Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Original Article

The Effects of an 8-Week Scapular-Focused Exercise Program on Shoulder Pain and Sports Performance in Wheelchair Basketball Players

Danial Moslehpour[1], MSc; Hassan Daneshmandi[1], PhD; Aynollah Naderi[2*], PhD

[1]Department of Sports Injuries and Corrective Exercises, Faculty of Physical Education, University of Guilan, Rasht, Iran
[2]School of Sport Science, Shahrood University of Technology, Shahrood, Semnan, Iran

ARTICLE INFO

Article History:
Received: 10/10/2021
Revised: 23/10/2022
Accepted: 29/04/2023

Keywords:
Exercise therapy
Para athletes
Shoulder pain
Sport performance

Please cite this article as: Moslehpour D, Daneshmandi H, Naderi A. The Effects of an 8-Week Scapular-Focused Exercise Program on Shoulder Pain and Sports Performance in Wheelchair Basketball Players. JRSR. 2023;10(3):126-136. doi: 10.30476/jrsr.2023.93192.1225.

ABSTRACT

Background : This study aimed to investigate the extent to which an 8-week scapular stabilizer strengthening and stretching exercise can reduce shoulder pain and improve wheelchair basketball sport skills.
Methods: This is a parallel-group randomized controlled trial involving twenty-five elite wheelchair basketball players aged 25 to 54 who experienced shoulder pain. They were randomly assigned to either the exercise group (n=13) or the control group (n=12). The 8-week exercise program consisted of strengthening exercises targeting the serratus anterior, scapular retractor, and shoulder external rotator muscles, as well as stretching exercises for the upper trapezius, pectoralis major and minor muscles, and the posterior glenohumeral capsule and underlying soft tissues. Shoulder pain intensity was assessed using the wheelchair user's shoulder pain index, and basketball performance was evaluated using wheelchairs' basketball skill tests. In addition, measurements of shoulder internal and external rotation range of motion, scapular upward rotation, maximal isometric muscle strength of middle and lower trapezius muscles, and pectoralis minor muscle length were taken at baseline and after the 8-week exercise intervention.
Results: Participants in the exercise group experienced a significantly lower level of shoulder pain (P=0.001) and demonstrated a higher level of sports performance in all tests (P<0.05) compared to the control group. Moreover, the exercise group showed significant improvements in shoulder internal and external rotation range of motion (ROM) (p>0.001), external rotators muscle strength (P<0.001), and middle and lower trapezius muscle strength (P=0.003 and P=0.004, respectively) in comparison to the control group. Additionally, scapular upward rotation (P<0.001) and pectoralis minor length (P<0.001) were significantly increased in the exercise group compared to the control group (P<0.05).
Conclusions: Indeed, the results suggest that an eight-week exercise program focused on scapular stabilizers and rotator cuff muscles can improve glenohumeral internal rotation, pectoralis minor length, and lower trapezius muscle strength. As a result, this exercise program could be considered a viable option for alleviating shoulder pain and enhancing sports performance in wheelchair basketball players.

Introduction

A wide variety of sports can be played in a wheelchair [1]. However, wheelchair basketball (WCB) stands out as one of the fastest-growing team sports, achieving significant success at the Paralympic Games [1]. The increasing popularity of wheelchair sports in recent years has brought about a rise in shoulder complex stressors and related complaints [2]. Supporting this fact, a descriptive

Corresponding author:* Aynollah Naderi, PhD; School of Sport Science, Shahrood University of Technology, Shahrood, Semnan, Iran. **Tel: +98 9177217462; **Email**: ay.naderi@shahroodut.ac.ir

epidemiological study has identified shoulder problems as the most common complaint among wheelchair athletes [3].

Generally, shoulder complaints in wheelchair athletes are reported to be prevalent, ranging from 21% to 76%, and the severity of shoulder pain tends to increase with time post-injury [4, 5]. In wheelchair basketball, the shoulder complex is continually subjected to stressors such as repetitive weight-bearing loads during daily activities, intermittent high-intensity activity for wheelchair propulsion, and frequent reaching overhead for shooting, passing, dribbling, and rebounding, all of which can lead to shoulder pain due to repetitive trauma [6].

Shoulder pain in wheelchair basketball has been attributed to various factors, including chronic overuse, muscle imbalances, postural changes, repetitive trauma, and direct physiological changes resulting from acute injuries [7]. As the upper extremities are the primary mode of force production for locomotion and involve frequent overhead arm motions during basketball shooting, using these upper extremities in the presence of shoulder pain negatively impacts the players' quality of life and social participation, affecting both daily life and sports activities [8].

Previous studies have shown that shoulder pain is associated with lower quality-of-life scores [9], higher levels of depressive mood, functional limitations [10], reduced physical activity and joint mobility, and can also have a detrimental effect on wheelchair basketball sport skills and performance [11, 12].

Studies have shown that surgery is typically considered the last resort for reducing shoulder pain in this population. One reason is that the strict post-surgery protocols may not be feasible for individuals who wish to maintain their independence [13]. Furthermore, there is currently no evidence supporting the superiority of surgical treatment over nonsurgical approaches. Thus, surgery is usually reserved for patients who have not responded to conservative management [13].

Although patient education on activity modification, injury mechanisms, and shoulder pain self-management is the standard care for individuals with shoulder pain, studies have reported clinically significant improvements in shoulder pain following strengthening and stretching interventions in manual wheelchair users [7, 14-16]. However, most of these studies were conducted on older adults and patients with spinal cord injuries who do not engage in overhead sports activities, specifically wheelchair basketball [7, 14-16]. Unfortunately, there is a lack of research specifically investigating the effectiveness of these interventions for wheelchair basketball athletes with shoulder pain. Nevertheless, a recent study on healthy wheelchair athletes demonstrated that a 6-week shoulder exercise program could improve overall shoulder range of motion (ROM) and scapular muscle strength [17].

The incidence of pain or complaints in wheelchair basketball players appears to be twice that of other wheelchair users who do not participate in sports [4]. This fact challenges competitive wheelchair athletes, especially non-ambulatory wheelchair athletes. Therefore, implementing a well-structured strength and stretch training program could be effective and warrants further investigation for its application in wheelchair athletes. Such a program could help counterbalance the repetitive nature of wheelchair strokes and overhead shooting.

The purpose of our study was two-fold: 1) to investigate the extent to which a scapular stabilizer and rotator cuff-focused exercise intervention can reduce shoulder pain and improve wheelchair basketball sport skills in elite wheelchair basketball players with shoulder pain, and 2) to evaluate the effects of changes in shoulder pain following the training intervention on wheelchair basketball sport skills.

Methods

Trial Design

This study was an 8-week, two-arm, parallel-group, randomized controlled trial that employed repeated measures, as illustrated in the study flow chart (Figure 1). The study received approval from the Institutional Review Board of the University of Guilan, and the trial was registered with the (IRCTID: IRCT20170114031942N9).

