

Research Paper



The Impact of OKC Exercises and TRX Exercises on Shoulder Joint Proprioception in Overhead Athletes With Shoulder Impingement Syndrome: A Randomized Controlled Trial

Aboozar Saadatian^{1*} , Mojtaba Babaei Khorzoghi², Mansour Sahebozamani³, Mohammad Taghi Karimi⁴

1. Department of Sport Science, Faculty of Human Sciences, Yasouj University, Yasouj, Iran.
2. Sport Injuries and Corrective Exercises, Center of Physical Education, Isfahan University of Technology, Isfahan, Iran.
3. Department of Sport Injuries and Corrective Exercises, Faculty of Sport Sciences, Shahid Bahonar University of Kerman, Kerman.
4. Department of Orthotics and Prosthetics, School of Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran.



Citation Saadatian A, Babaei Khorzoghi M, Sahebozamani M, Karimi MT. The Impact of OKC Exercises and TRX Exercises on Shoulder Joint Proprioception in Overhead Athletes With Shoulder Impingement Syndrome: A Randomized Controlled Trial. *Physical Treatments*. 2022; 12(2):77-84. <http://dx.doi.org/10.32598/ptj.12.2.519.1>

doi <http://dx.doi.org/10.32598/ptj.12.2.519.1>



Article info:

Received: 28 Nov 2021

Accepted: 26 Mar 2022

Available Online: 01 Apr 2022

Keywords:

Exercise therapy,
Proprioception, Athletes,
Shoulder Impingement
Syndrome

ABSTRACT

Purpose: Sub-acromial impingement syndrome (SAIS) is one of the most common causes of shoulder pain and affects shoulder joint proprioception. The closed kinetic chain (CKC) exercises with sling are more effective and safer than open kinetic chain (OKC) exercises. This study aimed to compare the effectiveness of OKC and total-body resistance exercises (TRX) sling training on shoulder joint position sense (JPS) in overhead athletes with shoulder impingement syndrome (SIS).

Methods: This article was a randomized control trial (RCT) study conducted in Kerman City, Iran, in 2019. The research sample included 33 overhead athletes with SIS who were randomly classified into three groups: OKC, sling, and control groups. Joint position sense (JPS) was evaluated in external rotation (ER), internal rotation (IR), and abduction of the dominant arm in the target angle concerning the shoulder range of motion with the Leighton flexometer. The obtained data were analyzed using the analysis of covariance (ANCOVA).

Results: The post-intervention results showed that a significant difference was observed between groups (ER, $P < 0.001$; IR, $P < 0.001$; abduction $P < 0.001$). The change in the sling exercises group was significantly higher in ER, and IR, except abduction JPS than in OKC ($P = 0.001$, $P = 0.001$, $P = 0.235$, respectively) and control groups ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively). Change in the OKC group was significantly higher in ER, IR, and abduction JPS ($P = 0.001$, $P = 0.019$, $P < 0.001$, respectively) than in the control group. The OKC and sling exercise improved the shoulder JPS of overhead athletes with SIS.

Conclusion: The study results showed that the sling exercises were more effective than the OKC exercise for the shoulder JPS because these exercises were CKC and performed on an unstable level.

* Corresponding Author:

Aboozar Saadatian

Address: Department of Sport Science, Faculty of Human Sciences, Yasouj University, Yasouj, Iran.

Phone: +98 (917) 7302800

E-mail: aboozar:saadat67@gmail.com

Highlights

- There is limited research that total-body resistance exercises (TRX) exercises can be effective in improving shoulder joint proprioception.
- Shoulder impingement syndrome is one of the most common injuries in overhead athletes.
- Various treatment methods have been suggested for this condition, one of the most important of which is therapeutic exercise.

Plain Language Summary

These exercises are usually performed as an open and closed kinetic chain, and it was found that closed chain of motion exercises on TRX have better effects in improving shoulder proprioception in overhead athletes with impingement shoulder syndrome. Of various treatment methods suggested for this condition, the most important one is therapeutic exercise.

