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The effect of perturbation training on volleyball players' strength, proprioception and performance

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Abstract

Background: Perturbation training which is in the context of volleyball routine practice is a type of neuromuscular exercises that is useful in overhead sports; leads to contraction responses through unpredictable perturbation.

Aim: The present study aims to investigate the effects of perturbation training on volleyball players strength proprioception and performance.

Materials and Methods: Twenty-four volunteer male volleyball players (age: 24.42±2.15 years; height: 181.46±3.00m; Weight: 73.87±3.77kg; BMI: 22.43±0.80) were recruited and randomly assigned into perturbation and control groups, Before the intervention, a set of isokinetic dynamometry was carried out to measure shoulder proprioception as well as rotator cuff muscles strength, what is more, the upper extremity performance was evaluated using Y-Balance Test. For a course of 6 weeks, players of the perturbation group implemented perturbation trainings, 3 times weekly while the control group performed its routine training. The dynamometry was repeated at the end of training period to compare trainings outcome. The Repeated Measures ANOVA statistic was used to find differences between groups.

Results: A significant difference in shoulder proprioception, as well as the YBT-UQ test, was observed between the groups; Also, the ANOVA showed a significant difference ($P<0.05$) in functional strength ratio followed by 6 weeks of perturbation training.

Conclusion: Perturbation trainings might have benefit to volleyball players conditioning by improvement rotator cuff strength, shoulder proprioception and upper extremity performance. Given this adopting kind of training as a part of regular basic training for volleyball players is highly recommended.

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1. Introduction

Volleyball is a complex and regular sport that requires high technique and tactics and is considered safer than other sports such as football, handball, basketball. The reason for this hypothesis is that in other sports, contact with opposing players is considered part of the game, while volleyball is a non-contact sport [1]. Most volleyball skills such as spike, set, serve, and block require repeated contact of the upper limb with the ball in the overhead position which can cause shoulder malfunction in the long term [2]. Performing repetitive and strong overhead movements will put too much load on the shoulder griddle, causing an imbalance and muscle weakness in the shoulder area [3]. Volleyball is the third most common type of sport including injuries among ball sports [4]. Researchers have also reported shoulder injuries in about 40% of athletic injuries in high school, university, and elite levels [5].

Musculoskeletal injuries are the most common cause of volleyball injuries, with injuries ranging from 1.7 to 10.7 injuries per 1000 hours [6]. Therefore, identifying risk factors and developing strategies for injury prevention are important components of preventive programs in sports injuries [7].

Since volleyball is a non-collision sport, its risk factors may be more related to repetitive overhead movements and changes in biomechanics (i.e., joint mobility, coordination, and disruption of the throwing technique) [8]. Other risk factors include asymmetric tilts and transitional patterns in the shoulder griddle in overhead movements which can cause imbalance and muscle weakness in the shoulder area [3]. Shoulder muscle imbalance is weaker in the external rotator muscles than in the internal rotator. This causes a difference in the range of motion in the internal and external shoulder joint rotation [9]. Deficiency in proprioception also causes impaired activity control, muscle timing, and joint disorganization [10, 11]. In general, a defect in neuromuscular control is a consequence of injury to the shoulder griddle [12]. Improvement of neuromuscular control and dynamic stability in the shoulder joint requires improvement of the neuromuscular system [13]. Perturbation training can help improve the neuromuscular system because of the variety of exercises and the similarity to the specific needs of the sport [12]. Perturbation training can help facilitate neuromuscular control and speed up the response to unexpected external stimuli [14]. This facilitation of neuromuscular control occurs by facilitating the improvement of partner muscles in motion as well as coordination in the motor chain [15].

Disturbances in overhead movements cause to bring about unpredictable changes in tissue length and muscle contraction response patterns. Perturbation training compared to other overhead exercises helps improve neuromuscular control due to the random nature and the unexpected forces that require both muscle activity preparation and muscle activity response to the stimulus. Performing perturbation exercises at the end of the range of motion improved the efficiency of these exercises because the capsular structures in the range were tightened which increased the sensory signals and increased activity of the muscles involved. In addition, these exercises can improve the sense of articulation [13].

