

Strength Training and Shoulder Proprioception

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Context: Proprioception is essential to motor control and joint stability during daily and sport activities. Recent studies demonstrated that athletes have better joint position sense (JPS) when compared with controls matched for age, suggesting that physical training could have an effect on proprioception.

Objective: To evaluate the result of an 8-week strength-training program on shoulder JPS and to verify whether using training intensities that are the same or divergent for the shoulder's dynamic-stabilizer muscles promote different effects on JPS.

Design: Randomized controlled clinical trial.

Setting: We evaluated JPS in a research laboratory and conducted training in a gymnasium.

Patients or Other Participants: A total of 90 men, right handed and asymptomatic, with no history of any type of injury or shoulder instability.

Intervention(s): For 8 weeks, the participants performed the strength-training program 3 sessions per week. We used 4

exercises (bench press, lat pull down, shoulder press, and seated row), with 2 sets each.

Main Outcome Measure(s): We measured shoulder JPS acuity by calculating the absolute error.

Results: We found an interaction between group and time. To examine the interaction, we conducted two 1-way analyses of variance comparing groups at each time. The groups did not differ at pretraining; however, a difference among groups was noted posttraining.

Conclusions: Strength training using exercises at the same intensity produced an improvement in JPS compared with exercises of varying intensity, suggesting that the former resulted in improvements in the sensitivity of muscle spindles and, hence, better neuromuscular control in the shoulder.

Key Words: joint position sense, neuromuscular control, muscle spindles

Key Points

- Improvements in joint position sense can be attained via standard strength-training exercises.
- Performing resistance exercises at consistent intensity rather than varying intensity resulted in better proprioception performance.

Improving muscle strength for joint stability is a goal of physical training for the shoulder.^{1–3} According to Myers and Lephart,⁴ the rotator cuff, deltoid, biceps, teres major, latissimus dorsi, and pectoralis major muscles are responsible for providing shoulder stabilization. Inman et al⁵ were the first to state that the coactivation force of the shoulder's dynamic stabilizers provides the joint stability. However, joint mechanics and stability may be compromised if such forces are not equalized. Therefore, in order to achieve joint stability, training must be directed at attaining proportional strength around the joint. Two main aspects should be taken into account during strength training: a specific muscle-force level and the force balance among muscles that act on the same joint.^{3,6}

Shoulder-joint stability is the result of passive and dynamic components.⁷ The bone geometry, relative intra-articular pressure, glenohumeral labrum, and capsuloligamentous structures are passive components,⁴ whereas dynamic components are provided by contractile muscle activity coordinated around the joint and modulated by the neuromuscular system.⁸ The basis of passive and dynamic interactions is the proprioceptive information emerging from mechanoreceptors in muscles, tendons, joint-capsule ligaments, and skin, which are centrally integrated.^{7,9} In this

context, kinesthesia, joint position, and force sense are described as proprioception submodalities.^{4,10–12}

Proprioception is essential to motor control and joint stability during daily activities and sports practice.^{10,11} Thus, *proprioception* can be defined as the ability to recognize and to locate the body in relation to its position and orientation in space.^{13,14} Allegrucci et al¹⁵ identified kinesthetic deficits in the dominant shoulder of throwing athletes as a mechanism for shoulder instability. The same result was found by Safran et al.¹⁶ Conversely, a recent study¹⁷ demonstrated that athletes have better joint position sense (JPS) than controls matched for age, suggesting that sport activity could have an effect on proprioception. Despite this result, the effect of strength training on proprioception remains unclear, although some authors^{17–20} have described the effects of muscle strengthening on proprioception. These researchers hypothesized that strength training directly affects the functional capacity of the dynamic stabilizers. For this reason, it is important to understand the effects of this training on proprioception so that we can improve the strength-training protocols to increase joint stability.

However, the effects of different strength-training programs on the JPS of healthy individuals remain debatable. Therefore, the focus of our study was to (1)



Figure 1. Testing position.

evaluate the effect of 8 weeks of strength training on shoulder JPS and (2) verify whether using the same or divergent training intensities for the shoulder muscles' stability produced any significant effects on JPS. We hypothesized that the JPS would be improved by strength training and that different strategies to control training intensity would promote different responses with regard to shoulder proprioception.

METHODS

Sample

This study was conducted according to recommendations from the Research Ethics Committee (Registration No. 23875C). A total of 90 male undergraduates (age = 20.8 ± 1.42 years, height = 177.2 ± 5.60 cm, weight = 72.6 ± 7.14 kg) were recruited for this study. They were randomly distributed in 3 groups: group 1 performed exercises at the same intensity, group 2 performed exercises at different intensities, and the control group performed no upper body exercise. All participants were right handed²¹ and asymptomatic, with no history of injury or shoulder instability. All participants signed an informed consent document before entering the study.

