Research Paper

The Effect of 8-week Online Scapular-focused Training on Scapular Kinematics, Proprioception, and Selected Muscles Strength in Female Volleyball Players With Glenohumeral Internal Rotation Deficit

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ABSTRACT

Purpose: One of the most significant risk factors for throwing athletes is an internal rotation deficit of the shoulder joint. This study aims to investigate 8-week online scapular-focused training on the scapular kinematics, proprioception, and strength of particular shoulder muscles in female volleyball players with glenohumeral internal rotation deficit.

Methods: The present study was conducted using a two-group with pre and post-test design. Based on the inclusion and exclusion criteria, 30 female athletes with abnormalities in the shoulder joint's internal rotation were split into two groups, experimental (n=15) and control (n=15). In the pre-test, goniometers were used to measure shoulder range of motion, isokinetic devices were used to measure proprioception and rotator cuff muscle strength, and inclinometers were used to measure scapular kinematics. The experimental group's participants underwent 8-week online scapular-focused training, lasting 30 minutes over three sessions each week. These exercises encompassed strength (with TheraBand) and stretching activities. Ultimately, intra-group and inter-group differences were examined using SPSS software, version 20 using paired t-tests and analysis of covariance (ANCOVA) at a significance level of 0.95.

Results: The results of paired t-test revealed that only the experimental group and the pre-test and post-test had a significant difference in all study variables (P<0.05). Additionally, the results of the analysis of covariance (ANCOVA) demonstrated a significant difference between the two groups' shoulder proprioception at 45° and 90° in the post-test (P=0.001 and P=0.01, respectively). The two groups also differed significantly in the scapular kinematics at all angles of 45°, 90°, and 135° as well as at the limit of the shoulder's range of motion (P=0.01, P=0.04, P=0.001, and P=0.001, respectively). Additionally, significant differences were observed between the two groups in all variables of isokinetic strength of concentric internal rotation, isokinetic strength of concentric external rotation, isokinetic strength of eccentric internal rotation, and isokinetic strength of eccentric external rotation (P=0.001, P=0.02, and P=0.001, respectively).

Conclusion: Based on the results, it can be concluded that 8-week online scapular-focused training improves scapular kinematics, proprioception, and shoulder internal and external rotator muscle strength in female volleyball players experiencing internal rotation deficiencies of the shoulder joint. It is advised that coaches, experts, and occupational therapists employ these workouts to enhance the aforementioned factors in female volleyball players experiencing shoulder internal rotation deficiencies.

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Highlights

• Online scapular-focused training improves scapular kinematics, proprioception, and strength of selected shoulder muscles of women volleyball players with internal rotation defects of the shoulder joint.

Plain Language Summary

One of the critical risk factors for shoulder joint injury in throwing athletes is internal rotation deficiency. Therefore, finding the best and most economical method to improve this defect is of great importance. Thirty female volleyball players with internal rotation defects of the shoulder joint were selected, and the training group performed focused scapular exercises for 30 minutes (three sessions per week) for eight weeks. According to the results obtained from the research, performing eight weeks of focused shoulder exercises led to the improvement of shoulder kinematics, shoulder proprioception, and shoulder internal and external rotator muscle strength in female volleyball players with internal rotation defects of the shoulder joint, and coaches, specialists, and occupational therapists can use these exercises to improve strength, proprioception, and scapular kinematics in female volleyball players with internal rotation defects of the shoulder joint.

1. Introduction

Overhead athletes have been shown to experience shoulder movement abnormalities, including decreased internal and external rotation and alterations in the strength of the shoulder rotator cuff muscles [1]. Age, pain, dominant hand, and playing time are a few variables affecting the range of motion [2]. The rotator cuff and deltoid muscles' compressive force stabilizes the arm in the glenoid cavity, which in turn stabilizes the dynamics of the shoulder joint. However, to stimulate the arm to decelerate during the deceleration phase of the overhead throwing, the rotator muscles of the posterior region of the shoulder should be eccentrically contracted [3].

