronkonkoma, NY) to assess passive and active shoulder joint reposition sense at 30° of internal rotation, 30° of external rotation, and 10° from full external rotation (active range of motion). Subjects were positioned supine on the Upper Body Exercise Table (Lumex, Ronkonkoma, NY) during testing. Two bathroom scales (model 1706, Healthometer, Saint Louis Park, MN) were used to determine the criterion weight for the OKC exercise group. A flexometer (model 67010, Leighton, Spokane, WA) was attached to the arm of the Cybex to determine the angle of shoulder rotation (Figure 1).

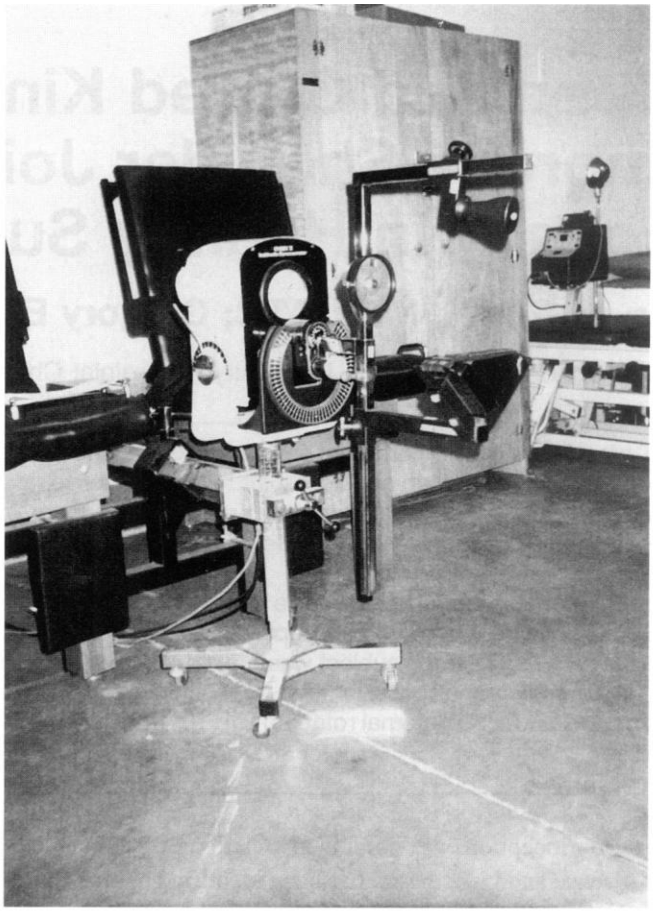

Figure 1. A flexometer was attached to the arm of the Cybex to determine the angle of shoulder rotation.

Assessment of Joint Proprioception

Before the training program began, we pretested all subjects for active and passive joint reposition sense. We positioned the subjects supine on the Upper Body Exercise Table with the shoulder joint axis aligned with the axis of rotation of the Cybex. Each subject's upper extremity was placed in 90° of elbow flexion, 90° of shoulder abduction, and neutral rotation. We applied an elastic wrap to each subject's hand to minimize tactile sensation from the lever arm of the Cybex. The orders of the active and passive testing and the angles of reproduction were counterbalanced. For the passive joint reposition test, we instructed subjects to relax while the shoulder was moved by the experimenter to one of the 3 predetermined angles and held for a total of 10 seconds. Once the shoulder was returned to the neutral position, the subject's shoulder was passively repositioned to the test position. We instructed the subjects to say "stop" when they sensed the test position was replicated. The angle at which this occurred was recorded and subtracted from the initial, predetermined angle. This difference was termed the "error." The examiner performed all passive movements at the speed of $6°\bullet sec^{-1}$, as measured by the Cybex II dynamometer. The procedure was repeated twice at the same angle, and an average of the absolute value of the 3 errors was used for statistical analysis. The remaining 2 angles were tested in the same manner. Active testing was performed using the same methods, except each subject actively moved the shoulder to the predetermined test angle with our guidance, then returned to the neutral position before attempting to actively replicate the angle. After 6 weeks of training, subjects were posttested in an identical manner.

