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Research Article

The Effect of Reactive Neuromuscular Training versus General Warm-up on Proprioception and Balance in Female Handball Players with Rounded Shoulder: A Controlled Laboratory Study

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Abstract

Background: This study aimed to compare the immediate effects of a session of reactive neuromuscular training (RNT) with warming-up exercises on shoulder proprioception and dynamic balance in female handball players with shoulder impingement.
Methods: In this controlled laboratory study, 18 female adolescent handball players from 14 to 18 years old were recruited from Samen City, Iran. The participants participated once in the warm-up routine program and once in the RNT program. Before and after each exercise program, shoulder proprioception was measured by photogrammetry and dynamic balance of the upper limb was measured using the Wye balance test. The paired t-tests, with a significance level of 0.05, were employed to compare pre-test and post-test data.
Results: Both exercise protocols had no significant effects on shoulder repositioning error ($P > 0.05$). However, participation in both exercise programs resulted in a significant improvement in the dynamic balance score of the upper limbs of the athletes ($P < 0.001$). Moreover, no significant differences were observed between the effect of routine handball exercises and the effect of RNT exercises on shoulder repositioning and dynamic balance in female handball players ($P > 0.05$).
Conclusion: It seems that routine warm-up exercises and RNT could not improve proprioception in the shoulders of student-athletes with round shoulders. However, both training methods caused a significant improvement in the dynamic balance of the upper limb, although there was no significant difference between the effects of the two methods.

Keywords: Students; Female; Proprioception; Shoulder; Therapeutics

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Background

With the advent of technology in modern lifestyles, human movement behavior has changed, leading to an increasing prevalence of improper physical conditions among students (1, 2). Proper posture is considered a prerequisite for musculoskeletal balance, minimizing the impact of physical stress on the body (3). Deviation from the natural posture indicates a muscle imbalance and imposes unnatural physical stresses on the musculoskeletal system (4). The rounded shoulder is a common abnormal postural deviation in the sagittal plane (3). Rounded shoulder is a condition where the acromion protrudes forward when viewed in the sagittal plane. Characteristics of a rounded shoulder include protraction, downward rotation, and anterior tilt of the shoulder due to the shortening of the pectoralis minor muscle (5, 6). Rounded shoulder, along with repeated pressure on muscles from repetitive movements or a static position, has been reported. The rounded shoulder is also associated with kyphosis of the upper thoracic spine and lordosis of the cervical spine (7).

The shoulder is a unique and complex joint in the human body, consisting of three bones and four joints, making it the most unstable joint due to its wide range of motion (ROM) (8). Shoulder injuries and shoulder pain are significant issues in overhead athletes such as baseball and softball pitchers, as well as in sports like volleyball, cricket, and tennis players (9-14). The incidence of shoulder injuries in overhead sports ranges from 0.2 to 1.8 per 1000 hours of activity (9, 15, 16).

Therapeutic exercises to manage a rounded shoulder include scapular protraction exercises in combination with stretching the pectoral muscles (17) and enhancing stability in the muscles around the shoulder (18). It is believed that exercise interventions aimed at strengthening weak muscles and stretching tight muscles can improve forward head posture and rounded shoulders (19). Additionally, studies have shown that performing stretching exercises on the pectoralis minor muscle and using orthoses can decrease the rounded shoulder angle (17). Kinesio taping is also one of the various interventions used to correct body posture (20), and in previous studies, the use of kinesio taping in people with rounded shoulders immediately improved shoulder alignments (21). Simple exercise programs, such as Thera-Band exercises and Foam Roller, have achieved positive therapeutic effects for scapular dyskinesia (22-24). Moreover, it is shown that myofascial release techniques or exercises have also been used for managing rounded shoulders (23).

Furthermore, in a clinical trial, it was revealed that reactive neuromuscular training (RNT) exercises could be part of the progression of a functional exercise in the treatment of overhead athletes with unstable shoulders, restoring dynamic stability and neuromuscular control. RNT is a novel technique designed to improve positional abnormalities. These types of exercises (RNT) are designed to recover dynamic stability and movement control. Studies indicate that incorporating RNT exercise principles into the treatment of unstable shoulders can increase the chances of athletes returning to their pre-injury performance level (25). It is worth mentioning that the results demonstrate the effectiveness of RNT exercises in improving craniovertebral angle, shoulder angle, and kyphosis angle in students with forward head posture (26). RNT techniques are considered complementary exercises to improve conventional rehabilitation, using exercises for proprioceptive and balance training to facilitate the return of functional performance (27). Proprioception is one of the many sensory perceptions of the body (28). It includes subtypes such as joint position sense, kinesthetic sense (movement sense), force sense, and perception of change in speed (29-32).