Participants

A total of 76 male wheelchair basketball players were initially screened for eligibility. Following the screening process, 25 players with shoulder pain were included in the study; 6 had dominant unilateral shoulder pain, and 19 had bilateral shoulder pain. The participants were recruited from February to October 2018 by distributing flyers and posters at various basketball clubs throughout the Fars province. The participants ranged from 25 to 54 years old, with an average age of 43.8±4.6 years.

Regarding the cause of disability, 56% of the participants had paraplegia due to spinal cord injury, 28% had spina bifida, and 16% had a leg amputation. Based on the IWBF's functional classification system, the participants' classification was as follows: class 1 (8/32%), class 1.5 (5/20%), class 2 (4/16%), class 2.5 (6/24%), and class 4.5 (2/8%).

The participants' experience in wheelchair basketball was 12.77±5.77 years for the control group and 11.64±4.16 years for the exercise group. The history of shoulder pain was 16.50±5.77 months for the control group and 14.82±8.38 months for the exercise group.

The sample size calculation for this study was based on the effect size of WUSPI scores (f=0.34) observed in a previous study of wheelchair users [14]. The researchers used the software package G*Power 3.1 to perform the calculation. They chose a 2-tailed significance level (α) of 0.05 and a desired power (1-β) of 0.85. The calculation indicated that a total sample size of 24 participants was required to detect the expected effect size with sufficient statistical power.

Inclusion Criteria

- Using a manual wheelchair as a primary means of mobility for at least 50% of the time.
- Experiencing unilateral or bilateral shoulder pain that impacts at least one function, such as sports activities and wheelchair use.

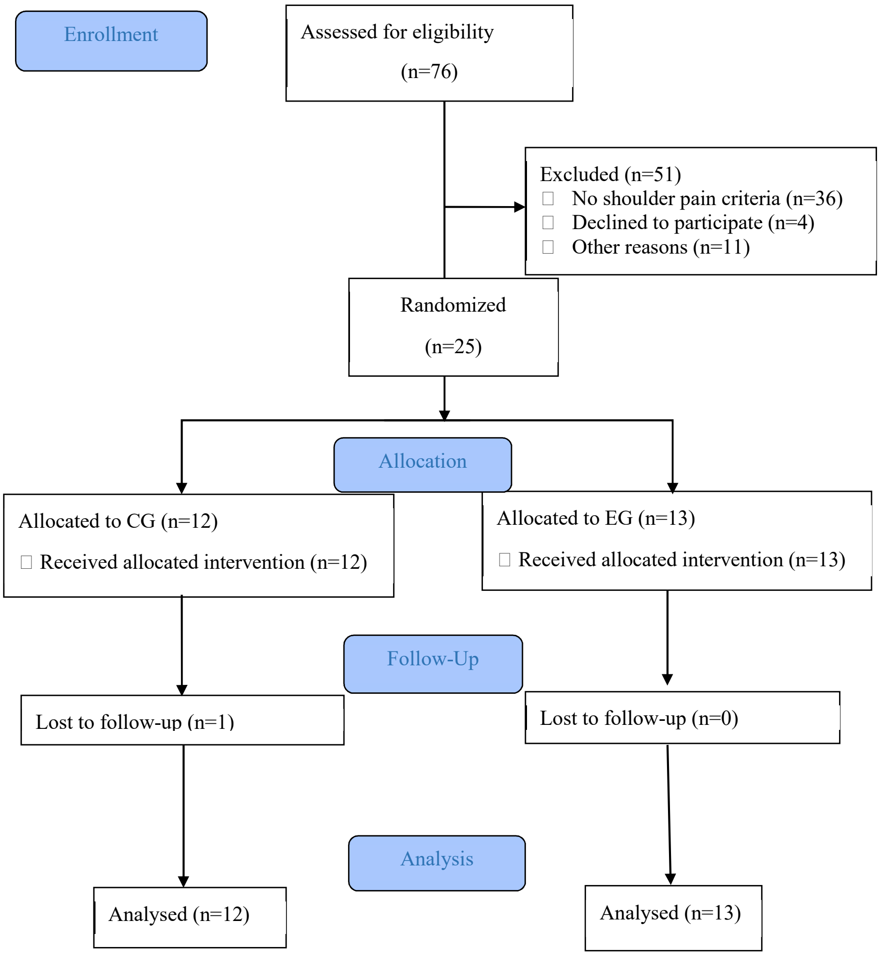

Figure 1: A diagram of the dropout and randomization of patients throughout the study.

• Confirmation of shoulder pain through positive findings in one of the Neer and Hawkins-Kennedy tests or pain during arm elevation.

Exclusion Criteria

• Hospitalization within the past year due to acute injury, fracture, or shoulder surgery.

• Confirmation of shoulder rheumatoid arthritis, adhesive capsulitis (defined as a loss of more than 25% of shoulder range of motion), severe shoulder instability, cervical radiculopathy, and rotator cuff rupture (confirmed by Jobe's Empty Can Test, Codman's Drop Arm Test, and/or external shoulder rotation against resistance).

• Undergoing cortisone injection into the shoulder within the past four months.

• Participation in physiotherapy or shoulder exercises during the past year

All procedures conducted in this study were in accordance with the principles outlined in the Declaration of Helsinki. Each participant received an information leaflet detailing the study, including the research objectives, laboratory procedures, and testing protocols. Before participating in the study, all participants were requested to provide written informed consent, signifying their understanding of the study's purpose and willingness to participate.

Randomization

The study coordinator was responsible for enrolling participants in the study. Before the commencement of the study, an independent assessor, who was blinded and had no further involvement in the study, generated a random allocation sequence using computer-generated software (Random Allocation Software 2.0). A block randomization design with block sizes of 2 and 4 was employed, and a 1:1 allocation ratio was used to ensure an equal number of participants in each group. Randomization was stratified accordingly to ensure equal representation of each type and level of disability in each study.

Group allocation information was concealed in sealed envelopes, which were only opened after all baseline assessments had been completed. Due to the nature of the intervention, it was impossible to blind the participants and the physical therapist providing the exercise training to group allocation. However, the laboratory specialist responsible for performing the measurements and the data analyst were blinded to group allocation to minimize potential bias in the study.

Measurements

All assessments were conducted one week before the first intervention session for each group, which served as baseline measurements. Subsequently, post-test measurements were taken after the completion of the last intervention session for each group. A trained physiotherapist administered these assessments.

The testing order was randomly determined for each participant to minimize order effects. This approach helped reduce potential biases that could arise due to the order in which the assessments were performed.