1. Introduction

The shoulder joint is continuously under different pressures and stresses, and one of the most common causes of chronic pain in the shoulder is lesions caused by hyperactivity [1, 2]. In this regard, Shoulder Impingement Syndrome (SIS) is one of the most common problems in overhead motions, sporting activities, daily life, and many jobs. SIS is the most common chronic shoulder complication in athletes younger than 35 with overhead motions [3, 4]. People with SIS have shown pain and reduced shoulder function. These signs are exacerbated by shoulder elevation [5]. People with SIS may show a proprioception defect, which affects muscle behaviors and shoulder motion kinematic patterns [6-9]. Neuromuscular control of the shoulder joint is essential for maintaining shoulder stability and general function of the shoulder [10].

Repeating the high-speed throwing motions can change the stability and mobility link and, finally, cause damage. Athletes with overhead motions have shown several adaptive changes. Impaired motion, change in muscle strength, and deficits in proprioception are among these changes [11]. Some researchers argue that exercises involving overhead motions can increase joint proprioception [12]. Improving muscle strength for joint stability is one of the goals of physical exercises. Rotator muscles of cuffs, deltoid, biceps, large round, large back, and large chest muscles are responsible for shoulder stability. The stability of the shoulder joint depends on active and passive components. The basis of active and passive interactions is proprioception information from muscle manipulators, tendons, joint ligament capsules, and skin [13].

Any damage to the muscular segments and joint mechanoreceptors or painful disorders, such as osteoarthritis or hypermobility, may disrupt proprioception. Studies have revealed impaired proprioception in patients with shoulder injuries [9, 14]. Several strategies have been proposed to improve proprioception disorders; one of these strategies is using people with shoulder impingement in sporting exercises. Studies have indicated that strength exercises can improve the shoulder joint proprioception [2, 13]. Nowadays, a new type of exercise is used to enhance performance, known as total-body resistance exercises (TRX). One of the characteristics of these exercises is to use a closed kinetic chain (CKC) and unstable surface for exercises and improve strength and flexibility, and balance simultaneously exercises [15, 16]. Studies have shown that unstable surface exercises increase muscle activity compared to other method exercises [17, 18]. However, no study has been conducted on the effectiveness of sling exercises on shoulder proprioception. This randomized control trial (RCT) study aimed to compare the effectiveness of the sling exercise and OKC exercise in overhead with Sub-Acromion Impingement Syndrome (SAIS) for the shoulder joint position sense (JPS) outcomes.

2. Materials and Methods

In this RCT research, the population included overhead athletes with SIS living in Kerman City, Iran, in 2019. After confirming SIS by a physiotherapist, the statistical sample of the research was randomly classified into three groups (CONSORT Chart). The purposive convenience sampling method was used in this study. All subjects completed the consent form before starting the study. The first, second, and third groups

included OKC exercises, TRX suspension exercises, and a control group, respectively.

The inclusion criteria included male and female athletes with overhead movements aged 18 to 45 years, unilateral pain for more than one week to the acromion, pain during flexion and abduction against resistance [19], a positive Neer's test [20], positive Hawkins [20], and a positive supraspinatus Empty Can Test (ECT), and pain when touching humeral tuberosity, [21] which was confirmed with a physical examination by a specialist physiotherapist.

The exclusion criteria included systemic diseases, neck pain during rest, pain during the neck activity, return of shoulder symptoms during shoulder active range of motion (AROM) [22], pain history or neck treatment during the last 12 months [23], history of vertebral and upper limb surgery [23], fracture in the spinal cord and upper limb [23], shoulder joint stiffness, positive sulcus sign tests, load and shift test, and active compression labral test [21].