Among the most significant injury risk factors for athletes are a deficiency in shoulder internal rotation and an imbalance in the strength of the external and internal rotator muscles [4]. According to studies, throwing athletes' shoulder internal rotation is decreased compared to the opposing shoulder, while throwing athletes' shoulder external rotation is increased [5]. Repetitive throwing motions diminish the total range of motion even though a higher range of external rotation is considered functionally advantageous [5]. Internal rotation range of motion deficits of the glenohumeral joint is the name given to these incompatible variations in the shoulders of overhead field athletes [6]. Internal rotation deficit is the term used to describe the discrepancy in the range of internal rotation between the dominant and non-dominant shoulders that negatively affects the biomechanics of shoulder joint motion during throwing and overhead sports, such as basketball, handball, and volleyball [4].

Dynamic stability of the shoulder joint, which is necessary for the best performance in overhead sports, is provided by the balance of the shoulder joint's range of motion and muscular strength between the agonist and antagonist muscles surrounding the scapula [7]. The anterior-superior displacement of the humeral head in the glenoid cavity is caused by posterior-inferior stiffness of the joint capsule. The posterior rotator tendon impingement is responsible for this displacement [8]. A person's neuromuscular awareness of position, movement, information linked to weight, and objects associated with the body is achieved by a process called "position sense," in which the degree of muscle contraction changes in response to a change in external force and a feedback system is developed [9]. Given the significant joint capsule looseness and excessive range of motion in throwers, proprioception is crucial for the dynamic stability of the shoulder joint [9]. According to the investigations, some researchers think that throwing athletes, such as volleyball players, make more delicate movements than non-athletes, and since powerful rotational movements are continually applied to the thrower's shoulder, this causes neuromuscular adaptation that enhances proprioception. However, others believe that the decrease in proprioception in these athletes is due to loose ligaments and capsules as well as from their greater range of motion [10, 11]. The posterior shoulder structures are the primary target of internal rotation deficits. Stretching workouts for the posterior shoulder muscles [12, 13], joint mobilization for the treatment of stiffness in the joint capsule [14], and numerous additional approaches, such as manual therapy [15], are some of the therapies available. The main emphasis in treating and resolving shoulder internal rotation deficits is muscle stiffness, lack of flexibility, muscular weakness, and joint capsule stiffness. To enhance shoulder performance in overhead sports, such as volleyball, strength training is required for rotator cuff muscle imbalance, particularly eccentric contractions [12, 15].

Scapular-focused training is employed for various purposes, including injury prevention, performance enhancement, strength development, proprioception enhancement, and rehabilitation following injury or surgery [16, 17]. The majority of these exercises target the neuromuscular system. The goal of the neuromuscular workout approach is to increase sensory control and attain functional stability. It focuses on biomechanical and neuromuscular principles [4]. By developing the proper physiological adaptations, scapular-focused training can help people master the skill of summoning motor units, increase the motor cortex's plasticity, and improve the muscles' application. Additionally, it is closely related to increased corticospinal excitability [17].

A new type of coronavirus with a human epidemic was first discovered in Wuhan City, China in 2019 after people there had pneumonia without a known reason and the available vaccines and treatments were ineffective [18]. Since the number of coronavirus victims surpassed 1 000, the World Health Organization (WHO) adopted the official name of the disease caused by it, COVID-19 which alludes to the coronavirus, the disease, and the year 2019 [18]. The borderless transmission of this new and lethal virus forced the cancellation of public centers, sports stadiums, and key events worldwide, including many sports contests and even the 2020 Olympics. On the other side, the WHO and the Ministries of Health of nations with high infection rates, such as the United States, China, Germany, Iran, Spain, Italy, etc forced the individuals to quarantine at home. The workouts for all participants were performed online as a result of the expansion of the Coronavirus and the great significance of online and home-based workouts due to the high prevalence of this disease and considering all the variables.

Numerous investigations have examined how stretching activities affect the range of motion in individuals with internal rotation deficits. On the other hand, contradictory findings have been reported due to the significance of proprioception and muscle strength in these individuals, as well as the dearth of studies that evaluate these variables in these individuals and the investigations that have been undertaken about strength. Few studies have examined how scapular-focused training affects isokinetic strength, proprioception of the shoulder joint, and scapular kinematics all at once. The current study was conducted to determine whether or not eight weeks of intensive shoulder training, which consists of various neuromuscular, strength, and stretching workouts, affects the scapular kinematics, proprioception, and strength of female volleyball players experiencing shoulder joint internal rotation deficits.

2. Materials and Methods

The current study is a clinical trial and an applied research project. Ultimately, a randomized clinical trial is the method of the current study.