Experimental Procedures

Participants were instructed not to perform upper body strength exercises for 1 month before the training program. This procedure was adopted to reduce the influence of previous exercises on the study results. The test apparatus was constructed in our laboratory, as described previously,⁹ and shown to be reliable. We did not find a significant test-retest difference ($P = .820$). We applied the intraclass correlation coefficient (ICC) and verified an ICC of 0.71 and standard error of measurement of 1.29° . The accuracy of the angular measurements was $\pm 1^\circ$. Participants were in a seated position with the shoulder and elbow flexed (both to 90° ; Figure 1).

For 8 weeks, groups 1 and 2 attended the strength-training program 3 sessions per week (Monday, Wednes-

Table. Exercises and Intensities Used During 8 Weeks of Strength Training

Exercise	Intensity, Maximum Repetitions		
	Group 1	Group 2	Control
Bench press	8–9	8–9	NA
Lat pull down	8–9	12–13	NA
Shoulder press	8–9	8–9	NA
Seated row	8–9	12–13	NA

Abbreviation: NA, Not applicable.

day, Friday) at the same time and place. Four exercises (bench press, lat pull down, shoulder press, and seated row) were performed, with 2 sets each. We chose these exercises based on the American College of Sports Medicine's description²² of multiple-joint exercises that involve large muscular groups related to shoulder movement. The techniques were presented individually to each participant, and 1 expert (J.I.S.) supervised all training sessions. The intensity was individually adjusted according to the range of maximum repetitions (MR) (Table). The expert asked the participants to increase the load whenever possible to produce concentric failure within the range of the specified MR. It is well established that this training prescription model, based on MR ranges, is effective and safe for improving strength in healthy individuals.²² Group 1 performed the 4 exercises at the same high intensity (8–9 MR), whereas group 2 performed the exercises at divergent intensities: high intensity (8–9 MR) for the bench press and shoulder press and moderate intensity (12–13 MR) for the lat pull down and seated row. The control group did not perform upper body exercises during the study.

Measurement of JPS

We determined range of motion (ROM) for shoulder rotation by measuring the amplitude between the maximum internal (IR) and external (ER) rotation. The JPS was assessed by applying the joint-position reproduction test, with a target position at 50% of ROM. Rotation started at the initial position (IR or ER) and progressed to the target position, which the participant held for 5 seconds in order to be measured. Variations of $\pm 5^\circ$ around the target position were allowed. If this variation was exceeded, the trial was discarded and repeated. In sequence, participants were asked to reproduce the joint position previously experienced. Both movements were voluntary. Three trials for each movement direction (ER \rightarrow IR and IR \rightarrow ER) were conducted (total of 6 trials). Only the dominant arm was tested. The participants were blindfolded and given task instructions orally by the examiner. The JPS was measured twice, 1 day before starting the training program (pretraining) and 1 day after finishing the program (posttraining). Individual error for each trial was determined by the difference between the position reproduced and the position experienced. Proprioceptive acuity was determined by the absolute error (AE). The AE was calculated by averaging the individual errors in the module.

Statistical Analysis

The dependent variable of interest was the AE generated by the JPS trials. We computed average values for each condition in PASW (version 18.0; SPSS, IBM Corporation,

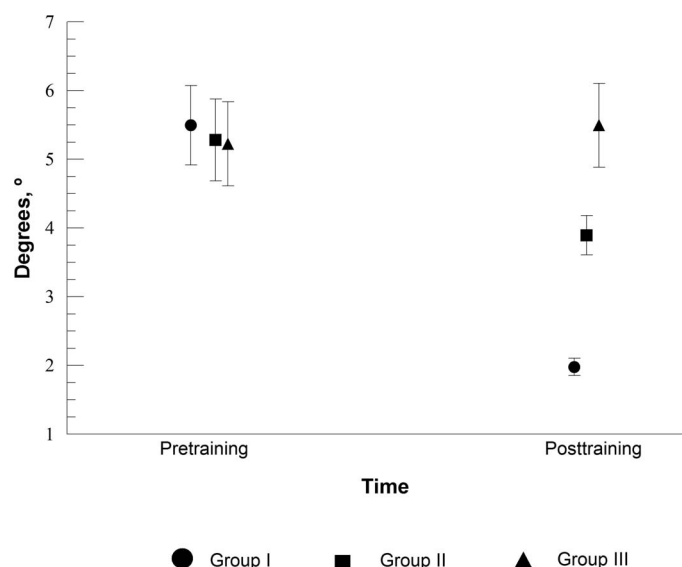


Figure 2. Absolute error values. Group 1: exercises performed with the same intensity; group 2: exercises performed with divergent intensities; control group: performed no upper body exercise. An interaction occurred between the factors of training group and time ($P < .05$).