In terms of sports pathology, the impairment of proprioception in various injuries holds significant importance. Proprioception is, in fact, crucial for motor control and joint stability during daily activities and sports exercises (33, 34). It can be defined as the ability to detect and locate the body in relation to its position and orientation in space (35, 36). For example, it has been demonstrated that proprioception, including the sense of movement and joint position, is disrupted in individuals with chronic ankle instability compared to healthy individuals (37). Meta-analyses of the benefits of proprioceptive exercises indicate their effectiveness in reducing pain and enhancing daily functional activities in patients with knee osteoarthritis, recommending their inclusion in rehabilitation programs (38). Research has shown that strength exercises and shoulder proprioceptive exercises are effective in improving shoulder proprioception (39). Therefore, it appears that working on proprioception is effective, but based on our findings, the effects of RNT exercises on shoulder proprioception have not been investigated.

As mentioned above, shoulder impingement is a common issue among athletes and students, leading to various complications. Various therapeutic approaches have been suggested, including exercise therapy, with one of them being RNT. Since it can have a compounded effect on exercise, it seems that it could be beneficial in this area. Based on this, in the present study, we aim to compare the immediate effects of a session of RNT with warming-up exercises on shoulder proprioception and dynamic balance in female handball players with shoulder impingement.

Methods

This study had a controlled laboratory study design. To determine the sample size, a preliminary study was conducted on 5 participants, and with the help of G*Power software (version 3.1), considering α= 0.05 and β= 0.20, it was shown that a minimum of 15 athletes were needed for this study. Then, to minimize the possible effects of dropouts, 18 female adolescent handball players from 14 to 18 years old were recruited from Samen City, Iran. The athlete students in this study had attended handball training at least three times a week for two consecutive years and had a history of participating in at least one provincial competition. To participate in the study, individuals had to have a shoulder angle greater than 54 degrees using photogrammetry. Participants were excluded from the study if they had a history of pain and discomfort due to musculoskeletal disorders, neurological diseases in the past three months before the study, a history of neurological and metabolic diseases, a history of surgery in the cervical spine or upper limbs, or other medical conditions that limited their ability to participate in this study. Prior to starting the investigation, study approval was obtained from the Biomedical Research Ethics Committee of Allameh Tabataba'i University, Tehran, Iran (ethics code: IR.ATU.REC.1402.004), and all participants gave written informed consent.

To initiate the study, we first visited the handball clubs in Samen City and explained the aim of the study to the female athlete students. It was also stated that the participants were free to discontinue the exercise at any stage and were not obligated to continue. Individuals participated in the project voluntarily and with the written, fulfilled, informed consent of their legal parents. After that, the data collection procedure was explained to them. All measurements were taken before and immediately after each exercise protocol. Each exercise protocol was prescribed on a separate day with a minimum interval of two days between each session. The exercise protocol prescription and data recording were performed by the first author.

Photogrammetry was used to assess the position of the head and neck in a standing position. Previous studies have confirmed the reliability and validity of this method (40, 41). For photogrammetric assessment, colored markers were attached to the bony landmarks, including the spinous process of the C7 vertebra, the midpoint of the acromion, and the tragus of the ear. Subsequently, a Canon digital camera was placed at a distance of 1.5 meters on a stable and non-rotating base, without any tilt, and the camera height was adjusted to the individual's shoulder level in lateral and frontal views (42). A fixed point at the height of the participant's nose was determined on the opposite wall (43). The participant was asked to bend and straighten their thoracic spine three times and, at the horizontal level, look at the specified point on the wall. Then, with a brief pause, the examiner took a photograph. This process was repeated three times at each view, and the average scores of the three tests were considered as the final score for the participant. Finally, the captured images were transferred to AutoCAD software, and the average angle of the marked points was obtained. Individuals with shoulder angles greater than 54 degrees were identified as having shoulder impingement (44). The height and weight of the participants were measured with adhesive tape attached to the wall and a digital scale, respectively. To measure the shoulder angle, the angle between the vertical line passing through the spinous process of the C7 vertebra and the line connecting C7 to the tragus of the ear was calculated.