The statistical population of the current study was made up of female academic volleyball players aged 18 to 24 years with shoulder internal rotation deficits. A statistical sample of 54 people was taken from this group using the G*Power software, version 3.1.9.2 with a power of 0.95 to 0.05 and an impact factor of 0.50. In the end, 60 participants (30 in each group) were enrolled in the study with a 10% probability of exclusion [17].

The inclusion criteria included active female academic volleyball players aged 18-24 years who engage in regular physical activity and volleyball-related training three times per week for at least 1.5 hours [19], maintaining physical activity in the present situation (COVID-19 disease), general health (confirmed by a doctor), a body mass index between 18 and 25 [19], a glenohumeral internal rotation deficit greater than 18° [20], being pain-free, and a history of shoulder dislocation and partial dislocation during the past year [20] The exclusion criteria included any prior history of shoulder fractures or surgeries [4], experiencing upper limb or spine disorders (like scoliosis and kyphosis), a history of shoulder surgery within the previous two years [4], non-continuous participation in training programs three times per week [19], and experiencing COVID-19 disease while performing research.

After selecting the research samples based on the inclusion and exclusion criteria, the participants were split into two groups, a control group (30 individuals) and online scapular-focused training (30 individuals). The steps to conduct the research were explained if needed. The research samples were requested to go to the gym on time as directed for the pre-test measurements. Following the subjects' presence, they initially filled out the basic information form, followed by anthropometric measurements for each individual. The subsequent measurements were then made regarding strength, shoulder proprioception, and scapular kinematics. It should be emphasized that the current study was conducted in the laboratory of the Sports Medicine Federation.

Shoulder range of motion measurement

A universal goniometer with a validity of 0.93 and a reliability of 0.87 was employed to measure the range of motion to identify the athletes with restricted shoulder internal rotation. The participants were informed that they should maintain the shoulder girdle muscles in a completely loose state while lying on the bed. The elbow was positioned 90° perpendicular to the bed, and the shoulder was 90° abducted on the edge of the bed. The examiner passively rotated the subject's shoulder joint surrounding the coronal axis to the inside by applying force to the subject's forearm and placing the other hand on the acromioclavicular (AC) joint. The internal rotation was subsequently stopped, and the sample's hand was steadied by a second person as soon as the movement was sensed in AC joint. For the moveable arm to be parallel to the forearm's midline and the fixed arm to be perpendicular to the ground, the goniometer's axis was placed on the olecranon bursa by the examiner. This method made it possible to calculate the rotation's range of motion around the coronal axis while moving toward the interior of the shoulder. The steps for measuring the range of rotation to the outside and inside of the shoulder joint were repeated three times, and the average of the three results was recorded [4] to improve measurement precision and lower test error rates. All steps were carried out for the dominant and non-dominant shoulder. Volleyball players were deemed to have a range of motion deficit if there was a difference of more than 18° of internal rotation in the range of motion between the dominant and non-dominant limbs [4].

Shoulder proprioception measurement

An isokinetic device with the American Biodex model was employed to measure proprioception. Initially, the device was introduced to the participants for familiarization purposes, and the test procedure was instructed. The samples were positioned on the isokinetic dynamometer chair with closed eyes to conduct the angle reconstruction test. To limit the sample's excessive trunk movements, straps were wrapped around its chest. The injured shoulder was positioned in the plane of the scapula, and the dynamometer's speed was adjusted to 5°/s [4]. The range of motion relative to the horizontal position of the dynamometer lever's arm was calculated as an angle and was determined to be 90°. Depending on the presence of the internal rotation deficit, the sample had to reconstruct an angle between 45° and 90° in the direction of the internal rotation range; 45° angle was the beginning position for a 90° angle, and 45° angle reconstruction required a 90° angle. Each of the three target angles was actively applied to the sample shoulder, which was then held there for 10 s. The participant was instructed to concentrate on this angle, and the arm was subsequently actively brought back to the initial position and then rested for 5 s. After completing this method twice, the participants were requested to voluntarily rotate their arms to the desired angle. The participants halted the lever arm when they thought they had achieved the desired angle. This procedure was performed three times, and the absolute value of the difference between the recorded angle and the target angle was reported as the error (absolute angular error), and the average of these values was employed for statistical analysis (Figure 1) [21].