Armonk, NY). The α level was initially set at $\leq .05$. The Shapiro-Wilk test demonstrated a normal distribution among variables. We used a 2-way repeated-measures analysis of variance (ANOVA) to compare groups (same intensity, divergent intensity, and control) and time (pretraining and posttraining).

RESULTS

Nine participants could not maintain the training protocol to the end and were excluded. Therefore, the participants per group were as follows: group 1, $n = 24$; group 2, $n = 27$; and control group, $n = 30$. We demonstrated an interaction between group and time ($F = 181.240$; $P < .001$). We also found mean effects for time ($F = 363.848$; $P < .001$) and group ($F = 133.539$; $P < .001$). At pretraining, there was no difference in JPS AE among groups, yet at posttraining, group 1 (same-intensity training) demonstrated less AE than group 2 (divergent-intensity training) and group 3 (control) did. Also, group 2 (divergent-intensity training) was different from the control group (Figure 2).

DISCUSSION

This study was aimed at shedding light on the effect of an 8-week strength-training program on shoulder JPS. Specifically, we investigated the results of 2 different training volume and intensity (same and divergent) strategies on the shoulder's dynamic-stabilizer muscles. Based on previous studies, we hypothesized that the JPS would be improved by strength training and that different training intensities would promote different responses with regard to shoulder proprioception. The main finding was an interaction between 2 factors, group and time. We also observed a main effect for both factors. To examine the interaction, we performed two 1-way ANOVAs to compare groups at each time. We did not find differences in AE among groups at

pretraining; therefore, the 3 independent samples represent the same population.

However, we determined that all groups were different at posttraining. Specifically, the control group maintained the same AE and did not improve proprioceptive acuity. The AE in group 2 decreased, which demonstrates an improvement in proprioceptive acuity, but the best performance was in group 1, which performed the same-intensity training: AE decreased when compared with both group 2 and the control group. Our results demonstrate that AE depended on training intensity; strength training improved healthy participants' ability to reproduce joint position. This finding confirms previous observations indicating that strength training improved proprioception.^{17–19} In particular, we noted that JPS in the same-intensity-training group improved when compared with the divergent-intensity-training group.

Strength-training exercises are used to increase muscular development and improve neuromuscular control.^{10,12} However, an ideal exercise program should improve not only neuromuscular abilities but also proprioception. In addition, strength training has been reported to improve proprioception. Our finding supports the current clinical practice of strength training to address proprioception deficits in JPS. Proprioception abilities affect injury risk²³ and can be enhanced by following the regimen of groups 1 and 2.

The JPS has been investigated by testing position reproduction, which consisted of verifying an individual's ability to reproduce a joint position after experiencing it.^{13,21} In JPS shoulder evaluations, AEs are higher in the midrange than at the end-range of the joint.²⁴ In the midrange, JPS is provided mainly by muscle mechanoreceptors due to the relative looseness of the joint capsule in this position compared with large variations in muscle length.^{4,21,23} In the present research, the position used was 50% of ROM, suggesting that improvements could not be attributed to capsuloligamentous receptors, which are responsible for signaling extreme ranges of motion.²⁵ Muscle spindles, muscle length, and sensors that detect changes in the rate of lengthening are responsible for JPS during voluntary muscle activation,^{17,26} such as that in our study.

Besides sending sensory information, spindles also receive efferent motor connections (gamma motoneurons) that activate regulatory system sensitivity during voluntary muscle contraction.²⁷ We suggest that the group that performed exercises with the same intensity, determined by the MR, provided the same weight in strength training for the involved muscles. By using the same intensities for agonist and antagonist muscles, it is possible to promote equivalent responses to training, increasing the force balance around the joint. Thus, the physiologic reason for the improved performance is that the proprioceptive spindles became more sensitive after strength training, resulting in better position detection, as previously proposed.^{3,25}

To stabilize the shoulder, muscles must create a compressive force in the joint, centering the humeral head in the glenoid cavity and maintaining the large amount of mobility required by the shoulder.²⁸ Then it is necessary for neuromuscular control to activate the muscles in preparation for and in response to joint movement.⁴ This control

includes coordinated activation and tonus regulations.⁴ When we take these observations into consideration, group 1's performance indicates that same-intensity training of the muscles that act on the shoulder joint is beneficial for athletes whose sports require precision movements, which depend on a high degree of proprioception.

CONCLUSIONS

To our knowledge, we are the first to investigate the effect of different training intensities (ie, same or divergent intensity) on JPS in healthy individuals. Strength training with the same exercise intensities (8–9 MR) produced an improvement in JPS relative to exercises with varying intensities (8–9 MR and 12–13 MR). Exercises at divergent intensities can be designed to improve neuromuscular control and may also be useful to individuals with a proprioceptive deficit in the shoulder. We suggest that this result is related to improvements in the sensitivity of muscle spindles and hence better neuromuscular control in the shoulder. We recommend that future authors include strength measures to address clinical meaningfulness.

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