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¿Puede el entrenamiento de oscilación y movilización aguda beneficiar el sentido de la posición articular y la fuerza de los músculos del manguito rotador en jugadores de tenis jóvenes?

Can acute mobilization and oscillation training profit on the joint position sense and strength of the rotator cuff muscles in young tennis players?

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Abstract. The rotator cuff is a group of muscles and tendons that act to stabilize the human shoulder and allow for its extensive range of motion. This study aimed to compare the immediate effect and durability of mobilization and oscillation dumbbell (OD) training on the Joint Position Sense (JPS) and strength of rotator cuff muscles in young tennis players. Twenty-six tennis players were divided into two experimental groups. G1 only performed mobilization techniques while G2 only performed OD training, before, after and after one week of the protocols, the strength and JPS of the shoulder joint were measured with an isokinetic dynamometer. Repeated analysis of variance (RMANOVA) and Bonferroni post hoc test were used to examine the differences between the groups. The analysis of covariance was used to examine the differences between the groups. In general, the results showed a significant effect of both mobilization techniques and OD training programs on the JPS and internal and external rotation strength of young tennis players, but only one difference was observed between the two in external rotation for the eccentric/concentric action at 120°/sec ($p=0009$; $\eta 2p= 0.32$). Moreover, the main findings showed that mobilization techniques and OD improved internal and external rotations after the protocol and after one week when compared with baseline for the concentric/concentric and eccentric/concentric at 60°/sec and 120°/sec ($p < 0.05$) with only one exception for the internal rotation concentric/concentric at 120°/sec for both groups ($p > 0.05$). Based on this, it seems that in healthy tennis players, both one-session mobilization techniques and OD training can be used to improve JPS and strength.
Keywords: Shoulder, Isokinetic, Torque, Resistance, Rotator cuff.

Resumen. El manguito rotador es un grupo de músculos y tendones que actúan para estabilizar el hombro humano y permitir su amplio rango de movimiento. Este estudio tuvo como objetivo comparar el efecto inmediato y la durabilidad del entrenamiento con mancuernas de movilización y oscilación (OD) sobre el sentido de posición articular (JPS) y la fuerza de los músculos del manguito rotador en tenistas jóvenes. Se dividieron veintiséis tenistas en dos grupos experimentales. G1 solo realizó entrenamiento de movilización mientras que G2 solo realizó entrenamiento OD, antes, después y después de una semana de los protocolos, se midieron la fuerza y JPS de la articulación del hombro con un dinamómetro isocinético. Se utilizaron análisis de varianza repetidos (RMANOVA) y la prueba post hoc de Bonferroni para examinar las diferencias entre los grupos. Se utilizó el análisis de covarianza para examinar las diferencias entre los grupos. En general, los resultados mostraron un efecto significativo de los programas de entrenamiento de movilización y OD sobre el JPS y la fuerza de rotación interna y externa de los tenistas jóvenes, pero solo se observó una diferencia entre los dos en la rotación externa para la acción excéntrica/concéntrica a 120 °/seg ($p=0009$; $\eta 2p= 0,32$). Además, los principales hallazgos mostraron que el entrenamiento de movilización y OD Mejoró las rotaciones internas y externas después del protocolo y después de una semana en comparación con el valor inicial para las rotaciones concéntrica/concéntrica y excéntrica/concéntrica a 60°/seg y 120°/seg ($p < 0,05$). Con una sola excepción para la rotación interna concéntrica/concéntrica a 120°/seg para ambos grupos ($p > 0,05$). Basándonos en esto, parece que en jugadores de tenis sanos, tanto las técnicas de movilización de una sesión como el entrenamiento OD pueden usarse para mejorar la JPS y la fuerza.
Palabras clave: Hombro, Isocinético, Torque, Resistencia, Manguito rotador.

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Introduction

Throwing athletes, racquet athletes such as tennis players, volleyball players, and swimmers need an unrestricted arm for optimal performance in their sports, chronic shoulder pain in overhead athletes is an important diagnostic issue, and the causes of chronic shoulder pain are countless and research shows (Meghdadi, Yalfani, & Minoonejad, 2019). In tennis players, a serve with good technique (Setyawan et al, 2024) and forehand drive (Santosa, Pratama, Imron, & Nadzalan, 2024) give significant advantages to tennis players. The shoulder injury is the most common in overhead athletes and injuries such as glenohumeral instability, rotator cuff injury, biceps brachii, scapular dyskinesia, and shoulder impingement syndrome (SIS) (Cools, Declercq, Cagnie, Cambier, & Witvrouw, 2008). In the United States, more than 21,000 tennis-related injuries are treated annually in doctors' offices, clinics, outpatient surgery centers, and hospital emergency rooms, and musculoskeletal injuries are the most common reason for visiting medical clinics, as well as shoulder injuries (Colberg, Aune, Choi, & Fleisig, 2015). Among the tennis