Testing procedure

Arm dominance was determined by asking the athletes which arm they used to throw a ball. After the warm-up, they sat individually on the chairs and were blindfolded in a quiet room. To prevent the motions of the trunk and the shoulder, subjects were fixed to the back of the chair with a strap. The JPS was assessed with a Leighton flexometer (Jtech Medical, UK) ($r=90\%-99\%$) [24]. Intra-tester and inter-tester reliability were calculated before data collection (intra-class correlation coefficient; ICC=0.95 and 0.98, respectively). AROM in the shoulder joint of each athlete for abduction, IR, and ER of the shoulder joint was evaluated before the test. Flexometer was fixed in the subjects' lateral and middle forearm with a hook-and-loop strap to test IR and ER of the shoulder joint; the flexometer was fixated on the middle of the outer forearm to assess abduction of the elbow, flexometer was fixed in the upper epicondyles humerus and posterior part of the arm. AROM was evaluated in the subjects' IR and ER in a sitting position on a chair with 90° of abduction and 90° flexion of the shoulder. The subjects were asked to actively rotate the shoulder to the endpoint of the range in both the IR and ER. Also, they were asked to move their arm to the endpoint of the abduction. During the evaluation of abduction of the dominant arm, both hands were relaxed at their sides in a natural position.

The IR and ER of the shoulder joint were evaluated in the natural position; that is, the forearm was horizontal to the ground (0° rotation of the shoulder) (Figure 1).

Then, the subjects were asked to bring their hands to the end of their Range of Motion (ROM), and AROM was recorded by the examiner. In assessing proprioception, the target angle was determined using the maximum ROM. Our target angles were determined as 10% of the overall range of motion. We used the percentage of the overall ROM; therefore, all subjects experienced a similar ROM [25]. The sample computation for target angles of ER was as follows: external rotation ROM of 130° , internal rotation ROM of 30° . Therefore, the overall ROM external and internal rotation was 160° . To evaluate the target angle for ER, we consider 10% of $160^\circ - 15^\circ$. Thus, $130^\circ - 15^\circ = 115^\circ$ would be the target angle for ER for this subject. Target angles were computed for all movements in the dominant shoulders and used to assess proprioception. It was tried to move hands to reach the target angle and stay in the same place for 5 s, which were enough to detect the subject's joint position and did not cause fatigue during testing. We asked subjects to bring their hands actively and slowly to the starting position. Then, the subjects were asked to actively move their hands toward the target angle and to inform the examiner each time they felt reaching the target angle. The obtained angle was recorded by the examiner. The proprioception test was performed three times for four motions with a 30-s rest between each effort. Errors in three attempts of each movement were calculated as the difference between the target angle and the rebuilding trail angle. The absolute errors were averaged over the three attempts and applied in the statistical analysis.

Intervention

The OKC group received the exercises for 8 weeks, 3 sessions per week, and each session lasted one hour, based on the protocol extracted from the previous studies [26, 27]. Each session included 10 minutes of warm-up, 45 minutes of the main exercise, and 5 minutes of cooling. The intensity of the exercises based on a one-Repetition Maximum (1RM) derived from each subject was 65% in the first and second weeks, 75% in the third and fourth weeks, 85% in the fifth and sixth weeks, and 90% in the seventh and eighth weeks. There were 10 repetitions of exercises in the first, third, fifth, and seventh weeks and 12 repetitions in the second, fourth, sixth, and eighth weeks. The value of the rating of perceived exertion in each session was taken from the subjects using the Borg scale [28].