Exercise Protocol

Subjects participated in the training program for 6 weeks. The subjects assigned to the CKC training group performed 3 sets of 15 repetitions of standard push-ups 3 days per week. The subjects in the OKC group performed 3 sets of 15 repetitions of the supine dumbbell press 3 days per week. To determine the criterion weight, we asked each subject to assume the up and down push-up position with each hand on identical bathroom scales. The average weight of the up and down push-up position was defined as the criterion or training weight (mean = 26.6 ± 6.55 kg). While the 2 exercises (dumbbell press and push-up) are somewhat different, we attempted to equate them by a criterion weight. The amount of weight lifted for the OKC group was 75% of the criterion weight for the first 2 weeks (mean = 20.6 ± 5.03 kg), 85% of the criterion for weeks 2 through 4 (mean = 23.3 ± 5.66 kg), and 95% the final 2 weeks (mean = 25.9 ± 5.98 kg). The control group performed no upper extremity exercises.

Mean Absolute Error Scores (degrees) ± Standard Deviations for Pretest and Posttest Joint Position Sense

	30° IR*		30° ER†		10° from Full ER	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
OKC‡	5.41 ± 1.43	2.12 ± .88	5.66 ± 2.18	1.88 ± .82	6.63 ± 2.19	2.04 ± .87
CKC§	5.27 ± 1.86	2.18 ± 1.36	5.90 ± 2.83	2.83 ± 2.83	6.71 ± 3.09	2.60 ± 1.80
Control	4.69 ± 1.55	5.11 ± 1.75	6.38 ± 4.57	5.57 ± 2.54	6.04 ± 2.97	6.59 ± 3.67

* IR, internal rotation.
† ER, external rotation.
‡ OKC, open kinetic chain.
§ CKC, closed kinetic chain.

Data Analysis

The average error scores were analyzed with a mixed-model analysis of variance (ANOVA) with type of training (OKC, CKC, control) as the between-subjects variable and test (pretest versus posttest), angle (30° internal rotation, 30° external rotation, or 10° from full external rotation), and motion (active versus passive) as the within-subjects variables. Tukey post hoc analyses were performed for significant effects. An α level of $P < .05$ was used for all statistical analyses.

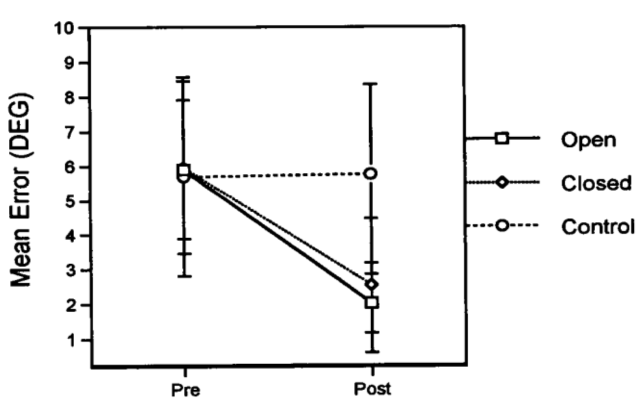

Figure 2. Both the open and closed kinetic chain groups showed significant decreases in mean error score from pretest to posttest.

RESULTS

The mean error scores obtained for each angle tested are listed in the Table. The ANOVA revealed a significant group-by-test interaction ($F_{2,36} = 29.29$, $P < .001$) (Figure 2). A Tukey post hoc analysis revealed that both the CKC and OKC groups showed significant decreases in mean error score from pretest to posttest in comparison with the control group, which did not show pretest to posttest changes. There was no significant difference between the 2 exercise groups.

A main effect for joint angle was also found ($F_{2,72} = 8.21$, $P < .001$). Ten degrees from full external rotation and 30° internal rotation had significantly less mean error than 30° external rotation. There was no difference between 10° from full external rotation and 30° internal rotation. No main effect ($F_{1,36} = 0.34$, $P = .56$) was found for active versus passive range of motion.