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players, the most damage was observed in the joints of the body (Suna & Alp, 2019). Due to its anatomical position, the shoulder joint is the most common injury among body joints, and its prevalence is 5 per 1000 patients per year (Ertan et al, 2015). Shoulder pain affects a person's functional ability to perform daily activities and has a high economic and social cost, and it is the third most common injury after back pain and knee pain among people with musculoskeletal disorders (Guimarães et al, 2016). SIS is the most common shoulder injury in people referring to orthopedic and physiotherapy clinics (44-65%) (García, Lobo, López, Serván, & Tenías, 2016). This syndrome is usually reported in the general population and is the main cause of the inability to work during daily activities and is seen as an important medical, economic, and social problem in Western societies (Struyf et al, 2013). SIS can be classified as primary and secondary, the primary includes the narrowing of the subarachnoid space, the destruction and degeneration of soft tissues and bone structures as a result of repeated trauma, which is the result of stiffness and weakness of the rotator muscles of the shoulder, and the syndrome secondary impingement, which is the most common cause of shoulder pain in overhead arm movements, is a result of functional disorders and instability of the glenohumeral joint and changes in the strength of shoulder stability muscles (Cools, Cambier, & Witvrouw, 2008). In another classification, SIS includes 3 grades, grade 1 is tendon inflammation, grade 2 is partial tear, and grade 3 is complete tear (Sein et al, 2007). Also, studies show that among the causes of SIS are anatomical abnormalities of the humeral head or lateral acromial appendage, excessive pressure, rotator cuff tendonitis, abnormal shoulder kinematics, inflammation of the subacromial space and weakness of the rotator cuff muscles causes this syndrome (Kaya, Zinnuroglu, & Tugcu, 2011; Loew et al, 2019).

According to studies, 95% of rotator cuff muscle tears are due to excessive and frequent use of the hand in the overhead position, which causes pressure in the shoulder joint (Kaya, Zinnuroglu, & Tugcu, 2011; Loew et al, 2019). Proprioception is a specific sense placed inside the joint, which is peripheral muscle and skin receptors about the position and movement of organs, having Joint Position Sense (JPS) is necessary for all daily activities and sports and professional work (Jooya & Delavari, 2019), and in adjusting and the coordination of muscle contraction and the stabilization of joint reflexes play a role, and in this way, the position and movement of the controlled joint and the contracted muscles and the stability of the joint are maintained, and as a result, it leads to a protective effect against repetitive movements in the structures of the capsule and ligaments (Sahin et al, 2017).

Adequate muscle strength is more important to prevent injury. Guney, Harput, Colakoglu, & Baltaci (2016) have stated that defects in the range of motion of internal rotation affect the strength of rotator cuff muscles of overhead arm athletes (Guney, Harput, Colakoglu, & Baltaci, 2016). Most of the past research has been related to strength and stretching training in the direction of shoulder injuries, which improved strength, and JPS and also reduced pain-related indicators (Jin-Ho, Ki-Jae, Mu-Yeop, Bang-Sub, & Jae-Keun, 2020). Despite the incidence of 0.3 injuries per 1000 hours of tennis play, there is no tennis injury prevention program, and the purpose of this study is to carry out a specific training protocol to prevent shoulder impingement injuries in young tennis players (Pas et al, 2018).

Mobilization techniques are considered for soft tissue and mostly as a rehabilitation program that includes evaluation and treatment of neurological, vascular, and neuromuscular joint disorders and the approach of this type of technique includes evaluation of the soft tissue system and the use of manual therapy strategies (Wasserman, Copeland, Upp, & Abraham, 2019), this technique used to improve soft tissue disorders, which is called sand mobilization (Alarab & Unver, 2020).

In today's era, people are constantly looking for faster and more efficient methods not only to maintain body function but also to increase physical fitness, this has led to the creation of products and programs that bring people to favorable physical fitness conditions in a short time (Ericsson, 2004). The oscillation dumbbell (OD) is an example of this training tool that increases muscle volume and strength and reduces fat, OD increases muscle activity by more than 300% compared to traditional dumbbell (Glenn, Cook, Di Brezzo, Gray, & Vincenzo, 2012). OD is sold by Fitness IQ in California and costs 2.5 pounds for women and 5 pounds for men (Porcari, Hackbarth, Kernozek, Doberstein, & Foster, 2011). During the last few years, the use of OD training as a training tool for athletes, the elderly and patients has increased significantly (Cochrane, 2011). OD training has several mechanisms to increase muscle strength. One of the most important mechanisms is the stimulation of proprioceptive receptors, and other mechanisms include the improvement of nerve and muscle coordination (Cochrane, 2011b). Priplata, Niemi, Harry, Lipsitz, & Collins (2003) reported that OD training is one of the best methods to stimulate JPS, which can have long-term effects on the condition of healthy people (Priplata, Niemi, Harry, Lipsitz, & Collins, 2003). Fontana, Richardson, & Stanton (2005) reported that low-frequency OD training in the experimental group could significantly prevent proprioceptive injury compared to the control group (Fontana, Richardson, & Stanton, 2005).