The Y-Balance Test (YBT) was employed to measure the upper limb balance. The YBT kit includes a central section and three straps arranged in the shape of a Y, representing medial, inferior-lateral, and superior-lateral directions. The participant was asked to maintain a single-leg stance, with the free hand performing a reaching movement in the medial, inferior-lateral, and superior-lateral directions towards the farthest possible point while maintaining balance without touching the free hand to the ground. The reaching action in all three directions was performed consecutively without rest, and the process was repeated for three rounds. If any of the following occurred: 1) the free hand made contact with the ground, 2) the participant could not return the free hand to the starting position and lost balance, or 3) either foot lifted off the ground, that round was repeated. To facilitate comparison with other individuals, the reaching values were normalized to the length of the upper limb (distance from the spinous process of the seventh cervical vertebra to the end of the longest finger in the 90-degree abduction and shoulder extension, elbow extension, wrist, and finger extension). The highest reaching distance in each direction (up to the nearest 5.0 cm) was recorded, and the overall composite score was calculated using the formula (45):

Composite Score = (Upper Limb Length × 3)/(Medial Reach + Inferior-Lateral Reach + Superior-Lateral Reach)

For comparing reaching scores in different directions separately, these scores were normalized to the length of the upper limb, and the normalized reaching score in each direction was used. The intra-rater (0.80% to 0.99%) and inter-rater (1.00) reliability of this test have been reported as excellent (46).

To measure shoulder proprioception, joint photography techniques were employed (47, 48). After marking the shoulder belt on the individual, a shoulder abduction movement at a 90-degree angle was created. Once the individual was seated, they were instructed to elevate their shoulder to 90 degrees abduction, and for internal rotation at a 60-degree angle, photographs were taken with open eyes (once) and closed eyes (three times). The second position involved the individual's hip in a flexed state, and if the shoulder performed 90 degrees of flexion, pictures were taken with open eyes (once) and closed eyes (three times). The third position required the individual to be in a swimming posture, and photographs were taken from the front of the person with a camera at shoulder level, with open eyes (once) and closed eyes (three times). These movements and images were repeated and recorded in all pre-tests and post-tests on both days. All measurements were repeated three times, and the average scores were considered as the test score. The captured images were imported into AutoCAD, and the created line segments connecting the markers were connected, and the angles were obtained (49). To evaluate shoulder proprioception in a swimming position, markers were placed on the midpoints of the scapula, the end of the elbow on its prominence, the lateral epicondyle of the elbow, and the midpoint of the subaxillary line before taking pictures. Individuals were asked to perform swimming movements with open eyes and to the maximum angle possible.

For all angles, the participants were asked to repeat the movements with closed eyes. The difference in the angle obtained at the shoulder joint in the two conditions of open and closed eyes was considered a repositioning error measure. After that, the pre-test and post-test measures were compared for each exercise protocol.

Reactive Neuro-Muscular Training Program: RNT exercises were employed, including:

1. Shoulder Retraction in a Standing Position

Individuals were instructed to bring their shoulders close together for three sets of 30 seconds each while standing. Despite the resistance from our hands preventing the shoulders from getting closer, participants were required to keep their heads straight, looking at a fixed point. They relaxed for 10 seconds between each set.

2. External Rotation of the Shoulder in 90 Degrees of Shoulder Abduction

Participants were asked to sit in the prostrate position on a bench, and with the examiner positioned above their heads, shoulders were abducted to 90 degrees, and elbows were pulled. In this position, to strengthen the external rotators of the shoulder, the examiner performed external rotation against the resistance created, maintaining this position for three sets of 30 seconds, with 10 seconds of relaxation between each set.

3. Shoulder Extension Movement Using Wood or Towel Behind the Back

Individuals were instructed to hold a piece of aerobic wood or their own towel behind their backs with hands open to the width of their shoulders. In this position, the examiner, located behind them, created resistance for shoulder extension. This exercise was performed in three sets of 30 seconds each, with 8 to 12 repetitions in each set.