Shoulder Pain

Shoulder pain intensity was assessed using the Wheelchair User's Shoulder Pain Index (WUSPI), a 15-item self-report instrument valid and reliable for measuring pain during various functional activities. These activities include transfers, loading a wheelchair into a car, wheelchair mobility, dressing, bathing, overhead lifting, driving, performing household chores, and sleeping. Participants used a 10-cm visual analog scale (VAS) to rate their perceived pain, with 0 indicating "no pain" on the left end of the scale and 10 representing "worst pain ever experienced" on the right end of the scale. The scores for individual items were then summed to calculate a total index score, ranging from 0 (indicating no pain) to 150 (the highest score indicating the most severe pain) [18].

Shoulder ROM

Shoulder internal and external range of motion (ROM) were measured using a 12-inch goniometer with 360° markings in 1° increments. The measurements were taken with the participant lying on their back and their shoulder abducted to 90°. The goniometer's axis was aligned with the long axis of the humerus, using the olecranon tip as a superficial landmark. The stationary arm of the goniometer was placed vertically, while the moving arm was aligned with the lateral aspect of the ulna.

One examiner provided stabilization to ensure proper scapular stabilization while the other performed the measurement. A towel was used to align the upper arm in the frontal plane. The limb was then passively rotated to its end range, which was determined when the scapula started to move in the stabilizing hand. A research assistant recorded The rotation angles as a mean of three trials [19].

Scapular Upward Rotation

Scapular upward rotation (SUR) was measured using an ACUMAR™ digital inclinometer (Model ACU 360, Lafayette Instruments Co, Lafayette, IN), following the method described by Johnson et al. [20]. Measurements were taken at three arm elevation angles: rest position, 60°, and 120°. During the testing, participants elevated their arm in the scapular plane, using the wall as a guide against the dorsal hand, with the thumb pointing toward the ceiling. The order of angle measurements was randomized before each test session to minimize bias.

The participant held the position at each arm elevation angle while the inclinometer locator rods were positioned over the scapular spine (posterolateral acromion and the root of the scapular spine). The amount of scapular upward rotation was then measured as the angle between the scapular spine and a horizontal reference.

After each level of arm elevation, a rest period of approximately 20 to 60 seconds, as determined by each participant, was allowed to minimize fatigue. Three trials were taken at each angle, and the average value was recorded as the participant's measurement for analysis. All measurements were taken bilaterally by the primary investigator, and participants did not perform warm-ups before the measurements.

To ensure blinding and minimize bias, the primary investigator was unaware of the arm dominance of each athlete, and the order of testing was alternated for each participant.

Maximal Isometric Muscle Strength

Maximal isometric muscle strength was measured using the 'make' technique, employing a handheld dynamometer (HHD: Manual Muscle Testing System; Lafayette Instruments Co, Lafayette, IN) [21]. During the 'make' technique, participants were instructed to gradually increase their force while the examiner held the dynamometer in a fixed position. Once maximal force was achieved, participants were asked to maintain that force for three to five seconds until a "beep" sounded from the dynamometer.

To measure muscle strength for internal rotation (IR) and external rotation (ER), the HHD was placed against the wrist joint (IR on the carpal side and ER on the dorsal side) while the participant was lying supine on a portable testing table with the shoulder abducted at 90° and the elbow flexed at 90°.

For assessing the strength of the lower and middle trapezius muscles, the participant was positioned in a prone position on the testing table, and the HHD was placed immediately proximal to the lateral epicondyle of the humerus. For lower trapezius muscle strength testing, the upper extremity was positioned diagonally overhead with 145° of abduction and the thumb pointing upward. The upper extremity was held at 90° of abduction for middle trapezius muscle strength testing.

To assess the strength of the serratus anterior (SA) muscle, the HHD was positioned on the ulna at the olecranon process along the long axis of the humerus. The participant was lying supine with the shoulder in 90° horizontal adduction and the elbow in 90° of flexion [22].

A research assistant recorded the maximal isometric muscle strength as the mean of three trials, with a 1-minute interval between trials and at least 3 minutes between testing different muscle groups.

Pectoralis Minor Muscle Length (PML)

To measure the pectoralis minor length (PML), the distance between the caudal edge of the fourth rib at the sternum and the medial-inferior aspect of the coracoid process was determined. The initial landmark was identified through palpation of the bony landmark while the participant was in a supine position. If necessary, adjustments to the landmark location were made while the participant was seated in their wheelchair.

The resting PML was measured while the participant was in a relaxed, natural sitting position in their wheelchair [23]. Subsequently, PML was measured during passively and actively lengthened conditions. Participants were instructed to maximally elevate and retract their scapula for the actively lengthened condition. Participants placed their arms in approximately 30° of flexion in the passively lengthened condition. Another clinician assisted in stabilizing the participant's trunk to ensure accurate measurements [23].

Wheelchair Basketball Field Tests

Wheelchair basketball (WCB) skill tests were conducted after the team's regular warm-up routine, which included low to medium-intensity wheelchair propulsion with and without the ball, acceleration, and agility drills, shooting, passing, and stretching exercises. The tests were conducted in the gym of each team on the basketball court during a regular on-court training session.

During data collection, participants used their wheelchairs for the skill tests. Each participant was allowed a 2-minute rest between each attempt and a 5-minute rest between each test to minimize fatigue and ensure that they could perform at their best during each test.

In the time-related tests, the players sprinted upon hearing a starting sound. A manual stopwatch with a precision of 0.01 seconds was used to record the time. The stopwatch was started when the front wheels of the wheelchair crossed the start line and stopped when the front wheels crossed the finish line. One trial was given to the participants for practice to ensure accuracy and familiarize the subjects with the test. After the familiarization trial, the tests were performed three times, and the average time of the three tests was recorded.

The following field tests were used to assess sport skill and performance in wheelchair basketball:

1. 5-meter Sprint Test (5mST): The time taken to propel the wheelchair as fast as possible along a 5-meter straight track, with the front wheels of the wheelchair behind the starting line [24].
2. 20-meter Sprint Test with Ball (20mST): The time taken to dribble a ball as quickly as possible on a 20-meter track, following the IWBF dribbling rules. Dribbling violations added 5 seconds to the trial time and touching an obstacle added 1 second to the trial time [1].
3. Slalom Test (SaT): The time taken to propel the wheelchair as fast as possible through a slalom course of five cones, with 1.5 meters distance between the cones and back [24].
4. Pick-up the Ball Test (PUT): The time taken to propel the wheelchair, pick up four balls from the floor (twice with the left hand and twice with the right hand), and place the ball in the LAP before throwing it away. The participant pushed the wheelchair once after each throw [1, 24].
5. Free-Throw Shooting Test (FTST): The score received by the participant for ten free throws, with a total score ranging from 0 to 30. A score of 3 was given for throws that entered the ring, 1 for throws that hit the ring but did not enter, and 0 for throws that did not touch the ring at all [25].
6. Lay-up's Test (LUT): The score earned by the participant for as many lay-ups as possible within a minute, with the ball behind the 3-point line, adhering to the IWBF dribbling rules. The scoring system was the same as in the FTST [26].
7. Spot Shot Test (SST): The score earned by the participant from five shots taken from four positions around the key (two at the top of the key and two at the base). The scoring system was the same as in the FTST [1].
8. Maximal Pass Test (MPT): The maximum distance (explosiveness) the participant could pass a ball from a stationary position using the chest pass. The first time the ball touches the floor should be within the boundaries of the basketball court. This action ensures that the pass is valid and that the distance measurement is accurate. The distance between the throwing point and where the ball first hit the floor was measured in meters [1, 24].
9. Pass-for-Accuracy (PfA): The score earned by the participant from 10 passes made toward a scoring board with two semicircular targets of different radii. The scoring board was located 7 meters from the baseline (throwing point), and its center was 1 meter above the floor. Participants received scores of 3, 1, or 0 based on where the ball hit the scoring board. Here's how the scoring was determined: a) If the ball hit the line or landed inside the small target, the participant received 3 points; b) If the ball hit the large target, the participant received 1 point; and c) If the ball landed outside both targets, the participant received 0 points. The sum of the scores from the ten passes was recorded as the participant's total score, which could range from 0 to 30. The scoring system awarded points based on where the ball hit the scoring board [1, 26].
10. Suicide Test (SuT): A speed ladder test conducted using all the field lines. The time taken to propel the wheelchair to the four lines of the field (first to the full line, then towards the half-land line, after that to the other full-line, and finally toward the line of the other ends of the field) and then return to the starting line was recorded as the score for the players [1, 26].

Study Intervention

The scapular stabilizer and rotator cuff-focused exercise intervention (Table 1) were developed based on interventions used in previous studies for shoulder pain [14, 15, 27]. The intervention included four stretching and five strengthening exercises, targeting specific muscle groups to alleviate shoulder pain and improve function. The strengthening exercises focused on the following muscle groups: the Serratus anterior muscle, scapular retractor muscles, scapular depressor muscles, and glenohumeral external rotator muscles. The stretching exercises aimed to increase flexibility in the following muscle groups: the upper Trapezius muscle, pectoralis major and minor muscles, and posterior glenohumeral capsule and underlying soft tissues.

Limb weight and TheraBand tubing were used as resistance during the strengthening exercises. The intensity of the strengthening exercises was gradually increased throughout the study, progressing through different levels of resistance and repetitions as demonstrated from yellow to red and green and finally blue and black and from 40% to 85% 1RM of free weight, sets (from 3 to 4), and reps (from 10 to 15 repetitions) in the isotonic strengthening exercises and time hold (from 20 s to 30 s), and reps (from 4 to 10 repetitions) in the stretching exercises as long as participants were able to demonstrate good-quality movement. Participants advanced to the next color-coded level of resistance with TheraBand (from yellow to red to green and finally blue and black and from 40% to 85% 1RM of free weight) once they could complete four sets of 15 repetitions for one week without experiencing an increase in symptoms.

Table 1: Scapular stabilizer and rotator cuff-focused exercise intervention framework

Exercise	Description	Target	Repetitions	Equipment
Scapular blade squeezing	Participants maintain a good sitting posture, placing the arms on the outside of the body with external rotation of the arms and moving scapular blades downward and close to each other	Improve the strength and endurance of scapular retractor and depurator muscles	Active from 15 to 30s hold the final position/ from 6 to 12 repetitions	Wheelchair
Upper Trapezius stretching	While maintaining a good sitting posture, the participant takes the wheelchair with one hand to fix the trunk. Then he bends his head slowly to the other side with his other hand.	Improve upper Trapezius muscle length	Active from 15 to 30s hold the final position/ from 6 to 12 repetitions	Wheelchair
TheraBand external rotators strengthening	The participant was instructed to place a towel roll between the trunk and each arm and hold the middle of the band about shoulder-width apart, with slight tension in the band. Keep his elbows at 90 ~~flexion~~ flexions on each side and forearms parallel to the ground. Pull the ends of the band outward, hold, and slowly return.	Improve strength and endurance of shoulder external rotator and scapular retractor muscles	3 to 4 sets / 6 to 12 repetitions	Yellow, red, green, blue, and black TheraBand
TheraBand Serratus anterior strengthening	While maintaining a good sitting posture, the participant holds the band that attaches to the back of the wheelchair about shoulder-width apart. Keep his elbows extended and forearms straight. Start with the shoulder blades, squeeze them down and together, and then punch the arm forward to pull the ends of the band upward, hold and slowly return.	Improve strength and endurance of Serratus anterior	3 to 4 sets / 6 to 12 repetitions	Yellow, red, green, blue, and black TheraBand
Middle and lower Trapezius exercise	The participant was supine on a firm, flat surface with arms at approximately 45 degrees of abduction beside the body on the ground. Then he tries to contract the lower and middle fibers of the Trapezius muscle by squeezing the shoulder blades down and together and pressing the arm against the ground in the direction of extension for resistance.	Improve strength and endurance of shoulder external rotator and scapular retractor muscles	Active from 15 to 30s hold the final position/ from 6 to 12 repetitions	Bodyweight
Doorway Pectoralis muscle stretching	Participants were instructed to position the wheelchair in a doorway with the arm raised at shoulder height, elbows bent, and hands grasping doorjambs. Lean forward on a door frame and slowly rotate the wheelchair away from the doorjambs.	Lengthen the pectoralis major muscle, expand the rib cage and anterior chest wall	Active from 20 to 30s holds /from 4 to 10 repetitions	Doorway or room corner
The long head of biceps stretching	The participant was instructed to position the wheelchair in a doorway with the arm slightly (approximately 45 degrees) abducted and the forearm on the doorjamb. Lean forward on a door frame and slowly rotate the wheelchair away from the doorjambs.	Lengthen long head of biceps	Active from 20 to 30s holds /from 4 to 10 repetitions	Doorway or room corner
Stretching exercises for the posterior glenohumeral joint capsule	The participant was supine on a firm, flat surface with the elbow joint at approximately 90-degree flexion and shoulder in maximum horizontal adduction. With a grip back of the elbow, participants pull the arm in more adduction and stretch the posterior glenohumeral joint capsule.	Increasing the flexibility of the glenohumeral joint capsule	Active from 15 to 30s hold the final position/ from 6 to 12 repetitions	Body part
Scapular Retractors and depressors	The participant sits in his wheelchair and pulls back the elastic band the trainer holds at shoulder height by extending and abducting the arms.	Posterior shoulder musculature stretches Posterior Shoulder Capsule	Active from 20 to 30s holds /from 4 to 10 repetitions	Body part

The rest intervals between sets and exercises were 30 and 90 seconds, respectively. The intensity of the exercise program was prescribed on an individual basis and progressed from light to moderate based on the participants' rate of perceived exertion (RPE) using the Borg scale [28] (Table 1 for details).

Control Group

In the control group, participants participated in a 10-session educational class that provided information about shoulder joints and injuries. The class also aimed to educate them on how to maintain the function of their shoulders and prevent injuries.