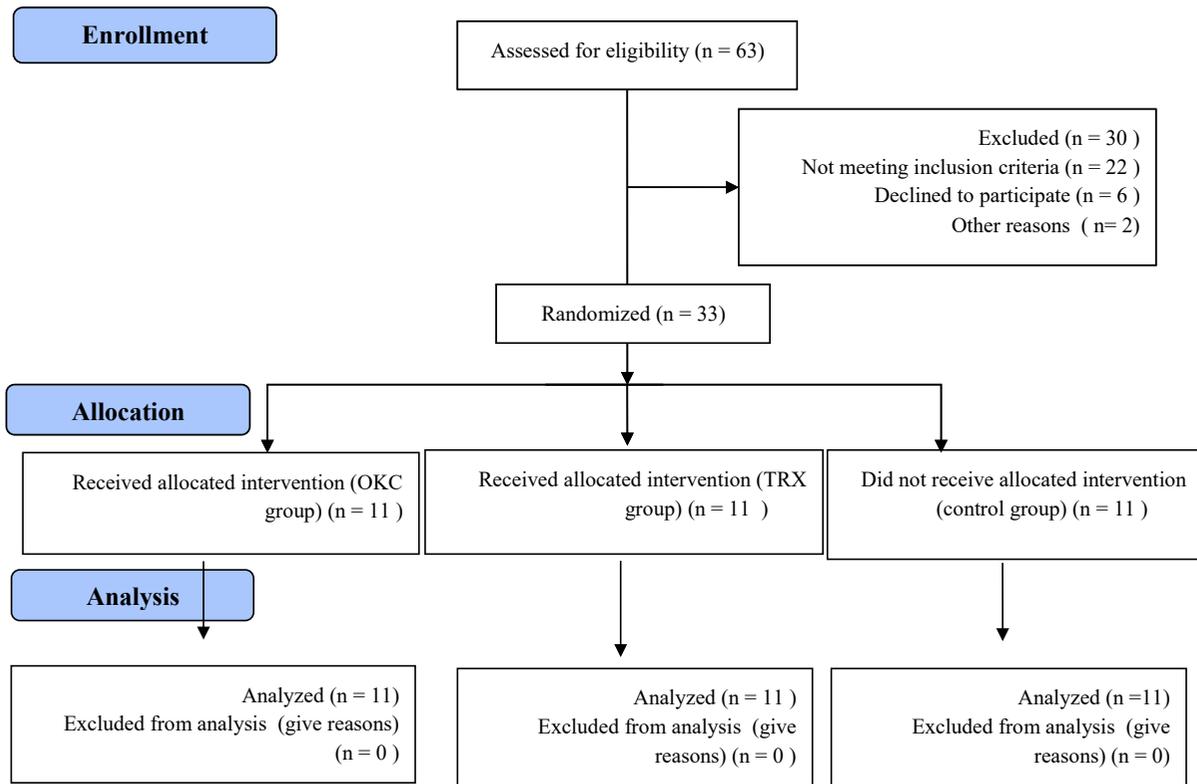


Figure 1. Measurement, internal rotation, and external rotation

The sling exercises were performed for 8 weeks, 3 sessions per week, each lasting one hour. These exercises were also prepared based on previous studies [15-29]. Each exercise session included a 10-minute warm-up, a 45-minute main exercise, and a 5-minute cool-down. The suspension exercises program was also selected based on previous studies and performed on the TRX tool. In performing the suspension exercises, it was tried

to use the pattern of exercises based on the pattern of OKC exercises. The rating of perceived exertion exercises was also matched with the Borg scale in two exercise groups [28]. Also, the control group received no exercise program except for daily activities.

The obtained data were analyzed using SPSS v. 24 software. The Kolmogorov-Smirnov (K-S) test was used for

Table 1. Demographic information of the subjects

Group	Mean±SD				
	Age (y)	Weight (kg)	Height (cm)	BMI (kg/m ²)	Sports history (y)
OKC training	28.18±2.01	81.80±3.24	188.18±2.55	23.02±1.77	8.27±0.67
Sling training	27.09±1.82	74.54±3.01	183.36±2.52	22.21±2.99	7.29±0.82
Control	29.09±1.83	77.00±2.41	184.18±2.09	23.20±2.35	8.54±0.71

PHYSICAL TREATMENTS

normal distribution, and the ANCOVA test was used for all variables at the P<0.05. Bonferroni post hoc test was used to evaluate inter-group changes.

3. Results

Table 1 presents the demographic information of the subjects separately for each group. Given the ran-

dom matching, no significant difference was observed among the variables.