To prevent the problems that a volleyball player may face and the high costs of treating injured people, it is essential to identify those at risk who can be rescued by providing appropriate preventive training. Muscle strength, proprioception and shoulder stability are the main factors of increasing the athlete's performance. Improving these factors is one of the important goals of coaches and athletes.

Our goal in this study is to investigate the effect of 6 weeks of upper extremity perturbation training on the functional rotator cuff muscle strength, shoulder joint proprioception, and upper body performance in college male volleyball players.

2. Materials and Methods

2. 1. Participation

The present prospective study population consists of academic male volleyball players prone to upper extremity injuries. Out of the whole study population, 24 individuals (Dominant hand: Right; age: 24.42±2.15 years; height: 181.46±3.00m; weight: 73.87±3.77kg; BMI: 22.43±0.80) were selected as the study sample size according to study inclusion criteria. Participants were then assigned to experimental (perturbation training) and control (no intervention) groups, each including 12 subjects. Inclusion criteria include: 1. Obtain less than 30 points on the CKCUEST test; 2. General health; 3. BMI between 19 and 25; 4.

Be right-handed. Exclusion criteria include: 1. Upper extremity injury in the past 6 months; 2. Missing more than three sessions in practice period; 3. Musculoskeletal abnormalities in the upper extremity; 4. Dissatisfaction with training. The CKCUEST test was used to identify people who were prone to upper limb injury.

2. 2. Procedure

All subjects completed a brief personal history form regarding date of birth, number of years of playing, and dominant arm and shoulder injuries. The present study included pre-test and post-test stages. In the pre-test phase, rotator cuff muscle strength and shoulder proprioception were measured by an isokinetic dynamometer. Upper extremity performance was also assessed by the Y Balance Test. Next, the experimental group performed an exercise program for 6 weeks, 3 sessions per week of perturbation training. The control group, on the other hand, only performed their routine pre-season training and did not participate in any regular perturbation training program. After completing the protocol, the post-test started under the same conditions as the pre-test.

2. 2. 1. Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) to identify people prone to injury

Two strips with a width of 1.5in were placed parallel to each other 36in apart on the tile floor measured with a standard tape measure. The starting position for the test was one hand on each piece of tape while assuming a push-up position (Figure 1). They had to pass one hand across their body and touch the tape line on the other side (left-hand-right tape cycle and diverse). After touching the hand, it returns to the initial state. Touches were counted as the number of touches by both hands. The total time for each trial was 15 sec. After warming up, the subject performs three tests and rests for 45 sec between each test. Average of the three tests used for data analysis [16].

2. 2. 2. Evaluation of the rotator Cuff muscles' proprioception using isokinetic system

Determine maximum external rotation (ER) and internal rotation (IR) to assess shoulder joint proprioception. Proprioception is measured by applying joint-position reproduction, with a target position at 50% ROM. The test started at the initial position (IR or ER) and progressed to the target position, which the participant held for 5 sec to be measured. Variations of ±5° around the target position were allowed. If this variation exceeds, the trial was discarded and repeated. Three tests for each movement direction (ER-IR and IR-ER) perform (6 tests). Just the dominant arm tested. The participants were blindfolded and given task instructions orally by the examiner. The difference between the position reproduced and the position experienced determines individual error [17].

__2. 2. 3. Assessing isokinetic shoulder rotator cuff muscle strength__

The pre-test and post-test of muscular strength with the isokinetic-engaged concentric internal rotator and eccentric external rotator peak torque assessments on the dominant shoulder. According to Wang et al. (2000), an angular velocity of 120° per second was chosen to reduce the risk of injury [18]. For warm-up and familiarization, the subject performed 10 passive contractions. Throughout the assessments, the subjects were seated without their legs touching the ground. A waist strap secures the trunk to the chair. The shoulder is abducted at 90° and the elbow flex at 90° (Figure 2).

Figure 1. CKCUEST test to identify people prone to injury

Figure 2. Subject positioned for isokinetic strength assessment

The range of motion for the test is set at 90° of external rotation and 30° of internal rotation (120°) because exceeding this range increases the risk of injury. First, the internal rotation concentric contraction and then the external rotation eccentric contraction were measured. Subjects each performed five maximal contractions [19].