PHYSICAL TREATMENTS

Figure 1. Shoulder proprioception measurement

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Figure 2. Shoulder strength measurement

Table 1. Training program

Training	(Set×Repetition)							
	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week
Towel slide	3×15	3×15					8×30	
Scapular proprioceptive Neuromuscular facilitation			3×20	3×20			3×30	
Inferior glide	3×15	3×15	3×20	3×20 s	3×25 s	3×25 s		
Scapular clock			3×20		3×25 s	3×25 s	3×30	3×30 s
Diagonal D1	3×15 s	3×15 s		3×20 s	3×25 s	3×25 s		3×30 s
Side lying external rotation	3×15 s	3×15 s						3×30 s
Knee push and push up plus		3×15 s			3×25 s		3×30 s	
Adduction movement with internal rotation			3×20 s	3×20 s		3×25 s		
Scapular punch	3×15 s	3×15 s	3×20 s	3×20 s				3×30 s
Full can					3×25 s	3×25 s	3×30 s	3×30 s
Prone horizontal Abduction with external rotation of 90° to 135°				3×20 s		3×25 s	3×30 s	3×30 s
Horizontal rowing					3×25 s		3×30 s	3×30 s

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How to measure the shoulder's internal and external rotator muscle strength

In this study, the isokinetic dynamometric system was employed to measure the strength of the rotator cuff muscles of the dominant shoulder at a speed of 90°/s. For this purpose, the participant was positioned on the dynamometer seat. Straps were fastened to the person's chest and used to fix the trunk. The dominant shoulder was positioned in the plane of the scapula (45° abduction, 30° flexion, 90° elbow flexion, and the forearm was strapped in a pronation state). The range of motion was established to be 90°, with the horizontal position of the dynamometer lever arm serving as the zero angle. In the absence of gravity, the range of shoulder rotations was made up to 90°, including almost 90° of external and internal rotations. After 30 s, the muscles were evaluated eccentrically after the initially concentric examination. The participants conducted three submaximal contractions to warm up both muscle groups after a brief explanation of how the device worked, followed by three repetitions with maximal intensity. The average maximum power was used as the measurement variable (Figure 2) [4, 21].

Measurement of scapular kinematics during shoulder abduction

Two inclinometers are used, one of which is attached via a band to the distal and external portion of the arm, above the external epicondyle, and the other is positioned on the spine of the scapula. The inclinometers were calibrated with the assumption that the arm had initially been at rest and moderately rotated to the outside. The participant was instructed to abduct his arm and hold it at angles of 45, 90, and 135° until the limit of the range of motion, at which point the numbers displayed by the inclinometer for the shoulder were recorded (ICC=0.80) [22].

Measurement of the scapular kinematics at 45°, 90°, and 135° angles, as well as at the limit of its range of motion

Training protocol

The protocol utilized in this study was adapted from studies by Moradi et al. (2020), Ellenbecker et al. (2010), [4, 23-25] and Laudner et al. [24], which were conducted in eight weeks with three sessions, each lasting 30 minutes and including stretching and strengthening workouts. The Table lists the required exercises. In the intended protocol, the participants completed the exercises each week by the given program. The interval between sets was a three-minute break, and between repetitions, it was a one minute break (Table 1).

The intra-group and inter-group differences between the experimental and control groups were examined using paired t parametric tests and analysis of covariance (ANCOVA), respectively. At a significance level of P<0.05, the data were analyzed with SPSS software, version 22.

3. Results

As previously noted, up to 30 participants took part in the study, and everyone took part in every phase of the exercise without leaving it (Table 1). In terms of demographic factors, including age, height, weight, and body mass index, the participants were homogeneous with no significant differences (P=0.31, P=0.45, P=0.12, and P=0.56, respectively) (Table 2).

The Shapiro-Wilk test was employed in this study to confirm the normality of the data distribution assumption (P>0.05). The Shapiro-Wilk test results revealed that the data regarding proprioception in two angles of 45° and 90°, internal and external rotation of the shoulder in concentric and eccentric contraction, and scapular kinematics in all angles possess a significant level greater than 0.05 (P>0.05). Therefore, intra-group and inter-group differences between the experimental and control groups were examined using paired t parametric tests and ANCOVA, respectively.