Therefore, the effect of mobilization techniques and OD training programs on the JPS and the activity time of the muscles of the upper limbs of healthy tennis athletes is essential and considering the existence of a vacuum in this area, this research aims to compare the immediate effect and durability of mobilization techniques and OD training on JPS and strength of rotator cuff muscles affect young tennis players.

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Material and Methods

The present study is a semi-experimental single-blind parallel design. After agreement and coordination with Sari (Iran) tennis clubs, tennis sports teams were invited and requested to participate in this research. Among the participants, 28 male tennis players (having an age range of 18 to 26 years, having a range of 3 to 8 years of tennis and having a training frequency of 3 times per week, 2 hours per session, with provincial competition level), based on the criteria for entering the research no upper limb injury, not participating in rehabilitation programs during the current training intervention period) were selected and randomly divided into two experimental groups. The participants were excluded from the study when having more than two absences in the training sessions, pain in any part of the body during the exercise which avoided any participation.

The researcher explained to the supervisors and trainers of the participants the objectives and methods of the present research. After completing the consent form based on the declaration of Helsinki and demographic characteristics (age, height, weight, BMI), the candidates became fully familiar with the method and process of the test. Participants were placed in two experimental groups. The first group only performed mobilization techniques (G1) and the second group performed OD training (G2). Also, before, after and after 1 week of both protocols, the players were tested again with the isokinetic device for strength and JPS of the shoulder joint.

After the pre-test, G1 did mobilization techniques and G2 did OD training for one session (30 minutes). The mobilization techniques were performed by a certified expert physiotherapist who had more than 8 years of experience, and the OD training was also performed by the same person immediately after the post-test. Also, the durability of the training was evaluated after one week.

To support the sample size, 28 tennis players were selected based on G power sample size software (ANOVA, repeated measures, within-between interaction: Beta= 0.95, P = 0.05, D = 0.36) to participate in the research, (both: n = 14) (Faul, Erdfelder, Lang, & Buchner, 2007)

Measure of shoulder JPS

To measure the JPS of the shoulder joint of healthy people, the Biodex Isokinetic Dynamometer - System 4 device was used as a reliable system with a high intergroup correlation coefficient (ICC=0.97) to collect data, the validity and reliability of which can be verified in various past study (Lund et al, 2005). This device includes an electro-goniometer, whose sensitivity level is 1°. In this test, the person was seated and turned his back to the chair, the shoulder was in the position of 90° abduction and 90° external rotation in the scapular plane (30° frontal plane) and the elbow was in a position of 90° flexion. This position was chosen for reconstruction in the abduction and external rotation movement. Participants were blindfolded to eliminate vision. After warming up and preparing the starting position, the participants were passively moved in one of the tests (45° or 60° shoulder external rotation) by the examiner. Participants were asked to focus on the desired angle for 3 seconds. Then the participant's shoulder was passively returned to the starting point by the examiner, after 3 seconds of rest in the starting position, the participant was asked to actively return to the set target angle, and when the participant felt that it was at the target point has pressed the switch to prevent excess movement of the dynamometer. This test was repeated 3 times at angles of 45° and 60° and 2 minutes of rest was determined between each test. The average reconstruction error was the difference between the desired angle and the target point. This technique has appropriate accuracy and validity to evaluate the sense of shoulder JPS (Beyranvand, Ebrahimipour, & Mirnasouri, 2020).

Measurement of shoulder rotator muscle strength

Biodex Isokinetic Dynamometer - System 4 device was used to measure the strength of rotator cuff muscles. The maximum torque of the internal and external rotators was measured separately with eccentric and concentric contractions at 60° and 120° speeds, to implement the power of the rotators in the neutral position in the general range of 60°. The shoulder was fixed at 45° abduction and the elbow at 90° flexion on the elbow stabilizing pad, and according to the device's instructions, the range of motion was between 60° external rotation and 80° internal rotation. The participants first warmed up and repeated the test 5 times at a speed of 60° per second, and then performed 5 repetitions of the test at a speed of 120° per second. During the test, the participants received verbal feedback and the rest time between each test was 60 seconds (Beyranvand, Ebrahimipour, & Mirnasouri, 2020; Letafatkar, Abbaszadeh Ghanati, & Sheikhi, 2018). The intergroup correlation coefficient was (ICC=0.87).