__2. 2. 4. Y-balance test__

Y balance test performs to evaluate upper extremity performance. Y Balance Test Kit consists of a stance platform in which three pieces of polyvinyl chloride tube attach in the medial, inferolateral, and superolateral reach directions. The angle between the posterior and anterior pipe is 135°, and between the posterior is 90°. Each pipe mark is in 0.5 cm increments for measurement. To the right-hand reach distance, the subject placed the right hand on a stance plate while the left reached the medial direction, immediately following the inferolateral and finally in the superolateral. After 3 trials on the right limb, the mean of three attempts was calculated and recorded. For normalization, the reach distance of each direction divides into the length of the upper limb (Distance from the C7 spinous process to the most distal tip of the right middle finger (cm) in 90° shoulder abduction) [20].

$$\text{Total score} = \frac{\text{Medial} + \text{Inferolateral} + \text{Superolateral}}{3 \times \text{Upper limb length}} \times 100$$

2. 2. 5. Intervention and Protocol

Perturbation exercises were performed for 6 weeks, 3 sessions per week and 30 min (warmup 5 min, perturbation training 20 min, cool down 5 min) per session. The training protocol included 11 exercises [13] (Figure 3).

Figure 3. Perturbation training

Exercises include forearm supination/ pronation, overhead press, waiter's walk, overhead lunge, windmill, overhead squat, overhead barbell walk, rocker board, wobble board.

2. 3. Statistic

Spss (version 22) use to analyze all data. Shapiro-Wilk and 2-factor repeated measures analysis of variance (ANOVA) with one between-subjects factor (group) and one within-subjects factor (time) were used to examine the normality of the data and inter-group and intra-group changes ($\alpha \leq 0.005$), respectively.

3. Results

Shapiro-Wilk test indicated the normality of data in both perturbation and control groups. The anthropometric data showed in Table 1.

Table 1. Characteristics of participants

Variable	(Mean ± SD) Perturbation	(Mean ± SD) Control	P-Value
Age	24.00 ± 2.13	24.83 ± 2.17	0.353
Weight	75.34 ± 4.25	72.41 ± 2.66	0.055
Height	182.42 ± 3.15	180.50 ± 2.65	0.121
BMI	22.63 ± 0.89	22.23 ± 0.68	0.224
CKCUEST	27.42 ± 1.44	27.33 ± 1.72	0.899

3. 1. Isokinetic strength

3. 1. 1. Peak torque values at 120° s^{-1}

Mean concentric and eccentric isokinetic peak torque (PT/BW) values for IR and ER showed in Table 2. The results showed that both concentric IR (F[1,22]= 7.017, *P*= 0.015) and eccentric ER (F[1,22]= 5.268, *P*= 0.032) peak torque was a significant difference between-subjects in the post-test. There was a significant increase in pre- to post-test (within-subjects) in peak torque values for concentric IR (*P*<0.0001) and eccentric ER (*P*<0.0001).

3. 1. 2. Functional strength ratio

Pre-and post-test ratios (eccentric ER strength/ concentric IR strength) showed in Table 2. The ANOVA revealed a statistically significant difference between-subjects for functional strength ratio (F[1,22]= 4.924, *P*= 0.037) and for within-subject pre- to post-test in the perturbation group (F[1,22]= 69.706; *P*<0.0001).

3. 1. 3. Proprioception

There was a significant difference between-subjects (F[1,22]= 0.17.495, *P*<0.0001) and between the pre-and post-test (within-subjects) in the perturbation group (*P*<0.0001; Figure 4). Results showed that shoulder internal and external proprioception significantly decreased in the perturbation group.

3. 1. 4. YBT-UQ test

The mean reach distance for all directions of YBT-UQ is present in Table 3. A significant difference was noticed between-subjects in the medial (F[1,22]= 6.159, *P*=0.021), superolateral (F[1,22]= 5.111, *P*=0.034), inferolateral (F[1,22]= 4.457, *P*=0.046), and composite score (F[1,22]= 5.212, *P*=0.032) and also there was a significant difference within-subjects in medial (F=7.701, *P*=0.011), superolateral (F=51.229, *P*<0.0001), inferolateral (F=344.049, *P*<0.0001) and composite score (F=166.764, *P*<0.0001) of YBT-UQ test.