All ANCOVA presumptions were observed for IR and ER and shoulder abduction, such as normal distribution, equality of variations, and correlation coefficient for all proprioception variables. The results of the 1-way ANOVA test indicated that no significant difference was ob-

Table 2. Results of the analysis of covariance for abduction, internal rotation, and external rotation joint pressure sense

Variables	Groups	Mean±SD	F	P	Partial Eta ²
Pre-test ER JPS	OKC	12.18±1.10	44.76	<0.001**	0.75
	Sling	11.18±2.08			
	Control	10.27±3.10			
Post+test ER JPS	OKC	7.81±2.35	27.48	< 0.001**	0.65
	Sling	4.09±2.45			
	Control	11.18±2.52			
Pre-test IR JPS	OKC	11.27±3.74	27.48	< 0.001**	0.65
	Sling	8.63±3.66			
	Control	9.90±2.21			
Post+test IR JPS	OKC	7.36±3.44	27.48	< 0.001**	0.65
	Sling	3.45±1.96			
	Control	10.45±1.69			
Pre-test abduction JPS	OKC	8.45±5.00	27.48	< 0.001**	0.58
	Sling	10.18±2.96			
	Control	10.08±3.04			
Post+test abduction JPS	OKC	5.18±2.71	27.48	< 0.001**	0.58
	Sling	3.90±2.84			
	Control	10.18±2.63			

IR: internal rotation; ER: external rotation; JPS: joint pressure sense; OKC: open kinetic chain.

** Significant P<0.001

PHYSICAL TREATMENTS

Table 3. The results of the post hoc test as compared to inter-groups

Variables	Groups	Mean±SD	P	
ER JPS	OKC	Sling	3.18±0.80	0.001**
		Control	-4.40±0.82	<0.001**
	Sling	OKC	-3.18±0.80	0.001**
		Control	-7.58±0.80	<0.001**
IR JPS	OKC	Sling	2.90±0.98	0.019*
		Control	-3.99±0.97	0.001**
	Sling	OKC	-2.90±0.98	0.019*
		Control	-6.18±0.93	<0.001**
Abduction JPS	OKC	Sling	1.89±1.03	0.235
		Control	-4.37±1.0	0.001**
	Sling	OKC	-1.89±1.0	0.235
		Control	-6.27±1.0	<0.001**

IR: internal rotation; ER: external rotation; JPS: joint pressure sense; OKC: open kinetic chain.

** Significant P<0.001. * Significant P<0.05.

served between mean groups in the Pre-test. The results of the ANCOVA test showed that a significant difference was observed between OKC and sling and control groups (ER $f=44.76$, $P<0.001$; IR $f=27.48$, $P<0.001$; abduction $f=20.01$, $P<0.001$) (Table 2). Table 3 presents the results of the post hoc test regarding the investigation of the inter-group difference. A significant difference was observed between OKC and sling exercises with the control group at post-intervention external and internal rotation and abduction JPS. In addition, the results showed that significant differences were observed between the OKC group and the sling group. However, the averages showed a higher decrease in the measured error rates in the sling group

4. Discussion

Rehabilitation programs, including exercises to restore sensory control of patients with shoulder injuries, are recommended. Because JPS is crucial for shoulder neuromuscular control, we examined the effect of eight weeks of OKC and sling exercises on shoulder JPS in the overhead athlete with SIS. Based on the research results, both exercise groups positively affect the improvement of proprioception. Previous studies confirmed these results [10-16]. Strengthening exercises increase muscle development and improve neuromuscular control. However, ideal exercises are those that not only improve neuromuscular control but also improve the function of proprioception receptors. In the research conducted

by Page, TheraBand exercises were influential in rehabilitating patients with patellofemoral syndrome, which decreased pain and improved the strength and function of patients [30]. Moreover, in the research conducted by Moharrami et al. six weeks of resistance training with elastic-band improved shoulder joint proprioception of males with SIS [2]. In the research conducted by Roy et al. resistance and motor control exercises improved shoulder function in people with SIS. Due to the effect on the muscles, especially in active motions, resistance exercises stimulate the muscular proprioception receptor [31]. When muscles are stretched in motorcycles, the muscle spindle stimulation rate becomes more than the position in which muscles are short, and this has a close relationship with accuracy and awareness of joint position. During active muscle contraction, simultaneous activation of gamma results in ascending increase in muscle spindle activity, and simultaneous contraction of muscles increases the proprioception accuracy sense by increasing sensitivity to stretching in the activated muscle spindles around the joint [32]. Moreover, the results showed that sling exercises had a better effect on ER and IR motions than OKC exercises. Since sling exercises are mostly performed in a CKC, they can improve shoulder joint proprioception. CKC exercises work on more than one muscle group and several joints simultaneously. Research has indicated that the CKC exercises cause more co-contractions in the lower limbs and increase the joint's stability compared to the OKC [31] since CKC