Data Analysis

The statistical analysis in this study was conducted using SPSS software (Version 18.0, SPSS Inc., Chicago, IL). The normality of the data was assessed using the Shapiro-Wilk test. To test the significant effects of the exercise training intervention on the variables, the researchers used a Multivariate Analysis of Covariance (ANCOVA). The level of statistical significance was set at $P<0.05$. Additional follow-up comparisons were performed using ANCOVA tests for multiple comparisons. The values are presented as mean ± standard deviation (SD) along with the 95% Confidence Intervals (CIs) to measure the estimate's precision.

Partial Eta Squared ($\eta p2$) values were calculated to understand the range of training gains better. These values express the effect size of the comparisons, with $\eta p2$ values between 0.01 and 0.059 considered to represent small effects, values between 0.06 and 0.139 indicating moderate effects, and values above 0.14 indicating large effects.

Correlation and multiple regression analyses were also conducted to examine the relationship between the change in the Wheelchair User's Shoulder Pain Index (WUSPI) and potentially correlated variables such as sports skills and postural variables (Glenohumeral Range of Motion, shoulder muscle strength, and Pectoralis Minor Length) changes after the exercise training intervention.

Results

In the study, it was found that there were no significant differences between the baseline measurements of the participants. Despite this finding, the researchers decided to include the baseline measurements as covariates in the statistical analysis to control for any potential effects they might have on the study outcomes (Table 2).

Regarding WUSPI, the univariate ANCOVA showed a statistically significant difference between the control and exercise groups (F(1, 32)=57.4, P<0.001, partial η2=0.64), indicating that the exercise training intervention had a significant impact on reducing shoulder pain. The effect size, represented by Cohen's d, was calculated as 0.83, indicating a large effect of the exercise intervention in reducing shoulder pain.

For the sport performance skills, the multivariate ANCOVA also showed a statistically significant difference between the control and exercise groups after the exercise intervention (F(10, 14)=31.1, P<0.001; Wilk's Λ=0.04, partial η2=0.95). This finding indicates that the exercise training intervention significantly affected various sport performance skills measured in the study. After controlling for baseline dependent measures, follow-up univariate ANCOVA analyses further confirmed significant group effects for all sport performance variables presented in Table 2.

According to the effect size represented by ηp2, the level of effects was large for all sport performance variables, indicating that the exercise training intervention substantially enhanced the participants' sport performance skills (Table 3).

Regarding MS, there was a statistically significant difference between the control and exercise group for shoulder MS (*F* (5, 24)=9.7, P<0.001; Wilk's Λ=0.33, partial η^2=0.67), indicating exercise training intervention significantly increased shoulder MS. Univariate ANCOVA analysis shows that ERs (%Δ; EG=11.7 vs. CG=-1.2), LT (%Δ; EG=14.9 vs. CG=-1.1), and MT (%Δ; EG=12.9 vs. CG=-0.7) muscle strength improved significantly in the exercise group compared to the control group, while there was no significant difference in SA (%Δ; EG=3.9 vs. CG=1.6) and IRs (%Δ; EG=5.7 vs. CG=1.1) muscle strength (Table 4).

Table 2: Demographic characteristics of participants of the exercise and control groups

Variables	Exercise Group (n=13)	Control Group (n=12)	t/X^2	P
	Baseline (Mean±SD)	Baseline (Mean±SD)		
Age (y)	63.2±9.92	62.2±6.22	1.25	0.23
Weight (Kg)	72.1±3.2	71.4±9.8	0.64	0.53
Game experience (y)	26.2±3.4	25.2±5.8	1.59	0.13
Place of shoulder pain (D/BL)	(2/11)	(4/8)	1.10	0.29
History of shoulder pain (month)	16.50±5.77	14.82±8.38	1.7	0.10

Table 3: The summary of results from the ANCOVA analysis for pain and Wheelchair basketball field tests

Variables	Exercise Group (n=)		Control Group(n=)		Between-group different (95%CI)	ANCOVA		
	Baseline (Mean±SD)	Post-test (Mean±SD)	Baseline (Mean±SD)	Post-test (Mean±SD)		$F_{(1,23)}$	P	η_p^2
WUSPI	52.5±26.6	32.2±22.9	52.9±29.0	54.1±29.6	21.9 (-40.1 to -3.8)	57.4	0.001*	0.64
5 m sprint test	2.48±0.34	2.39±0.25	2.18±0.26	2.42±0.22	0.2 (0.04 to 0.44)	10.4	0.01*	0.31
20 m sprint test with ball	7.17±1.1	7.44±0.70	6.54±0.86	7.31±0.67	0.8 (0.1 to 1.4)	38.5	0.001*	0.62
Slalom test	6.36±0.62	6.77±0.78	5.95±0.62	6.75±0.77	0.8(0.2 to 1.4)	45.5	0.001*	0.64
Pick-up the ball	17.6±2.1	18.2±1.6	15.7±1.2	19.5±3.4	3.8 (1.6 to 5.9)	7.0	0.02*	0.23
Free-throw shooting test	16.41±4.1	16.83±1.75	19.67±2.39	17.1 ±3.1	2.6 (0.3 to 4.9)	10.5	0.01*	0.31
Lay-up's test	43.0±7.26	42.6±7.22	48.6±7.2	42.3±6.9	6.3 (0.3 to 12.2)	38.1	0.001*	0.62
Spot shot test	29.9±6.3	30.3±2.5	35.2±5.6	29.9±4.2	5.2 (1.0 to 9.4)	10.2	0.01*	0.31
Maximal pass test	40.5±7.2	39.2±7.9	47.2±8.9	39.2±8.1	7.9 (0.7 to 15.2)	14.5	0.001*	0.39
Pass-for-accuracy	21.8±4.0	21.3±3.3	25.8±3.9	21.3±2.9	4.5 (1.4 to 7.6)	54.4	0.001*	0.70
Suicide test	48.0±8.4	47.2±4.3	42.0±4.3	47.5±5.2	5.5 (1.4 to 9.6)	18.9	0.001*	0.45

WUSPI; Wheelchair User's Shoulder Pain Index. *Indicate between-group difference, [aI]ndicate within-group difference, [b]Indicate a significant correlation with WUSPI

Table 4: The summary of results from the ANCOVA analysis for shoulder muscle strength