Interventions

Oscillation dumbbell training

The exercise protocol of the present study was taken from a previous study (Pilianidis et al, 2016). The description of the training was as follows. This training was done using a 1 kg Shake Weight tool (Pilianidis et al, 2016) which includes 2 movements with the training intensity on the 10-point Borg scale (8 of 10) (Shariat et al, 2018). Before starting the movements, people were first asked to warm up their bodies for five minutes. It should be noted that at the end of the work, it also took five minutes to cool down.

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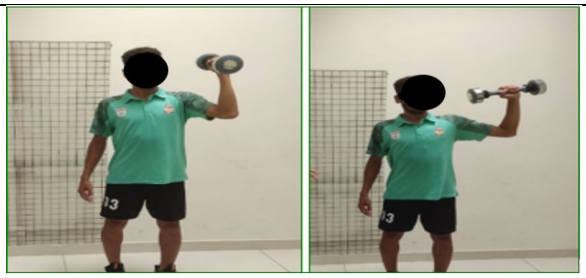
Table 1.
Oscillation dumbbell training

Exercise volume	
	2 exercises (Scaption with 90° elbow flexion and Shoulder abduction with 90° elbow flexion) * 4 repetitions
Training period	15 seconds per exercise
Training intensity	vigorous (8 of 10) - Continuous
Training interval	2 minutes of rest after each set and 4 minutes of rest between two exercises

Mobilization techniques

Four mobilization techniques were performed separately, including lower sliding, posterior sliding, anterior sliding, and stretching of the longitudinal axis of the limb, each technique was performed 2 to 4 times and 30 seconds each. All mobilization techniques were 15 minutes (Conroy & Hayes, 1998).

Figure 1. Mobilization techniques; Lower sliding, posterior sliding, anterior sliding, and stretching of the longitudinal axis of the humerus head.

Statistical Analysis

Data were analyzed using Statistical Package IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test for normality and Levene's test for homogeneity were used. Data were presented as means and standard deviations (SDs). Repeated measures ANOVA analysis with partial eta squared (ηp^2) and the Bonferroni adjustment post hoc test were used to compare pre-post interventions and groups [(2 groups) × 3 moments]. Statistical significance was set a $p < 0.05$. Cohen's D effect size (ES) with confidence intervals (CI, 95%) was calculated to measure the magnitude effects of the between groups differences. Cohen's D method suggested that $d = 0.2$ is considered a 'small' effect size, $d = 0.5$ is considered a 'medium' effect size and $d = 0.8$ is considered a 'large' effect size (Keselman et al, 1998).

Ethics

This prospective and pragmatic study was reviewed and approved by the local Human Studies Institutional Review Board at an Islamic Azad University in Sari.

Results

Participants' characteristics

All 28 participants participated in all phases (e.g., allocation, follow-up), thus permitting data analysis (Figure 2). Table 2 lists the general characteristics of the players while comparing both groups which showed that both groups were homogeneous ($p > 0.05$).

Table 2.
Descriptive variables of the participants (mean ± SD).

Variable	G1 (Male, N=14)	G2 (Male, N=14)	T (df)	p
Age (yr)	22.69 ± 3.19	21.92 ± 2.49	0.68 (26)	0.50
Height (m)	1.75 ± 0.28	1.74 ± 0.03	0.82 (26)	0.41
Weight (kg)	70.30 ± 3.22	69.76 ± 2.80	0.45 (26)	0.65
BMI ($kg.m^{-2}$)	22.93 ± 0.85	22.93 ± 1.48	- 0.25 (26)	0.78
EE (yr)	5.69 ± 0.95	5.76 ± 1.36	- 0.16 (26)	0.86

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BMI; Body mass index, EE; Exercise Experience; G1; group 1 – Mobilization techniques, G2; group 2 - Oscillation dumbbell.

Outcomes

Table 3 shows the analysis of variance with 2×3 ANOVA (treatment group × time) showing non-significant group by time and group interactions for all variables except EREC/CON120 (p=0009; η2`p= 0.32, Greenhouse–Geisser correction). There was a significant difference between the two training groups in EREC/CON120 only during the post-test, so the mean difference was 1.84 superior to the OD training group (p=0.02; CI -3.43 to -0.24, Greenhouse–Geisser correction), also the effect size of the training was in the mobilization (ES= - 1.25; CI – 2.05 to – 0.44) and the OD (ES= - 2; CI – 2.89 to – 1.10) groups.