exercises cause more co-contraction and improve joint stability in the upper limbs [33, 34]. Lin et al. (2007) argued that CKC exercises increased the activity of muscle spindles [35]. Chug et al. also argued that using non-stabilizing devices was effective in reducing back pain and increasing the sensitivity of soft tissues stabilizing the joints. In addition to the advantages such as higher muscle activation in unstable exercises, these exercises may also increase the sense of proprioception. Exercising in an unstable environment increases the demand in the musculoskeletal system for joints, which may be due to the placement in the unstable environment.

The novelty of this study was to apply the TRX training method and compare it with traditional exercises. The primary limitations associated with this study were the low sample size and the lack of both genders as participants. Therefore, it is recommended to conduct a study with a high number of male and female participants.

5. Conclusion

According to the results, it can be concluded that OKC and sling exercise improve the shoulder joint proprioception. Also, given the research results and mean changes, sling exercises improve the shoulder joint proprioception in overhead athletes with SIS. Thus, these exercises can be used as a rehabilitation intervention to improve proprioception.

Ethical Considerations

Compliance with ethical guidelines

This study was registered at the Iranian Registry of Clinical Trials with the IRCT number of IRCT20171222037994N1.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Data analysis and Writing–review & editing: All authors; Data collection and Investigation: Aboozar Saadatian; Mojtaba Babaei; Supervision: Mansoureh Sahebozamani and Mohammad Taghi Karimi.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank all the overhead athletes who participated in this study.

References

- [1] Karatsolis K, Athanasopoulos S. The role of exercise in the conservative treatment of the anterior shoulder dislocation. *Journal of Bodywork and Movement Therapies*. 2006; 10(3):211-9. [DOI:10.1016/j.jbmt.2005.10.008]
- [2] Mornieux G, Hirschmüller A, Gollhofer A, Südkamp NP, Maier D. Multimodal assessment of sensorimotor shoulder function in patients with untreated anterior shoulder instability and asymptomatic handball players. *Journal of Sports Medicine and Physical Fitness*. 2018; 58(4):472-9. [DOI:10.23736/S0022-4707.17.06874-8] [PMID]
- [3] Page P. Shoulder muscle imbalance and subacromial impingement syndrome in overhead athletes. *International Journal of Sports Physical Therapy*. 2011; 6(1):51-63. [PMID] [PMCID]
- [4] Creech JA, Silver S. *Shoulder impingement syndrome*. 2022. Treasure Island: StatPearls Publishing; 2022. [PMID]
- [5] Ettinger LR, Shapiro M, Karduna A. Subacromial anesthetics increase proprioceptive deficit in the shoulder and elbow in patients with subacromial impingement syndrome. *Clinical Medicine Insights: Arthritis and Musculoskeletal Disorders*. 2017; 10:1179544117713196. [DOI:10.1177/1179544117713196] [PMID] [PMCID]
- [6] Lin JJ, Hsieh SC, Cheng WC, Chen WC, Lai Y. Adaptive patterns of movement during arm elevation test in patients with shoulder impingement syndrome. *Journal of Orthopaedic Research*. 2011; 29(5):653-7. [DOI:10.1002/jor.21300] [PMID]
- [7] Ettinger L, Shapiro M, Karduna A. Subacromial injection results in further scapular dyskinesia. *Orthopaedic Journal of Sports Medicine*. 2014; 2(8):2325967114544104. [DOI:10.1177/2325967114544104] [PMID] [PMCID]
- [8] Haik MN, Camargo PR, Zanca GG, Albuquerque-Sendin F, Salvini TF, Mattiello-Rosa SM. Joint position sense is not altered during shoulder medial and lateral rotations in female assembly line workers with shoulder impingement syndrome. *Physiotherapy Theory and Practice*. 2013; 29(1):41-50. [DOI:10.3109/09593985.2012.676722] [PMID]
- [9] Ager AL, Borms D, Bernaert M, Brusselle V, Claessens M, Roy JS, et al. Can a conservative rehabilitation strategy improve shoulder proprioception? A systematic review. *Journal of Sport Rehabilitation*. 2020; 30(1):136-51. [DOI:10.1123/jsr.2019-0400] [PMID]
- [10] Nodehi-Moghadam A, Nasrin N, Kharazmi A, Eskandari Z. A comparative study on shoulder rotational strength, range of motion and proprioception between the throwing athletes and non-athletic persons. *Asian Journal of Sports Medicine*. 2013; 4(1):34-40. [DOI:10.5812/asj-sm.34528] [PMID] [PMCID]
- [11] Cools AM, Witvrouw EE, Mahieu NN, Danneels LA. Isokinetic scapular muscle performance in overhead athletes with and without impingement symptoms. *Journal of Athletic Training*. 2005; 40(2):104-10. [PMID] [PMCID]
- [12] Jin-Ho YO, Ki-Jae SO, Mu-Yeop JL, Bang-Sub LE, Jae-Keun OH. Effect of a 12-week rehabilitation exercise program on shoulder proprioception, instability and pain in baseball players with shoulder instability. *Iranian Journal of Public Health*. 2020; 49(8):1467. [DOI:10.18502/ijph.v49i8.3890] [PMID] [PMCID]