Variables	Exercise Group (n=)		Control Group(n=)		Between-group different (95%CI)	ANCOVA		
	Baseline (Mean±SD)	Post-test (Mean±SD)	Baseline (Mean±SD)	Post-test (Mean±SD)		$F_{(1,23)}$	P	η_p^2
IRsS	146.6±17.4	154.9±15.7	142.9±13.8	144.4±16.0	10.6 (1.0 to 21.5)	3.4	0.08	0.11
ERsS	108.4±14.7	121.1±15.5	109.2±15.1	107.9±11.4	13.2 (3.9 to 22.5)	13.1	0.001*	0.32
LTS	86.3±14.1	99.2±14.0	87.3±16.4	86.3±12.8	12.8 (3.6 to 22.0)	10.8	0.003*	0.28
MTS	107.8±14.2	121.7±16.9	108.6±14.5	107.9±13.4	13.8 (3.3 to 24.2)	10.2	0.004*	0.27
SAS	149.2±14.8	155.0±12.4	146.2±13.8	148.5±16.7	6.5 (-3.7 to 16.7)	1.2	0.3	0.04

MS; Muscle Strength, IRsS; Internal Rotators Strength, ERsS; External Rotators Strength, LTS; Lower Trapezius Strength, MTS; Middle Trapezius Strength, SAS; Serratus Anterior Strength. *Indicate between-group difference, [a]Indicate within-group difference, [b]Indicate a significant correlation with WUSPI

Table 5: The summary of results from the ANCOVA analysis for shoulder ROM

Variables	Exercise Group (n=)		Control Group (n=)		Between-group different (95%CI)	ANCOVA		
	Baseline (Mean±SD)	Post-test (Mean±SD)	Baseline (Mean±SD)	Post-test (Mean±SD)		$F_{(1,23)}$	P	η_p^2
SIR	44.4±8.1	49.5±8.5	43.7±8.4	44.7±7.7	4.8 (-0.7 to 10.4)	17.5	0.001*	0.35
SER	88.8±9.9	95.5±8.8	89.7±11.5	88.2±9.1	7.3 (1.1 to 13.5)	22.6	0.001*	0.42

ROM; Range of Motion, SIR; Shoulder Internal Rotation, SER; Shoulder External Rotation. *Indicate between-group difference, [a]Indicate within-group difference, [b]Indicate a significant correlation with WUSPI

Table 6: The summary of results from the ANCOVA analysis for scapular upward rotation

Variables	Exercise Group (n=)		Control Group(n=)		Between-group different (95%CI)	ANCOVA		
	Baseline (Mean±SD)	Post-test (Mean±SD)	Baseline (Mean±SD)	Post-test (Mean±SD)		$F_{(1,23)}$	P	η_p^2
SUR resting	3.0±4.3	5.3±5.8	2.9±5.4	2.6±5.5	2.7 (-1.2 to 6.6)	9.2	0.01*	0.23
SUR60	17.1±3.3	21.8±5.1	17.5±4.2	17.3±4.7	4.5 (1.2 to 7.9)	16.3	0.001*	0.35
SUR120	32.7±4.9	40.3±6.7	31.3±3.4	31.5±4.2	8.7 (4.8 to 12.6)	27.6	0.001*	0.48

SUR: Scapular Upward Rotation; *Indicate between-group difference, [a]Indicate within-group difference, [b]Indicate a significant correlation with WUSPI

Table 7: The summary of results from the ANCOVA analysis for pectoralis muscle length

Variables	Exercise Group (n=)		Control Group (n=)		Between-group different (95%CI)	ANCOVA		
	Baseline (Mean±SD)	Post-test (Mean±SD)	Baseline (Mean±SD)	Post-test (Mean±SD)		$F_{(1,23)}$	P	η_p^2
RPML	17.3±1.9	18.9±2.2	17.6±1.8	17.8±1.7	1.7 (0.4 to 3.0)	29.6	0.001*	0.49
APML	19.7±1.7	21.6±1.8	19.8±2.1	19.9±2.2	1.5 (0.2 to 2.7)	21.6	0.001*	0.41

RPML; Resting Pectoralis Minor Length, APML; Active Pectoralis Minor Length. *Indicate between-group difference, [a]Indicate within-group difference, [b]Indicate a significant correlation with WUSPI

There was also a statistically significant difference in GH ROM between the control and exercise group (F (4, 26)=21.4, P<0.001; Wilk's Λ=0.4, partial η^2=0.59). Univariate ANCOVA analysis discovered significant differences between control and exercise groups for shoulder IR (%Δ; EG=11.5 vs. CG=2.3) and ER (%Δ; EG=7.5 vs. CG=1.1) ROM in favor of the exercise group. These findings indicate that exercise training intervention significantly increased GHROM (Table 5).

There was also a statistically significant difference in SUR between the control and exercise group (F (4, 26)=16.3, P<0.001; Wilk's Λ=0.36, partial η^2=0.64). Univariate ANCOVA analysis discovered significant differences between control and exercise groups for SUR at arm resting (%Δ; EG=77 vs. CG=-10) in 60° (%Δ; EG=27.5 vs. CG=-1.2) and 120° (%Δ; EG=23.2 vs. CG=0.6) arm abduction, in favor of exercise group. These findings indicate that exercise training intervention significantly increased SUR (Table 6).

There was a statistically significant difference in PML between the control and exercise group (F (2, 30)=19.9, P<0.001; Wilk's Λ=0.43, partial η^2=0.57). Moreover, ANCOVA analysis discovered a significant difference between control and exercise groups for RPML (%Δ; EG=9.2 vs. CG=1.1) and APML (%Δ; EG=9.6 vs. CG=0.5) in favor of the exercise group. These findings also indicate that exercise training intervention significantly increased PML in resting and active positions (Table 7).

Discussion

The primary objective of this study was to examine the impact of a scapular stabilizer and rotator cuff-focused exercise intervention on the shoulder function and sports performance of elite wheelchair basketball (WCB) players who were experiencing chronic shoulder pain. The 8-week exercise program yielded promising results, including decreased shoulder pain, and improved shoulder muscle strength, glenohumeral ROM, and sports skills.

Our study observed a significant decrease of 38.7% in WUSPI scores after an 8-week exercise intervention. These findings align with previous studies on manual wheelchair users with spinal cord injuries [7, 14, 15]. Those studies demonstrated that a high-dose scapular stabilizer and rotator cuff strengthening program reduced WUSPI scores ranging from 40% to 70% over 12 to 24 weeks [7, 14, 15].

The magnitude of pain relief observed in our study is remarkable, as it exceeds the estimate of a minimal clinically significant chronic pain reduction in patients treated for rotator cuff disease (1.4 cm on a 10-cm VAS) [29]. This substantial pain relief enhances the athletes' overall well-being and performance.

Wheelchair basketball players face significant biomechanical challenges due to the repetitive nature and high biomechanical loads associated with sport-specific demands such as ball handling and overhead activities, as well as the repetitive nature of wheelchair propulsion and unfavorable sitting posture [6, 20]. These repetitive and sustained activities acutely lead to muscle fatigue and chronically lead to muscle imbalance that can cause altered posture and scapular orientation[6, 20]. These factors place considerable strain on the shoulder girdle tissues, leading to the risk of impairment and overuse injuries in WCB players [6, 20].