Table 2. Demographic characteristics of research participants (n=30 in each group)

Variables	Mean±SD		P
	Control	Experimental	
Weight (kg)	61.31±4.28	61.75±3.07	0.12
Height (cm)	165.09±5.43	164.13±4.89	0.45
Age (y)	24.84±1.69	25.44±2.50	0.31
Body mass index (kg/m²)	61.1±54.22	74.1±04.23	56.0

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Table 3. Results of a paired t-test and an ANCOVA to evaluate the intra-and inter-group variations in scapular kinematics and shoulder proprioception (n=30 in each group)

Variables	Test Steps	Control Group	t (p)	Experimental Group	t (p)	F (p)	Partial Eta-Squared
Scapular kinematics, 45°	Pre-test	5.06±2.91	-0.56 (0.58)	4.66±2.86	-3.15 (0.001)	7.01 (0.01)*	-0.20
	Post-test	5.20±2.62		5.73±2.63			
90° angle	Pre-test	13.8±3.68	-0.26 (0.79)	15.73±3.47	-3.76 (0.002)*	9.69 (0.004)*	0.26
	Post-test	13.68±3.36		16.66±3.28			
135° angle	Pre-test	25.73±5.90	0.89 (0.38)	28.2±5.73	-3.97 (0.001)*	15.02 (0.001)*	0.35
	Post-test	25.53±5.79		30.4±6.24			
Limit range of motion	Pre-test	43.46±5.46	1.51 (0.15)	43.26±6.28	-4.54 (0.001)*	18.72 (0.001)*	0.41
	Post-test	45.93±5.90		42.53±6.53			
45° angle shoulder proprioception (mean reconstruction error)	Pre-test	5±1.77	-0.8 (0.43)	5.06±1.79	1.53 (0.001)*	57.27(0.001)*	0.67
	Post-test	5.13±1.55		3.53±1.71			
90° angle proprioception (average reconstruction error)	Pre-test	8.4±2.47	-0.20 (0.77)	8.26±2.34	3.21 (0.006)	6.48 (0.01)*	0.19
	Post-test	8.46±2.53		4.66±2.86			

*P>0.05 significant level

PHYSICAL TREATMENTS

Table 4. Results of a paired t-test and an ANCOVA to evaluate the intra- and inter-group variations in shoulder muscle strength (n=30 in each group)

Variables	Test Steps	Control Group	t (p)	Experimental Group	t (p)	F (p)	Partial Eta-Squared
Isokinetic strength of the concentric internal rotator	Pre-test	11.13±1.45	-1.00 (0.33)	10.93±1.94	-5.99 (0.001)*	25.19 (0.001)*	0.48
	Post-test	11.33±1.17		13.00±1.85			
Isokinetic strength of the concentric external rotator	Pre-test	13.73±1.94	0.82 (0.42)	13.40±1.45	-2.47 (0.02)*	5.35 (0.02)*	0.16
	Post-test	13.53±1.45		13.93±1.36			
Isokinetic strength of the eccentric internal rotator	Pre-test	13.8±1.97	-1.58 (0.13)	13.26±1.53	-2.69 (0.01)*	6.86 (0.01)*	0.20
	Post-test	14.13±1.59		14.13±1.59			
Isokinetic strength of eccentric external rotation	Pre-test	17.8±4.6	-0.52 (0.61)	17.61±4.06	-5.91 (0.001)*	15.41 (0.001)*	0.36
	Post-test	17.93±4.9		18.59±4.09			

*P>0.05 significant level

PHYSICAL TREATMENTS

The results of the paired t-test in Table 3 demonstrated that only the experimental group had a significant difference between the pre-test and the post-test (P=0.001, P=0.002, P=0.001, P=0.001, respectively) for the scapular kinematic variables at 45°, 90°, 135°, and the limit of the range of motion). However, the difference in the control group was not statistically significant for any of the listed variables (P=0.58, P=0.79, P=0.38, and P=0.15). Furthermore, the results of the ANCOVA to evaluate the inter-group differences revealed that in all scapular kinematic variables, a significant difference was detected between the two groups in the post-test (P=0.01, P=0.004, P=0.001, and P=0.001, respectively) (Table 3). This indicates that after eight weeks of consistent online scapular workouts, female volleyball players experiencing shoulder internal rotation deficits have improved scapular kinematics.