- [13] Salles JI, Velasques B, Cossich V, Nicoliche E, Ribeiro P, Amaral MV, et al. Strength training and shoulder proprioception. *Journal of Athletic Training*. 2015; 50(3):277-80. [DOI:10.4085/1062-6050-49.3.84] [PMID] [PMCID]
- [14] Herrington L, Horsley I, Rolf C. Evaluation of shoulder joint position sense in both asymptomatic and rehabilitated professional rugby players and matched controls. *Physical Therapy in Sport*. 2010; 11(1):18-22. [DOI:10.1016/j.ptsp.2009.10.001] [PMID]
- [15] Sahin E, Dilek B, Baydar M, Gundogdu M, Ergin B, Mansali M, et al. Shoulder proprioception in patients with subacromial impingement syndrome. *Journal of Back and Musculoskeletal Rehabilitation*. 2017; 30(4):857-62. [DOI:10.3233/BMR-160550] [PMID]
- [16] Mohamed TS. Effect of trx suspension training as a prevention program to avoid the shoulder pain for swimmers. *Science, Movement & Health*. 2016; 16(2):17-26. [Link]
- [17] Jeong SY, Chung SH, Shim JH. Comparison of upper trapezius, anterior deltoid, and serratus anterior muscle activity during push-up plus exercise on slings and a stable surface. *Journal of Physical Therapy Science*. 2014; 26(6):937-9. [DOI:10.1589/jpts.26.937] [PMID] [PMCID]
- [18] Park SJ, Choi YK, Lee JH, Kim YM. Effects of shoulder stabilization exercise on pain and functional recovery of shoulder impingement syndrome patients. *Journal of Physical Therapy Science*. 2013; 25(11):1359-62. [DOI:10.1589/jpts.25.1359] [PMID] [PMCID]
- [19] Ellenbecker TS, Cools A. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: An evidence-based review. *British Journal of Sports Medicine*. 2010; 44(5):319-27. [DOI:10.1136/bjism.2009.058875] [PMID]
- [20] Lewis JS, Wright C, Green A. Subacromial impingement syndrome: The effect of changing posture on shoulder range of movement. *Journal of Orthopaedic & Sports Physical Therapy*. 2005; 35(2):72-87. [DOI:10.2519/jospt.2005.35.2.72] [PMID]
- [21] Zanca GG, Saccol MF, Oliveira AB, Mattiello SM. Shoulder internal and external rotations torque steadiness in overhead athletes with and without impingement symptoms. *Journal of Science and Medicine in Sport*. 2013; 16(5):433-7. [DOI:10.1016/j.jsams.2012.09.004] [PMID]
- [22] Land H, Gordon S, Watt K. Isokinetic clinical assessment of rotator cuff strength in subacromial shoulder impingement. *Musculoskeletal Science and Practice*. 2017; 27:32-9. [DOI:10.1016/j.msksp.2016.11.012] [PMID]
- [23] Daneshmandi H, Rahmaninia F, Shahrokhi H, Rahmani P, Esmaili S. Shoulder joint flexibility in top athletes. *Journal of Biomedical Science and Engineering*. 2010; 3(8):811-5. [DOI:10.4236/jbise.2010.38108]
- [24] Dover GC, Kaminski TW, Meister K, Powers ME, Horodyski M. Assessment of shoulder proprioception in the female softball athlete. *American Journal of Sports Medicine*. 2003; 31(3):431-7. [DOI:10.1177/03635465030310031801] [PMID]