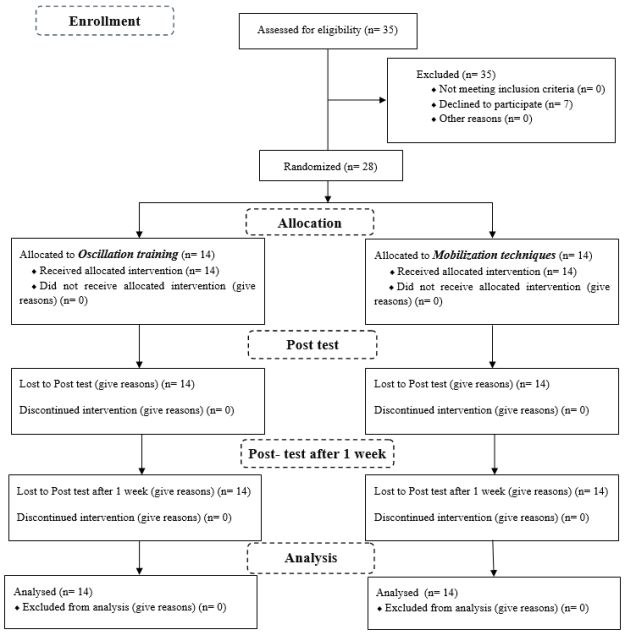

Figure 2. CONSORT flow diagram of the study.

Table 3.
Score of JPS and strength before and after 2 intervention conditions (mean ± SD) and Bonferroni post hoc.

Variables	Condition	G1 Mean ± SD	G2 Mean ± SD	F (df)	P (time× group)	η^2_p
JPS 45°	Pretest	3.53 ± 1.05	3.23 ± 0.92	0.57 (1.26)	0.57	0.046
	Post test	**1.61 ± 0.86**	**1.62 ± 0.65**			
	Post 1	**1.69 ± 0.85**	**1.84 ± 1.21**			
JPS 60°	Pretest	3.07 ± 0.86	2.92 ± 1.03	0.39 (1.26)	0.68	0.03
	Post test	**1.46 ± 0.77**	**1.30 ± 0.63**			
	Post 1	2.07 ± 0.30	**1.61 ± 0.18**			
IRCON/CON60 °/s	Pretest	52.59 ± 4.62	53.35 ± 3.74	0.29 (1.26)	0.74	0.02
	Post test	**54.66 ± 3.69**	**56.13 ± 5.38**			
	Post 1	**54.49 ± 3.93**	**55.36 ± 4.78**			
IRCON/CON120 °/s	Pretest	46.17 ± 3.47	45.51 ± 2.85	0.18 (1.26)	0.83	0.01
	Post test	47.83 ± 4.89	48.03 ± 5.60			
	Post 1	47.86 ± 4.29	47.87 ± 5.58			
IREC/CON60 °/s	Pretest	41.42 ± 4.74	41.29 ± 3.81	0.20 (1.26)	0.81	0.01
	Post test	**44.09 ± 5.99**	**44.75 ± 5.07**			
	Post 1	**43.79 ± 6.00**	**44.50 ± 5.20**			
IREC/CON120 °/s	Pretest	38.30 ± 4.77	41.33 ± 3.71	0.36 (1.26)	0.69	0.03
	Post test	**41.40 ± 4.76**	**44.21 ± 3.64**			
	Post 1	**40.55 ± 4.11**	**43.06 ± 3.44**			
ERCON/CON60 °/s	Pretest	14.42 ± 1.24	14.19 ± 1.65	2.55 (1.26)	0.09	0.17
	Post test	**15.72 ± 1.31**	**16.46 ± 1.94**			
	Post 1	**15.73 ± 2.07**	**16.07 ± 2.07**			
ERCON/CON120 °/s	Pretest	10.84 ± 1.95	10.63 ± 2.19	2.68 (1.26)	0.08	0.18
	Post test	**12.28 ± 2.32**	**12.87 ± 1.85**			
	Post 1	**12.21 ± 2.15**	**12.49 ± 1.42**			
EREC/CON60 °/s	Pretest	20.19 ± 2.20	19.88 ± 2.27	3.11 (1.26)	0.06	0.20
	Post test	**21.51 ± 2.38**	**21.41 ± 2.36**			
	Post 1	**21.20 ± 2.32**	**21.33 ± 2.61**			
EREC/CON120 °/s	Pretest	23.09 ± 1.41	23.21 ± 2.11	5.67 (1.26)	0.009*	0.32
	Post test	**25.14 ± 1.92**	**26.13 ± 1.98**[a]			
	Post 1	**24.91 ± 2.11**	**26.09 ± 1.93**			

G1; group 1 – Mobilization techniques. G2; group 2 - Oscillation dumbbell. JPS; Joint Position Sense. IR; Internal Rotation. CON; Concentric. EC; Eccentric. ER; External Rotation. ηp^2; partial eta squared (effect size). °/s; Degree/Second. Post 1; Post test after 1 week.
Note: Scores in bold are statistically significant from pretest. * are statistically significant between groups. [a] are statistically significant from G1.