Shoulder proprioception

Additionally, when investigating intra-group variations in the proprioceptive variable, the results of the paired t-test revealed that only in the experimental group a significant variation was observed between the pre-test and post-test in both the 45° and 90° angles (P=0.001 and 0.006, respectively). At 45° and 90° angles, this difference was not statistically significant in the control group (P=0.43 and P=0.77, respectively). A significant difference was observed between the two groups in shoulder proprioception at both 45° and 90° angles in the post-test, according to the results of the ANCOVA used to evaluate inter-group differences (P=0.001 and P=0.01, respectively). This indicates that women volleyball players experiencing internal rotation deficits of the shoulder joint who performed eight weeks of targeted online workouts for the shoulder showed decreased target angle reconstruction error and improved shoulder proprioception.

Isokinetic strength of shoulder muscles

Considering all variables of concentric internal rotator isokinetic strength, concentric external rotator isokinetic strength, eccentric internal rotator isokinetic strength, and eccentric external rotator isokinetic strength between the pre-test and post-test, the paired t-test revealed a significant difference only in the experimental group in terms of intragroup differences of the isometric strength of the shoulder's internal and external rotator muscles during concentric and eccentric contractions (P=0.001, P=0.02, P=0.01 and P=0.001, respectively). However, this difference was not statistically significant in any of the control group's variables (P>0.05). Additionally, the results of the covariance analysis test to examine inter-group differences revealed a significant difference between the experimental and control groups in all variables at the post-test (P=0.001, P=0.02, P=0.01, and P=0.001, respectively) (Table 4). This demonstrates the impact of eight weeks of online shoulder workouts on the isometric strength of the shoulder's external and internal rotator muscles in female volleyball players suffering from deficits in shoulder joint internal rotation.

4. Discussion

The results of this study revealed a significant difference between the two experimental and control groups after 8-week online scapular-focused training in female volleyball players experiencing internal rotation deficits of the shoulder joint in terms of scapular kinematic variables in all angles, shoulder proprioception in two angles of 45° and 90°, and isometric strength variables of shoulder's internal and external rotation. One of the body's most mobile joints, the shoulder complex, is frequently stressed and prone to mild injuries as a result of repeated use in some activities and overhead motions [26]. In athletes who perform overhead movements, movement abnormalities, such as decreased internal and external rotation, alterations in the strength of the shoulder rotator muscles, decreased proprioception, and alterations in biomechanical patterns have been observed [27].

Scapular kinematics: The scapula will return to its normal kinematics if the hyperactive muscles are inhibited, and the weak muscles' activity and strength are improved. The scapula moves more freely in the scapulothoracic joint as the arm's range of abduction increases [28]. The shoulder aids the range of motion through the upper rotation and can play a very significant part in the generation of such motions, although it requires stability during arm movement. Since the stabilizing function of the shoulder has improved as a result of targeted exercises for this area, increased upper rotation of the shoulder looks normal.

In a study, including thirty participants experiencing scapular dyskinesia, Neumann et al. discovered that rotator cuff stabilizing, stretching, and strengthening activities have a positive impact on the three-dimensional scapular kinematics. The current study found that these exercises have a somewhat positive effect on scapular kinematics.

It can be suggested that these workouts help the upper and lower shoulder rotator muscles recover to their normal length by the results of this study [29]. Also, the stiffness of the lower shoulder rotator muscles is reduced as one of the causes of this improvement. The strengthening of the shoulder muscle group and the muscles in charge of maintaining the ideal alignment of the scapula, which in turn participates in the shoulder muscles' improved performance in overhead activities, is likely one of the possible mechanisms engaged in the improvement of scapular kinematics throughout participants experiencing shoulder internal rotation deficits [30]. It appears that by correcting the correlation between the length and tension of the acting muscles on the positioning and stability of the scapula, the workouts employed in this research for the participants with shoulder internal rotation defects who suffered from a reduction in muscle strength as a result of scapular positioning disorder have decreased muscle tension in the scapula and arm complex. By improving the ability to transmit energy throughout the movement chain, they have also contributed to strengthening the muscles around the shoulder joint [31]. On the other hand, the workouts employed are likely to have consequences, such as improved position and enhanced scapular stability as a result of the increasing operation of the stabilizing muscles, in addition to strengthening and improving the stimulation of the trunk muscles to return the natural force couple in the scapular muscle complex. These workouts are effective in improving scapular kinematics through the mechanism mentioned above [32]. On the other hand, the intended workouts may have strengthened proximal stability in this joint and established sturdy support for the upper limb for optimal performance [33].