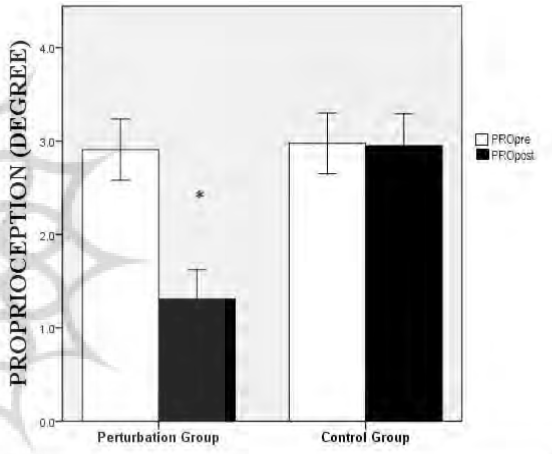

Figure 4. Pre- to post-test mean joint position sense (degree) between the 2 groups. PRO= proprioception; pre = pre-test; post = post-test. * Significant difference (*P*< 0.05) from PRO pre-test

Table 2. Mean concentric and eccentric peak torque values (N.M/BW) for internal rotation (IR) and external rotation (ER) of the dominant shoulder at 120°.s^{-1}. CON = concentric IR: ECC = eccentric ER.

	Mean ± SD		F	Sig. (2-tailed)
	Pre test	**Post Test**		
Concentric IR pre-post test	52.808 ± 2.656	53.883 ± 3.159	240.385	0.000
Eccentric ER pre-post test	36.579 ± 1.666	36.967 ± 1.713	17.807	0.000

* Significant difference (*P*< 0.05) from CON IR pre-test value. † Significant difference (*P*< 0.05) from ECC ER pre-test value

Table 3. Functional (external rotation/ internal rotation) strength ratios at 120°.s-1 in N.m*

	Pre EX/IR ratio 120°.s^{-1}	Post EX/IR ratio 120°.s^{-1}
Perturbation	0.693 ± 0.010	0.678 ± 0.009
Control	0.693 ± 0.009	0.695 ± 0.008

* Pre = pre-test; post = post-test; ER = External Rotation; IR = Internal Rotation

Table 4. Mean reach distance of YBT-UQ in Cm*

Group		Pre	Post
Perturbation	M	103.99 ± 1.89	104.88 ± 1.03
	Sly	74.88 ± 2.29	77.62 ± 1.94
	IL	83.53 ± 3.62	88.49 ± 3.20
	C	93.55 ± 1.23	96.63 ± 1.47
Control	M	103.09 ± 1.30	103.06 ± 1.23
	SL	74.53 ± 1.71	74.32 ± 2.17
	IL	83.67 ± 1.75	83.69 ± 1.80
	C	93.84 ± 1.48	93.75 ± 1.50

* Pre = pre-test; post = post-test; M = Medial direction; SL = Superolateral; Il = Inferolateral; C= Composite Score

4. Discussion

The present study aim is to investigate the effect of 6 weeks of upper extremity perturbation training on the functional rotator cuff muscle strength, shoulder joint proprioception, and upper body performance in college male volleyball players. Twenty-four volleyball players are prone to upper limb injuries were studied. The results showed that the concentric strength of the internal rotators and the eccentric strength of the external rotators increased, and the functional strength ratio of the rotator cuff muscles decreased after 6 weeks in the experimental group.