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In general, the results showed that both training groups affected JPS and shoulder strength, except for IRCON/CON120 ($p > 0.05$) Figure 3.

There was no within-group difference between post test-post 1. On the other hand, the results of our research showed that both training (mobilization and OD) were permanent after 1 week except for JPS60° in G1.

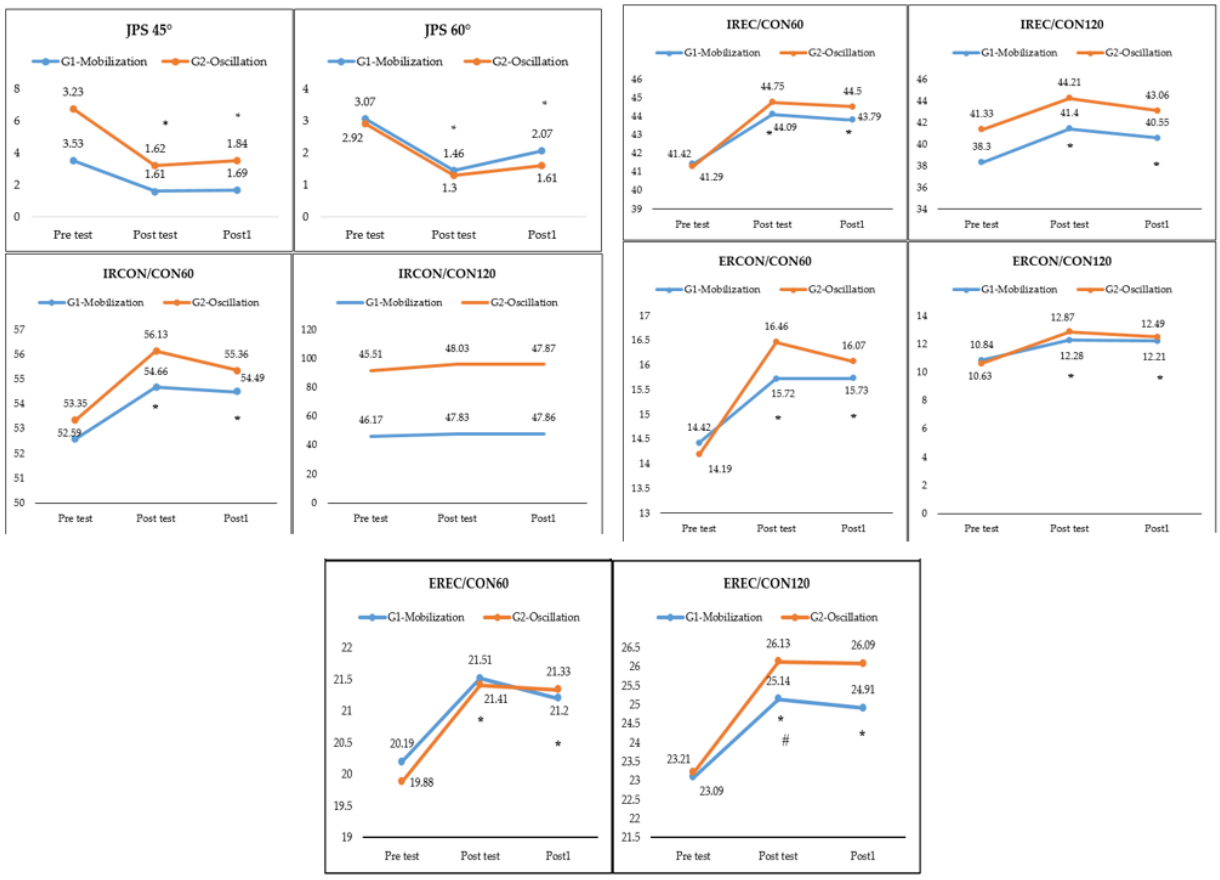

Figure3. Shoulder strength results at different times. * denotes significant difference to pre test for both groups. # denotes the difference between G1 versus G2 ($p < 0.05$).

Discussion

The present study was conducted with the aim of immediate effect and durability of mobilization techniques and OD training on JPS and strength of rotator cuff muscles affect young tennis players. According to the results of RMANOVA in two groups, they were effective in the variables of shoulder strength and JPS, so after a durability training session, a significant difference between the pre-post-test average was seen, except for IRCON/CON120. Also, in terms of durability, they were significant compared to pre-test, except for JPS60° and IRCON/CON120, but no significant difference was found in all the variables compared to the post-test - durability. In the field of comparing the effects of training between the two groups in the repeated measurement test, no significant difference was found except for EREC/CON120, with these results, it can be concluded that no significance was found between the two training groups.