4. Pectoral Muscles Stretch

Participants were asked to stand within a frame, with hands in abduction in the frame, feet open to the width of the shoulders, head straight, and in a neutral position. They performed a chest and head stretch forward for three sets of 30 seconds each, and the examiner, positioned in front of them, provided resistance opposing the movement of the shoulders approaching and stretching their chest muscles.

5. Latissimus Dorsi Stretch

A resistance band was used by placing it under the right foot and holding the other end with the right hand. The hand, in an abducted position at a 45-degree angle to the body, was raised upwards at a 90-degree angle. Each set was performed for 30 seconds, and three consecutive sets were done with 8 to 12 repetitions in each set (25, 50, 51).

Routine Handball Training Session Method

The routine method for a handball training session lasts for 120 minutes. After players warm up with the coach-prescribed stretching exercises, starting from the neck and shoulder area, shoulder belt, arms, wrists, and fingers, moving towards stretching the core muscles and lower back, in the next stage, they perform stretches for the muscles of the thighs, knees, and ankle joints. This stage takes about 8 to 10 minutes, followed by a brief 4-minute run accompanied by leg box exercises, skiing movements, three-step movements, change of direction, and more. After the initial movements, dynamic warm-ups, including warming up the shoulder belt and warming up the core muscles and ankle joints, which are among the most important exercises in handball, take place. The dynamic exercises also require 8 to 10 minutes. Depending on the competition season, aerobic exercises, agility exercises, and body weight exercises are added to the training for about 10 minutes in each session after warming up. After the warm-up without a ball, the warm-up with a ball is performed for about 15 to 20 minutes, including various passing, three-step passing, shots, defense, and warming up the goalkeeper. After these stages, the players are ready for a handball game, which lasts for two halves of 10 to 25 minutes each. After finishing the game, 10 minutes of stretching and cooling-down exercises are performed, concluding a complete handball training session.

Data Analysis: The SPSS software (version 26, IBM Corporation, Armonk, NY, USA) was used for data analysis. Descriptive statistics were used to describe the data, and paired t-tests, with a significance level of 0.05, were employed to compare pre-test and post-test data

Table 1. Comparing the effect of routine exercises versus reactive neuromuscular training (RNT) exercises on shoulder repositioning error and Y-Balance Test (YBT) in 18 female athlete students

Variable	Time	Routine exercise			RNT exercises		
		Mean ± SD	t	P-value	Mean ± SD	t	P-value
Shoulder flexion (degree)	Pre-test	5.72 ± 6.93	1.693	0.109	3.28 ± 2.76	0.217	0.831
	Post-test	5.11 ± 6.88			3.11 ± 2.94		
Shoulder abduction (degree)	Pre-test	3.94 ± 4.02	0.489	0.631	5.44 ± 6.82	-0.986	0.338
	Post-test	2.83 ± 2.94			7.06 ± 3.15		
Composite YBT score (%)	Pre-test	79.89 ± 10.20	-4.954	< 0.001*	87.06 ± 9.63	-6.080	< 0.001*
	Post-test	5.72 ± 6.93			99.78 ± 10.37		

*Significant differences were observed
RNT: Reactive neuromuscular training; SD: Standard deviation; YBT: Y-Balance Test

Results

The female athlete students who participated in this study had a mean average age of 15.89 ± 1.60 years, height of 168.28 ± 3.12 centimeters, weight of 56.94 ± 11.53 kilograms, body mass index (BMI) of 20.00 ± 3.34 kg/m^2, and rounded shoulder angle of 58.17 ± 1.54 degrees.

Based on the results of the normality check, a paired samples t-test was utilized to investigate the effect of different exercise training protocols on shoulder repositioning error and upper extremity dynamic balance. The results showed that both exercise protocols had no significant effects on shoulder repositioning error. However, participation in both exercise programs resulted in a significant improvement in the dynamic balance score of the upper limbs of the athletes (P < 0.001) (Table 1).

To compare the results of two training methods on shoulder repositioning sense, the pre-test results were subtracted from the post-test results and the obtained data were compared between the two training methods. After checking the data normal distribution with the Shapiro-Wilk test, a paired samples t-test was run to analyze data. The results showed that there were no significant differences between the effect of routine handball exercises and the effect of RNT exercises on shoulder repositioning and dynamic balance in female handball players (P < 0.05) (Table 2).