DISCUSSION

The primary finding of our study was that the OKC and CKC exercise groups had significantly improved joint reposition sense from pretests to posttests when compared with the control group. The exercise groups were better able to reproduce angles and had a better awareness of the location of their upper extremity in space in comparison with the control group. This finding is for our subjects who participated in multiple sports at a military institute and cannot necessarily be generalized to all 16-year-old males.

Previous investigators have explored the adaptive effect of upper extremity and lower extremity activity on proprioception. [1,8] Allegrucci et al[1] found that athletes who participated in unilateral upper extremity sports had greater difficulty detecting motion in the dominant shoulder when compared with the nondominant shoulder. Barrack et a1[8] found that members of a professional ballet company scored more poorly than controls in joint reposition testing of the knee. These authors theorized that decreased proprioceptive sense was due to joint hypermobility in the 2 subject populations. The effect of a specific training regime designed to correct these proprioceptive deficits was not assessed.

In contrast to Allegrucci et al[1]and Barrack et a1,[8] another study found that trained athletes may have heightened proprioceptive awareness.[21] Lephart et a1[21] demonstrated that gymnasts had a better threshold to detection of knee motion than nonathletic controls.[21] These investigators also reported that training may refine proprioceptive awareness in athletes with ligament injury and diminished proprioception.[21] However, further research is needed in this area.

It is not surprising that highly trained athletes (without joint hypermobility) have better joint reposition sense than nonathletes. We were impressed that performing only 1 resistance exercise 3 days a week for 6 weeks made a difference in joint reposition sense in uninjured individuals. Moreover, the exercises used in our study were not specifically designed to train the proprioceptive system, as opposed to the exercises used in other studies.[2,18]

The mechanism for the improvement of shoulder joint reposition sense in our study is most likely related to the additional stimulation of the joint and muscle receptors brought about by the resistance exercise. How these receptors and the corresponding afferent-efferent loops adapt to bring about these improvements in proprioception is not entirely clear. Receptors responsible for detecting joint position include the Pacinian corpuscles and Ruffini end-organs found in the joint capsule and the Golgi tendon organs and muscle spindles found in the muscle. All these receptors are sensitive to changes in tension within the muscle (Golgi tendon organs and spindles) or noncontractile tissues (Pacinian corpuscles and Ruffini end-organs).

Voight et a1[22] assessed joint reposition sense in uninjured subjects before and after a shoulder-fatigue protocol. They found significantly greater error in both active and passive reposition testing immediately after strenuous exercise to fatigue when compared with the pretest. These authors emphasized the importance of the muscle receptors in the detection of joint position sense.

Gandevia and McCloskey[23] attempted to isolate the contributions of the joint and muscle receptors to position sense. With the distal interphalangeal joint anesthetized, the ability to detect motion, although altered, was still intact.[23] Thus, it is likely that a combination of both joint and muscle receptors is responsible for joint proprioception.

The relative importance of each type of receptor may be related to the particular position in which the joint is placed.[9] In the midrange of joint motion, movement results in significant length changes in the muscle, but the tension in the joint capsule increases relatively little.[9] However, in the endrange of motion, small changes in joint motion are accompanied by large increases in capsule tension that are easily detected by the joint receptors.[9] In these endranges of motion, there may be only a small amount of change in muscle length, resulting in relatively little stimulation of the muscle mechanoreceptors. In our study, the 30° internal rotation position had a significantly smaller error with reposition testing, along with 10° from full external rotation. These findings are supported by Blasier et a1,[24] who found the least error in the externally rotated position and theorized that it was due to the increased tautness of the joint capsule. The joint capsule is also taut when moving into internal rotation. It may be that the muscle receptors are just as important as the capsule receptors in controlling joint reposition sense; however, one cannot credit the training sessions, since the difference between the joint angles was a main effect and thus included scores from pretests and posttests.

The clinical implications of our findings are that both OKC and CKC resistance exercise improved joint reposition sense in healthy subjects. A strengthening program designed to improve neuromuscular control may also be of benefit to individuals with shoulder proprioceptive deficits. Further study using subjects with unstable shoulders is needed to confirm our clinical impressions.

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