Effect and durability of mobilization techniques and OD training on the JPS

The results of the present study show the effect of applying mobilization techniques and OD programs on the improvement of shoulder JPS in young tennis players. but no significant difference was observed in the comparison of the two groups. No study was found in healthy people to compare its results with the results of the present study. However, the results of the present study on the effect of joint mobilization and manipulation with the results of (Savva, Karagiannis, Korakakis, & Efstathiou (2021) pointed to the analgesic effect of mobilization and manipulation of the shoulder joint in tendinopathy (Savva, Karagiannis, Korakakis, & Efstathiou, 2021). For instance, Winton (2021) pointed to the effect of OD on the shoulder JPS (Winton, 2021) and Babaei Mobarakeh, letafatkar, & barati (2017) pointed out the effect of resistance training using powerball on JPS in volleyball

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players with tennis elbow (Babaei Mobarakeh, letafatkar, & barati, 2017). JPS receptors are located in muscles, skin, and joints, as well as ligaments and tendons, which can convert mechanical changes into nerve signals. Since the elbow bears a lot of force during overhead throws to prevent injury, the sensorimotor system must control and disperse the applied tension by establishing coordination between the movement and the position of the joint. When the applied forces are too large, joint stabilizing structures are at risk of damage (Babaei Mobarakeh, letafatkar, & barati, 2017). Resistance training increases movement control, strength and increases motor performance of people with tennis elbow. After concentric and eccentric resistance training, increasing the control over the elbow joint muscles and the JPS of the wrist joint muscles increases the function of the upper limb (Babaei Mobarakeh, letafatkar, & barati, 2017). Resistance training such as OD training used in this study increases motor control and improves performance (Babaei Mobarakeh, letafatkar, & barati, 2017). One of the possible reasons for JPS improvement following selected therapeutic training in the present study could be the neuromuscular adaptation created during exercise (Arumugam, Björklund, Mikko, & Häger, 2021). Previous studies also showed that with the increase in the level of muscle activity, the stimulation levels of muscle spindles and Golgi tendon organs also increase (Kistemaker, Van Soest, Wong, Kurtzer, & Gribble, 2013; Lee & Chen, 2024). In other words, the improvement of the JPS of the secondary end of the muscle spindle occurs by increasing the activity of alpha and then gamma motor neurons, which may show itself in the functional movements of the shoulder (Depreli & Erden, 2024). Finally, it can be concluded that regular mobilization techniques and OD training or training with complex movement patterns by affecting the inputs of afferent receptors can improve JPS (Thompson, Mikesky, Bahamonde, & Burr, 2003).

In this regard, it should be mentioned that the use of exercise and gradual loading strategies, electrophysical factors, shock (neural) therapy, and manual therapy are among them. In recent years joint mobilization and manipulation have been the participants of research and clinical attention due to their role and contribution to the management of various musculoskeletal diseases, including back pain, neck pain, chronic ankle sprain, cervicogenic headache, and dizziness (Coulter et al, 2018). Joint mobility and manipulation are passive and skillful movements applied by doctors to improve joint mobility and pain (Bishop et al, 2015). Additionally, these methods have been advocated for pain management and improved tendon function (Lucado, Dale, Vincent, & Day, 2019; Savva, Karagiannis, Korakakis, & Efstathiou, 2021). Limited evidence suggests that the use of joint mobility and local or adjacent manipulation of the affected joint may reduce tendon pain and improve motor function, studies suggest that these methods can be used as an analgesic intervention considered for the management of tendinopathy (Minkalis, Vining, Long, Hawk, & De Luca, 2018). In this regard, the results of the present study showed the effect of using mobilization techniques and OD training programs on improving shoulder JPS. Regarding the lack of difference between the effect of the two programs, no study was found to compare its effect with the effect of the present study, but the reason for the lack of difference in the two training programs on the JPS variables could be the health of the athletes or the immediacy of the training (doing the training in a session) and it may be necessary to perform training for a longer period of time to create a significant difference between the effects of the two programs.

Effect and durability of mobilization techniques and OD training on the Strength

The results of the present study show the effect and durability of applying mobilization techniques and OD programs to improve the shoulder strength of young tennis players. The results of this study were in line with the results of studies by Eliason, Harringe, Engström, & Werner (2021) who pointed out the effect of shoulder joint mobilization on improving shoulder function (Eliason, Harringe, Engström, & Werner, 2021). Kim, Yoo, & Kim (2021) pointed out the effect of soft tissue mobilization using OD stimulation on shoulder muscle activity (Kim, Yoo, & Kim, 2021). Babaei Mobarakeh, letafatkar, & barati (2017) pointed out that the effect of resistance training using Powerball on strength in volleyball players with tennis elbow (Babaei Mobarakeh, letafatkar, & barati, 2017) is consistent. In this regard, Watson, Warby, Balster, Lenssen, & Pizzari (2016) conducted an intervention based on strength training using elastic bands and double OD training in healthy young people (Watson, Warby, Balster, Lenssen, & Pizzari, 2016) and after four weeks of intervention, with five weekly sessions, they observed improvements in shoulder muscle strength. In another research, it was also pointed out that shoulder training increases the mobility, strength and performance of the shoulder (Oyama, Sosa, & Romero, 2018). Introducing shoulder training, regardless of condition, is beneficial in improving shoulder function (Oyama, Sosa, & Romero, 2018). Also, the intervention of the study by Oyama, Sosa, & Romero (2018) also led to the improvement of the internal and external rotation strength of the shoulder (Oyama, Sosa, & Romero, 2018), which is in line with the present study.