Most researches have focused on improving muscle strength, which is known as the basis of physical activity. Exercises such as weight-based exercises [21], ballistic and explosive resistance exercises [22], electrical stimulation exercises [23], and vibration exercises [24] have been used to improve and increase strength. Reasons to improve strength include the adaptation of the neuromuscular system such as increased firing frequency, improved coordination of motor units, increased excitability of motor units, and increased motor unit flow [25]. The shoulder is a joint with a high range of motion. To generate force in the joint needs sufficient stability. External and internal rotator muscles are the most important muscles of the shoulder area to stabilize shoulder joint movements. To keep the humerus head in the glenoid cavity, a balance of a couple of forces between the external and internal rotators is required; hence, in assessing upper extremity strength, measuring the ratio of external and internal rotator power is the most important factor for injury prevention. Some researchers have reported a normal range of FDR ranging from 0.66 to 1.54 and a BR range between 0.46 and 1.05, which varies depending on the type of test. FDR is the ratio of the eccentric strength of the external rotator muscles to the concentric contraction strength of the internal rotator muscles, whereas BR is the ratio of the eccentric contraction strength of the rotator cuff muscles. Ellenbecker et al. (2004) reported a normal range of shoulder functional strength ratio from 0.6 to 0.75 [26]. If this ratio is less than 0.6 or greater than 0.75, it is considered abnormal. In this case, the muscles become imbalanced, and the risk of shoulder injury increases. Perturbation during overhead activity can cause changes in movement patterns through unexpected changes in muscle length and quick response to muscle contraction [27]. During training, joint forces balance due to improvements in a couple of forces [28]. Improvement in joint forces increases the efficiency of neuromuscular control and better dynamic stability than the dependence on non-contractile tissues involved in static stability [27, 28]. Perturbation exercises are more effective in neuromuscular control than other overhead exercises because of randomness and unpredictable movements [15]. Therefore, these exercises can be useful for improving movement patterns, enhancing function, and injury prevention.

After 6 weeks, perturbation training showed a significant effect on the proprioception of the shoulder joint in the experimental group. The findings indicated a decrease and improvement in shoulder joint proprioception, which is consistent with previous studies [17, 29, 30, 31].

Swanik et al. (2002) found that plyometric exercises improved shoulder sensation. The peripheral and central nervous adaptations that occur with plyometric exercises improve joint proprioception. These adaptations may be due to repeated stimulation of the mechanical receptors around the joint at the end of the range of motion during exercise. Quick length-tension changes of tendon-muscle structures during eccentric loads facilitate the spindle and Golgi's tendon adaptation. Muscle stretching increases the sensitivity of the muscle spindle, which increases the cooperation of sensory nerves with the central nervous system and finally improves depression [31].

Proprioception receptors identify changes in joint angle, muscle length, and muscle strength. The muscle spindle is one of the proprioceptive receptors. Muscle spindles regulate the activity of alpha motor neurons and participate in tensile reflexes by responding to changes in muscle length or tissue elongation ratio. In this study, the limb position was selected for training at the end of the range of motion because it would challenge proprioception and motor control.

Janwantanakul et al. (2001) reported that joint proprioception improved at the end of the ROM more than at other positions. At the end of the range of motion, the joint capsule is stretched, and the input sensory impulses increase, which activates the muscles further [11].

The upper extremity function evaluates by the Y-balance test. The results showed a significant increase in distance reach in all directions of the Y-balance test after 6 weeks of perturbation training in the experimental group. Most studies have compared the upper extremity function of athletes in different sports or injuries. Upper extremity performance can evaluate by various tests such as Y-balance, CKCUEST, medicine ball throw, etc. Research evaluating upper-extremity performance with Y-balance was scarce.

Fathi et al. (2019) found that strength and plyometric training improved throw performance in adult volleyball players. They suggested strength or plyometric exercises to volleyball-specific exercises to improve performance [32].

In another study, Ignjatovic et al. (2012) showed that resistance training improved the distance of throwing the medicine ball and increased performance [33]. Shoulder movements are the result of a complex process of synthesizing central and peripheral nervous system information for the design, coordination, and synergy of afferent and efferent neurons in feedback and feedforward processes [34]; hence, the performance of overhead athletes requires a static and dynamic stabilization mechanism for coordinating the glenohumeral and thoracic joints to produce an appropriate motor response [11]. Perturbation training facilitates neuromuscular control increases the speed of response to disturbances, and can increase upper extremity function [14].

Facilitation of neuromuscular control probably occurs through the facilitation of the recovery of partner muscles in motion as well as coordination in the kinetic chain from the proximal to the distal limbs [15]. Perturbation may improve coordination in muscle contraction, promote function, and reduce injury [27].

5. Conclusions

Due to the effect of perturbation training on performance, strength, and proprioception, these exercises recommend to coaches and athletes whose upper extremity performance is impaired or at risk of injury.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design: Writing, Review and Editing [all authors], Methodology [all authors], Supervision [Maliheh Hadad Nezhad], Advisor [Mahdi Khaleghi Tazji].

Ethical considerations

The authors have completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.
Ethical Code: (IR-KHU.KRC.1000.129)

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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