Wheelchair basketball (WCB) participation can lead to altered scapular orientation, including redacted scapular upward rotation, increased scapular anterior tilt, protraction, and increased shoulder internal rotation. These alterations can potentially decrease the subacromial space and contribute to the impingement of the underlying structures, leading to shoulder pain [6, 8, 30]. Athletes with shoulder pain often exhibit muscle imbalances, such as shortened pectoralis minor and upper Trapezius and weakened lower and middle Trapezius and Serratus anterior muscles [31]. To address these issues and promote muscle balance while correcting posture and scapular orientation, we designed an effective exercise protocol based on the theory that the repetitive nature of the wheelchair stroke pattern can cause muscle imbalances and shoulder pain [7].

Our study's observed increase in scapular upward rotation and pectoralis minor length may contribute to shoulder pain relief in wheelchair athletes. Previous research has shown that decreased scapular upward rotation and shortened pectoralis minor length, caused by scapular anterior tilting and protraction, are associated with shoulder impingement [32, 33]. Therefore, the greater amount of upward rotation and minor pectoralis length in our study could alleviate shoulder pain in wheelchair basketball (WCB) players by improving scapular kinematics.

Shoulder impingement syndrome is a common cause of shoulder pain in basketball players [7]. The increase in scapular upward rotation and pectoralis minor length may help relieve pain in WCB players by promoting better scapular motion and reducing the risk of impingement. Strengthening the middle and lower Trapezius muscles can neutralize the lateral translatory force related to the Serratus muscle and the elevation forces related to the upper Trapezius muscle, thereby helping to control scapular motions.

Furthermore, the increase in length of the upper Trapezius and pectoralis muscles observed in our study may contribute to improved scapular posterior tilting and external rotation, essential for normal scapular motions and shoulder range of motion. Anterior muscular tightness can lead to a lack of external rotation, altering the scapulohumeral rhythm and reducing posterior scapular tilt [31]. Previous studies have highlighted significant weakness in external rotator muscle strength among wheelchair users with shoulder pain [8, 34].

The improvement in external rotator muscle strength observed in our study aligns with previous research, which has also recommended strength training for these muscles as part of the rehabilitation treatment for wheelchair athletes with shoulder pain [34]. The targeted exercise intervention in our study effectively increased the strength of the external rotator muscles over the 8-week training period.

On the other hand, the strength of the internal rotator and Serratus anterior muscles did not show significant improvements in our study. This lack of significant increase may be attributed to the low to moderate intensity of the exercise training used. A previous study indicates that high-repetition doses have more pain relief effects than lower doses [7]; thus, the high-repetition, low-resistance loading pattern we chose may not be optimal for promoting hypertrophy, but it could lead to improved endurance of these muscle groups, which we did not directly assess.

Following the exercise training intervention, wheelchair basketball (WCB) skills improved, which was expected based on previous studies showing a significant correlation between shoulder pain levels and physical activity and sport performance scores [35, 36]. Gómez and Pérez-Tejero [36] found that athletes with shoulder pain had weaker WCB sports performance than those without pain. Chronic pain can impact athletes' attention and motor function, as both processes require limited capacity attention resources [37]. Thus, being pain-free allows athletes to focus more effectively on task implementation, leading to better sport skill scores.

Moreover, chronic pain reduces maximum and submaximal muscle strength and affects synergistic muscles' function through altered motor control [38], which can impair performance during skills requiring high muscle strength and coordination. The relief of shoulder pain through the exercise intervention may improve basketball sport performance through central effects on the motor control system, increased motor unit firing, and improved inter and intramuscular coordination. However, more in-depth studies are needed to explore these effects further. The implications of shoulder pain relief on sports performance are important for athletes and athletic trainers.

Several limitations should be acknowledged in the present study. Firstly, individual evaluations for each participant were not performed, and there were no radiological findings or other diagnostic data to determine the specific cause of shoulder pain in each participant. The study focused on the effects of a standardized intervention rather than individually prescribed, problem-specific shoulder treatment programs. Secondly, the sample size was relatively small, which could have influenced the results. Additionally, the study participants were limited to wheelchair basketball players, and the results may not be generalizable to non-athletic individuals or athletes in different sports. Despite these limitations, this study represents the first investigation into the effects of a scapular stabilizer and rotator cuff muscle-focused exercise intervention on shoulder pain and sports performance in wheelchair basketball players.

Conclusion

Following the 8-week conservative, targeted exercise intervention focused on the scapular stabilizer and rotator cuff muscles; we observed a significant reduction in shoulder pain among wheelchair basketball players with existing shoulder pain. This pain relief was also associated with improvements in sports performance.

However, to establish the full effectiveness of this exercise intervention, further research is warranted to compare its outcomes with other intervention approaches. Additionally, investigating the potential for earlier prevention interventions to mitigate the development of shoulder pain and related tissue pathology would be valuable.

In this context, exploring the impact of shoulder pain on wheelchair basketball sports skills would provide crucial insights for physiotherapists and coaches. Understanding how shoulder pain can affect sports performance can guide the health assessment and screening of players during the sports season, along with developing specific prevention training programs considering the shoulder joint.

Acknowledgment

This article is based on the BSc thesis of Danial Moslehpour, and it is reported here as a randomized clinical trial following the CONSORT guidelines. The authors would like to thank the wheelchair basketball players and coaches of Fars province for their wholehearted cooperation throughout the study.

Funding

This research was not funded by any specific public, commercial, or not-for-profit sector grant.

Conflict of Interest: None declared.