Shoulder proprioception

Typically, practice leads to learning. Perceptual learning, seen in sensory modalities, such as vision, hearing, and vibration, refers to increased sensory discrimination ability as a consequence of training. The precision of situation sensing may rise as a result of increased signal processing brought on by perceptual learning in an accustomed environment. The role of muscle receptors will be more significant with the effect of the exercises on the muscles, particularly during active movements, given that the proprioception is more reliant on receptors in the muscles and joints and that the intervention is through specific rotator cuff workouts. The pace at which the muscle spindles are stimulated increases when the muscles are stretched during movement cycles and this is intimately associated with how accurately the sensation of joint position and awareness of the location of the body joints are perceived. The concurrent activity of gamma nerves during active muscle contractions also increases the ascending function of the muscle spindles, and the muscles that are activated simultaneously enhance proprioception precision by making the activated muscle spindles surrounding the joint more sensitive

e to tension. Eventually, the stimulation of proprioceptors during closed-chain neuromuscular activities appears to be the primary contributor to increased proprioception [34].

According to their locations, these receptors are categorized into three groups: Joint receptors, muscle receptors, and skin receptors. The fundamental and major function of joint receptors is to detect joint movement and pain [35]. Muscle receptors, which are a part of each joint's dynamic components, are crucial to the sense of position. Muscular atrophy, weakening, and inhibition are all effects of joint trauma on the muscles. Therefore, the joint injury may impact the muscles and interfere with the transfer of afferent data from the existing receptors [36].

With the effect of the workouts on the muscles, particularly during active movements, the role of muscle receptors becomes more significant. This is because the sense of position relies more on the receptors in the muscles and joints. The rate of muscle spindle stimulation is higher whenever the muscles are stretched during movement cycles than when the muscles are at their short length, and this is directly connected to the precision of joint position sensing and awareness of body joints position [37].

Muscle strength in the external and internal rotators

Increased total contractile protein, particularly myosin, increased quantity and strength of connective tissue, tendons, and ligaments, increased capillary density in each muscle fiber, and an increased frequency of fibers as a consequence of the longitudinal division of muscle fibers that enhances muscle strength are all alterations that occur after the execution of specific rotator cuff exercises in skeletal muscles. Additionally, it appears that specific rotator cuff activities influence the length of muscle tendons, normalizing muscle length and increasing force production by the length-tension curve. Additionally, it improves neuromuscular coordination and enhances the harmony of the function of the parallel and non-parallel muscles. The muscles around the shoulder joint become stronger as a result of these situations.

The Jenda or pathokinesiological point of view is one of the most significant aspects relating to the efficacy of exercises performed in the current study on the strength of the internal and external rotator muscles of the shoulder girdle. According to this perspective, Jenda highlights that the nervous system can select the best muscle contraction movement inside a movement so that the movement can be carried out in its most optimal state and with the highest level of efficiency. Jenda’s hypothesis can demonstrate that the dominant muscle is inhibited and the weak muscle can perform its particular motion more effectively than beforehand if the workouts can engage the less worked muscles without the requirement for lengthening workouts, which is known as reflex inhibition [38]. Considering the aforementioned situations, probably the workout protocol used in this study was successful in substantially increasing the strength of these muscles by engaging the shoulder’s internal and external rotator muscles.

5. Conclusion

According to the results of the study, 8-week online scapular-focused training had a positive impact on the scapular kinematics, proprioception, and strength of selected shoulder muscles in female volleyball players experiencing shoulder internal rotation deficits. To treat athletes experiencing internal rotation deficits, it is recommended that rehabilitation specialists, as well as volleyball coaches and athletes, use online scapular-focused training on scapular kinematics, proprioception, and strength of selected shoulder muscles.

Research Limitations

The transmission of COVID-19, difficulties in getting athletes to their training location, and the limited sample size are among the limitations of the current research. Therefore, it is recommended that researchers conduct this study on a larger sample size following the end of the COVID-19 outbreak.

Ethical Considerations

Compliance with ethical guidelines

The Research Institute of Physical Education and Sports Sciences of University of Tehran approved the study (Code: IR.SSRC.REC.1401.050).

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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