The shoulder joint is the most mobile in the body, and both passive (bony structures, ligaments and tendons) and active (muscles) factors play a role in its stability. The special shape of this joint is a ball and a shallow bowl. The relative laxity of the capsule, the wide range and freedom of movement of the shoulder joint, and the role of muscles in creating its stability are very important (Diederichsen, Nørregaard, Krogsgaard, Fischer-Rasmussen, & Dyhre-Poulsen, 2004). Internal and external rotator muscles of the shoulder play a vital role in the stability and mobility of the shoulder joint,

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especially in athletes with overhead movements (Ramsi, Swanik, Straub, & Mattacola, 2004). So maintaining the balance of the pair of internal and external rotating forces is necessary for the stability of the humeral head in the shoulder joint cavity (Berckmans et al, 2017). Considering that professional athletes spend a lot of time training and competing (Chung & Wang, 2009), the skeletal-muscular system of these athletes is affected by tensile and compressive loads. The compressive force of the rotator and deltoid muscles stabilizes the arm in the glenoid cavity and ultimately stabilizes the dynamics of the shoulder joint during movement. However, in the deceleration phase of the overhead throw, the rotator cuff muscles should be stretched externally to lead to the deceleration of the arm (Saadatian, Sahebozamani, & Mohamadipour, 2014). As a result, the presence of optimal muscle strength in the performance of the shoulder joint is essential for athletes. In this regard, it has been stated that muscles and also supporting skeletal structures play an important role in the movement of joints. A muscle must have enough muscle tone to help stabilize the joint and must also be flexible enough to allow the joint to move. Concerning increasing strength, the contraction of muscle fiber is obtained from the interaction of myofilaments in sarcomeres called actin and myosin, which plays a role in creating muscle strength (Mendenhall, 2018) having healthy and desirable muscle fibers is important for producing optimal muscle strength. Joint mobilization techniques and OD training can help to produce strength in muscles (Cochrane, 2011a). In addition, training that helps the person to be aware of the muscles of the joint will increase the person's awareness of the position of the joint (Cochrane, 2011a). Also, this training increases JPS and improves nerve afferents to the central nervous system. Based on the results of the present study, by performing instant mobilization techniques and OD training, not only can the strength of the muscles around the joint be improved, but it may also improve the kinematics of the shoulder movement, which needs to be investigated. Regarding the lack of difference between the effect of the two programs, no study was found to compare its effect with the effect of the present study, but the reason for the lack of difference in the two programs on the variable of shoulder internal and external rotation strength can be the health of the athletes or the immediacy of the training (doing the training are in one session) and it may be necessary to perform the training for a longer period of time to create a significant difference between the effects of the two programs.

Limitations and future directions

The current study presents some limitations. Firstly, both interventions were tested after one single session which only provided information on acute effects. Secondly, the participants were male tennis players which avoids generalizations to other sports, non-athletic populations, or individuals with different ages (Mohammadi Nia Samakosh et al, 2024; Luna-Villouta et al, 2024) and sex (Fernandes Machado et al, 2024; Villouta et al, 2024). Thirdly, the range interval of tennis experience between 3 to 8 years should also be taken into consideration when interpreting the results (Fernandes Machado et al, 2024). Fourthly a more robust approach would be to switch the interventions in both groups to confirm if the results were similar or not. Finally, the addition of a control group would provide more robustness to the findings.

Thus, future research should consider testing the chronic effects by applying longitudinal studies, using different age ranges and populations to confirm the present results, including a two-arm study to increase robustness since both groups would be tested with the same interventions and adding a control group for better control of external factors.

Conclusion

In general, the results of the present study showed a significant effect and durability of both mobilization techniques and OD training programs on JPS and internal and external shoulder rotation strength of young tennis players, but no difference was observed between the two immediate and durability programs. Based on this, it seems that in healthy tennis players, both mobilization techniques and OD programs can be used in one session to improve JPS and strength, and in this way help to improve the performance of athletes.

Conflict of Interest

In this study the authors declare that they have no conflicts of interest.

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Consent for publication

All figures in the manuscript got permission and consent to be published by all participants.

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analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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