References

1. De Groot S, Balvers IJ, Kouwenhoven SM, Janssen TW. Validity and reliability of tests determining performance-related components of wheelchair basketball. Journal of Sports Sciences. 2012;30(9):879-87.
2. Ferrara M, Davis R. Injuries to elite wheelchair athletes. Spinal cord. 1990;28(5):335.
3. Webborn N, Emery C. Descriptive epidemiology of Paralympic sports injuries. PM&R. 2014;6(8):S18-S22.
4. Akbar M, Brunner M, Ewerbeck V, Wiedenhöfer B, Grieser T, Bruckner T, et al. Do overhead sports increase risk for rotator cuff tears in wheelchair users? Archives of physical medicine and rehabilitation. 2015;96(3):484-8.
5. Yildirim NU, Comert E, Ozengin N. Shoulder pain: a comparison of wheelchair basketball players with trunk control and without trunk control. Journal of back and musculoskeletal rehabilitation. 2010;23(2):55-61.
6. Heyward OW, Vegter RJ, De Groot S, Van Der Woude LH. Shoulder complaints in wheelchair athletes: A systematic review. PloS one. 2017;12(11):e0188410.
7. Curtis K, Tyner T, Zachary L, Lentell G, Brink D, Didyk T, et al. Effect of a standard exercise protocol on shoulder pain in long-term wheelchair users. Spinal cord. 1999;37(6):421.
8. Morrow MM, Hurd WJ, Kaufman KR, An K-N. Shoulder demands in manual wheelchair users across a spectrum of activities. Journal of Electromyography and Kinesiology. 2010;20(1):61-7.
9. Stirane D, Kiukucane E, Vetra A, Nulle A, editors. The consequences of shoulder pain intensity on quality of life and community participation in paraplegic wheelchair users. SHS Web of Conferences; 2012: EDP Sciences.
10. Wang J-C, Chan R-C, Tsai Y-A, Huang W-C, Cheng H, Wu H-L, et al. The influence of shoulder pain on functional limitation, perceived health, and depressive mood in patients with traumatic paraplegia. The journal of spinal cord medicine. 2015;38(5):587-92.
11. Nickel R, Lange M, Stoffel DP, Navarro EJ, Zetola VF. Upper limb function and functional independence in patients with shoulder pain after stroke. Arquivos de neuro-psiquiatria. 2017;75(2):103-6.
12. Ballinger DA, Rintala DH, Hart KA. The relation of shoulder pain and range-of-motion problems to functional limitations, disability, and perceived health of men with spinal cord injury: a multifaceted longitudinal study. Archives of physical medicine and rehabilitation. 2000;81(12):1575-81.
13. Dorrestijn O, Stevens M, Winters JC, van der Meer K, Diercks RL. Conservative or surgical treatment for subacromial impingement syndrome? A systematic review. Journal of shoulder and elbow surgery. 2009;18(4):652-60.
14. Mulroy SJ, Thompson L, Kemp B, Hatchett PP, Newsam CJ, Lupold DG, et al. Strengthening and optimal movements for painful shoulders (STOMPS) in chronic spinal cord injury: a randomized controlled trial. Physical therapy. 2011;91(3):305-24.
15. Van Straaten MG, Cloud BA, Morrow MM, Ludewig PM, Zhao KD. Effectiveness of home exercise on pain, function, and strength of manual wheelchair users with spinal cord injury: a high-dose shoulder program with telerehabilitation. Archives of physical medicine and rehabilitation. 2014;95(10):1810-7. e2.
16. Cratsenberg KA, Deitrick CE, Harrington TK, Kopecky NR, Matthews BD, Ott LM, et al. Effectiveness of exercise programs for management of shoulder pain in manual wheelchair users with spinal cord injury. Journal of Neurologic Physical Therapy. 2015;39(4):197-203.
17. Wilroy J, Hibberd E. Evaluation of a shoulder injury prevention program in wheelchair basketball. Journal of sport rehabilitation. 2018;27(6):554-9.
18. Curtis KA, Roach KE, Brooks Applegate E, Amar T, Benbow CS, Genecco TD, Gualano J. Development of the wheelchair user's shoulder pain index (WUSPI). Spinal Cord. 1995 May;33(5):290-3.
19. Norris ES, Wright E, Sims S, Fuller M, Neelly K. The reliability of smartphone and goniometric measurements of hip range of motion. Journal of Rehabilitation Sciences & Research. 2016;3(4):77-84.
20. Johnson MP, McClure PW, Karduna AR. New method to assess scapular upward rotation in subjects with shoulder pathology. Journal of Orthopaedic & Sports Physical Therapy. 2001;31(2):81-9.
21. Visser J, Mans E, De Visser M, Van den Berg-Vos R, Franssen H, De Jong J, et al. Comparison of maximal voluntary isometric contraction and hand-held dynamometry in measuring muscle strength of patients with progressive lower motor neuron syndrome. Neuromuscular disorders. 2003;13(9):744-50.
22. Michener LA, Boardman ND, Pidcoe PE, Frith AM. Scapular muscle tests in subjects with shoulder pain and functional loss: reliability and construct validity. Physical therapy. 2005;85(11):1128-38.
23. Finley M, Goodstadt N, Soler D, Somerville K, Friedman Z, Ebaugh D. Reliability and validity of active and passive pectoralis minor muscle length measures. Brazilian journal of physical therapy. 2017;21(3):212-8.
24. Gorostiaga EM, Llodio I, Ibáñez J, Granados C, Navarro I, Ruesta M, et al. Differences in physical fitness among indoor and outdoor elite male soccer players. European journal of applied physiology. 2009;106(4):483-91.
25. Brasile FM. Wheelchair basketball skills proficiencies versus disability classification. Adapted Physical Activity Quarterly. 1986;3(1):6-13.
26. Vanlandewijck Y, Daly D, Theisen D. Field test evaluation of aerobic, anaerobic, and wheelchair basketball skill performances. International journal of sports medicine. 1999;20(08):548-54.
27. Nawoczenski DA, Ritter-Soronen JM, Wilson CM, Howe BA, Ludewig PM. Clinical trial of exercise for shoulder pain in chronic spinal injury. Physical therapy. 2006;86(12):1604-18.
28. Muyor JM. Exercise intensity and validity of the ratings of perceived exertion (Borg and OMNI Scales) in an indoor cycling session. Journal of human kinetics. 2013;39(1):93-101.
29. Tashjian RZ, Deloach J, Porucznik CA, Powell AP. Minimal clinically important differences (MCID) and patient acceptable symptomatic state (PASS) for visual analog scales (VAS) measuring pain in patients treated for rotator cuff disease. Journal of Shoulder and Elbow Surgery. 2009;18(6):927-32.
30. Morrow MM, Kaufman KR, An K-N. Scapula kinematics and associated impingement risk in manual wheelchair users during propulsion and a weight relief lift. Clinical biomechanics. 2011;26(4):352-7.
31. Page P. Shoulder muscle imbalance and subacromial impingement syndrome in overhead athletes. International journal of sports physical therapy. 2011;6(1):51-8.
32. Finley MA, Ebaugh D. Association of Pectoralis Minor Muscle Extensibility, Shoulder Mobility, and Duration of Manual Wheelchair Use. Archives of physical medicine and rehabilitation. 2017;98(10):2028-33.
33. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. Journal of orthopaedic & sports physical therapy. 2005;35(4):227-38.
34. Burnham RS, May L, Nelson E, Steadward R, Reid DC. Shoulder pain in wheelchair athletes: the role of muscle imbalance. The American journal of sports medicine. 1993;21(2):238-42.
35. Gutierrez DD, Thompson L, Kemp B, Mulroy SJ. The relationship of shoulder pain intensity to quality of life, physical activity, and community participation in persons with paraplegia. The journal of spinal cord medicine. 2007;30(3):251-5.
36. Gómez SG, Pérez-Tejero J. Wheelchair basketball: influence of

shoulder pain in sport skills. Revista de psicología del deporte. 2017;26(1):45-9.
37. Brewer BW, Van Raalte JL, Linder DE. Effects of pain on motor performance. Journal of Sport and Exercise Psychology. 1990;12(4):353-65.
38. Graven-Nielsen T, Arendt-Nielsen L. Impact of clinical and experimental pain on muscle strength and activity. Current rheumatology reports. 2008;10(6):475.