- [25] Andrews JR, Harrelson GL, Wilk KE. Physical rehabilitation of the injured athlete. Amsterdam: Elsevier Health Sciences; 2012. [Link]
- [26] Kuhn JE. Exercise in the treatment of rotator cuff impingement: A systematic review and a synthesized evidence-based rehabilitation protocol. *Journal of Shoulder and Elbow Surgery*. 2009; 18(1):138-60. [DOI:10.1016/j.jse.2008.06.004] [PMID]
- [27] Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *European Journal of Applied Physiology*. 2013; 113(1):147-55. [DOI:10.1007/s00421-012-2421-x] [PMID]
- [28] Dawes J. Complete Guide to TRX Suspension Training Tapa blanda. Human Kinetics, 1st ed.; 2017. [Link]
- [29] Page P. Effectiveness of elastic resistance in rehabilitation of patients with patellofemoral pain syndrome: What is the evidence? *Sports Health*. 2011; 3(2):190-4. [DOI:10.1177/1941738111398595] [PMID] [PMCID]
- [30] Roy JS, Moffet H, Hébert LJ, Lirette R. Effect of motor control and strengthening exercises on shoulder function in persons with impingement syndrome: A single-subject study design. *Manual Therapy*. 2009; 14(2):180-8. [DOI:10.1016/j.math.2008.01.010] [PMID]
- [31] Herter TM, Kurtzer I, Granat L, Crevecoeur F, Dukelow SP, Scott SH. Interjoint coupling of position sense reflects sensory contributions of biarticular muscles. *Journal of Neurophysiology*. 2021; 125(4):1223-35. [DOI:10.1152/jn.00317.2019] [PMID]
- [32] Dannelly BD, Otey SC, Croy T, Harrison B, Rynders CA, Hertel JN, et al. The effectiveness of OKC and sling exercise strength training in women. *The Journal of Strength & Conditioning Research*. 2011; 25(2):464-71. [DOI:10.1519/JSC.0b013e318202e473] [PMID]
- [33] Burke W, Kibler WB, Uhl TL. Post-operative rehabilitation for scapular muscle reattachment: A case report. *International Journal of Sports Physical Therapy*. 2021; 16(2):527-38. [DOI:10.26603/001c.21240] [PMID] [PMCID]
- [34] Prokopy MP, Ingersoll CD, Nordenschild E, Katch FI, Gaesser GA, Weltman A. Closed-kinetic chain upper-body training improves throwing performance of NCAA Division I softball players. *Journal of Strength & Conditioning Research*. 2008; 22(6):1790-8. [DOI:10.1519/JSC.0b013e318185637] [PMID]
- [35] Kotteeswaran K. Effectiveness of multidirectional wobble board lateral step up exercise and unidirectional wobble board lateral step up exercise on joint position sense in oa knee. *International Journal of Current Research and Review*. 2021; 13(9):26-32. [DOI:10.31782/IJCRR.2021.13919]
- [36] Mutlu Cuğ EA, Özdemir RA, Korkusuz F, Behm DG. The effect of instability training on knee joint proprioception and core strength. *Journal of Sports Science & Medicine*. 2012; 11(3):468-74. [PMID] [PMCID]