Table 2. Comparing the effect of routine exercises versus reactive neuromuscular training (RNT) exercises on shoulder repositioning error and Y-Balance Test (YBT) in 18 female athletes students

Variable	Routine exercise	RNT exercises	t	P-value
	Mean ± SD	Mean ± SD		
Shoulder flexion (degree)	2.22 ± 1.96	2.50 ± 2.01	-0.589	0.564
Shoulder abduction (degree)	3.83 ± 3.60	4.83 ± 5.10	-0.452	0.657
Composite YBT score (%)	7.94 ± 6.80	12.72 ± 8.88	-1.464	0.161

RNT: Reactive neuromuscular training; SD: Standard deviation; YBT: Y-Balance Test

Discussion

The present research aimed to compare the effect of one session of RNT exercises with a routine warm-up on shoulder proprioception and upper extremity dynamic balance in female high school handball players with rounded shoulders. The results of the current study regarding the impact of warming up on the shoulder proprioception of handball players with rounded shoulders demonstrated no significant difference between the effects of the two warming-up methods on shoulder proprioception. These findings align with studies that have shown no significant effect of resistance band exercises on shoulder proprioception in athletes with shoulder proprioception disorders (52) or static stretching warm-ups on knee proprioception in athletes (53).

In general, no study was found that investigated the effect of warming up using different methods on shoulder proprioception in individuals with rounded shoulders for a comparison with the results of this study. However, it seems that one of the reasons for the lack of an impact of warming up using various methods on shoulder proprioception in handball athletes is the presence of long-term rounded shoulders in these participants. It appears that changes in shoulder alignment may lead to a reduction in shoulder proprioception, suggesting that short-term and single-session exercises may not positively affect proprioception. Studies on the impact of abnormalities on proprioception have shown that musculoskeletal disorders can reduce proprioception. In this regard, it has been demonstrated that changes in the thoracic, lumbar, and shoulder angles following carrying a backpack can be associated with changes in proprioception in these individuals (54). Based on these findings, correcting shoulder alignment and reducing shoulder impingement through corrective exercises are recommended to improve shoulder proprioception in handball athletes.

The results of the current study demonstrated that both conventional and RNT warming up significantly improved the YBT performance as a dynamic and functional balance test in female handball athletes with rounded shoulders. However, the results did not show a significant difference between different warming-up methods. The shoulder movement pattern includes several diagonal levels, such as extension, adduction, internal rotation, flexion, abduction, and external rotation. Combining diagonal movements of the upper limb at different levels may help improve dynamic balance in the upper shoulder and its stability in overhead movements (55). Dynamic balance in the lateral direction is related to functional stability in diagonal patterns, including shoulder flexion, extension, horizontal adduction, internal rotation, and external rotation (56). It is worth mentioning that an appropriate level of strength and dynamic balance is required to perform the YBT. Most overhead movements, such as throwing, serving, and spiking, are performed in a similar diagonal pattern, accompanied by shoulder extension, adduction, and internal rotation movements. Studies also recommend strength, stabilizing, and proprioceptive training using the proprioceptive neuromuscular facilitation (PNF) technique for overhead athletes with a history of shoulder injury (55). In general, based on the results, it seems that the use of conventional warm-up and RNT programs can lead to improved performance in YBT by affecting the strength and ROM of the shoulder girdle. Additionally, for better results, it is advisable to incorporate a long-term use of conventional warm-up and RNT programs alongside corrective exercises to address changes in shoulder proprioception and upper limb balance.

Although the results of this study provide useful information on the effect of different exercises on shoulder proprioception and upper limb dynamic balance, the results can be criticized from several perspectives. First of all, this study only examined the acute effect of RNT and routine warm-up methods, and therefore, their possible long-term effects remained unknown. Secondly, this study was conducted on students without a history of shoulder pain, and the results of this study may not be generalizable to athletes with shoulder pain. In the end, it can be said that in this research, the effect of two training methods on the sports performance of students has not been investigated; thus, it is suggested that more studies be done to clarify this issue.

Conclusion

This study praised that routine warm-up exercises and RNT could not improve proprioception in the shoulders of student-athletes with round shoulders. However, both training methods caused a significant improvement in the dynamic balance of the upper limb, although there was no significant difference between the effects of the two methods. It seems that warm-ups may affect sports performance or injury reduction in athletes through a different mechanism than improving proprioception.

Conflict of Interest

The authors declare no conflict of interest in this study.

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