The Effect of a Debilitating Fatigue Session on Shoulder Muscle Strength of Young Bodybuilders

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Abstract

Introduction: shoulder muscle fatigue in exercise is very common among bodybuilders. Fatigue can lowers the performance quality and seriously damage athletes' shoulder joints. This study aimed to determine the effect of fatigue on the force of flexor, extensor, elevator, depressor, retractor, and abductor shoulder muscles in young bodybuilders after a session of debilitating fatigue. **Materials and Methods:** In this quasi-experimental study with a pre-test and post-test design, 25 active athletes in the field of bodybuilding (age: 26.12±2.78 years, height: 1.82±0.035 m, weight: 78.92±4.23 kg, BMI: 23.71±1.40 kg / m2, and sport history: 2.96±0.97 years) were selected. Before and after the fatigue, the force of flexor, extensor, elevator, depressor, retractor, and abductor muscles of shoulder was evaluated using a portable tensile-compression tachometer. To analyze the statistical part, the paired samples t-test was used to compare the fatigue protocol. **Results:** The results of the study showed a reprise of debilitating fatigue reduced the force of flexor (P=0.001), extensor (P=0.001), elevator (P=0.001), depressor (P=0.001), retractor (P=0.001), and abductor (P=0.001) of shoulder muscles. **Conclusion:** In general, the results of the present study showed the effect of fatigue on the reduction of flexor, extensor, elevator, depressor, retractor and abductor muscles of the shoulder, and this force decrease can be a factor for reducing performance quality in fatigue conditions and probably increasing the risk of injury in athletes.

Keywords: Bodybuilding; Force; Fatigue; Shoulders

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Introduction

Today, many people in the world engage in sports activities. In recent years, one of these sports which have attracted the attention of many young people and athletes is bodybuilding (1). Bodybuilding is a sport similar to weightlifting, strongest men competitions and Olympic weightlifting, aimed at raising muscle mass, symmetry, and introducing the body(2). Most of the injuries resulting from bodybuilding are in the shoulder, elbow, spine, lumbar, and knee(3). Muscular sprains and strains are the most common type of injury and account for 46.1% of all resistance training injuries. Most bodybuilders complain of pain and lack of interruptions in training(4). Bodybuilders are trying to reach an ideal muscular body. For some athletes, the sport may become a constant struggle to achieve the best body. Serious injuries, which usually occur during exercise with weight, include vascularization, tension, tendon ruptures, and compartment syndrome(5). Common critical injuries include inflammation of the rotator cuff tendon and patellar tendinopathy, as well as stress fracture injury in the vertebras, clavicle, and upper limb(5). Undoubtedly, studying the mechanism of shoulder injury in exercise in addition to a better understanding of shoulder injuries would help us to consider a proper recovery and treatment process for these injuries and, more importantly, by understanding how shoulder damage happens, more effective prevention protocols could be designed (6). The injuries that occur in the shoulder part include pectoral (chest) muscle injury, rotator cuff muscle rupture, supraspinatus muscle tendonitis, scapular, biceps, and triceps due to repetitive and improper movements (5). Glenohumeral joint is considered to be the most mobile and least stable joint because there is a mismatch between joint proximal surfaces of the humeral head and glenoid components (7). The addition of fibrous-cartilaginous labrum, the presence of joint capsule and glomerular joint ligaments enhance the stability of the shoulder joint. The joint stability , in addition to static stabilizer structures, is further supported by the muscles around the shoulder girdle, which provide its dynamic stability (8). The dynamic stability of the shoulder joint is the result of the neuromuscular control between scapular muscles and rotator. The dynamic stability of the shoulder joint is the result of the neuromuscular control between scapular muscles and the rotator cuff. Scapular muscles decrease instability in the shoulder joint with proper orientation, and rotator cuff muscles result in the compression of the arm in the glenoid cavity, as well as with their non-symmetric shrinkage, thereby causing the rotation of the arm during the shoulder movement (6).

Fatigue is defined as an unknown phenomenon to decrease power generation capacity regardless of the performed operation. Fatigue is also associated with the break-in of events from the central nervous system to the muscle fibers (9, 10). Fatigue in workouts is an integral part of the exercise during and after the workout (9). Muscle fatigue resulting from exhaustive activity is a common phenomenon that occurs during exercise, impairing the motor performance of individuals (9). Muscle fatigue as one of the important risk factors in the occurrence of sport injuries is inevitable and paying attention to this importance in prevention of sport injuries is very necessary (11, 12). On the other hand, the shoulder joint provides a large part of its strength through its surrounding muscles and the role of the muscles in the dynamic strength of this joint is crucial (13). Fatigue in different muscles can negatively affect joint stability. For example, fatigue in rotator cuff muscles may cause disruption in the rhythm of the glenohumeral joint movement (14). Attention to the endurance and strength of shoulder girdle muscles and, more importantly, coordination and balance between different muscle groups involved becomes more important when the desired exercise involves repetitive movements of the upper limb with the exercise of high force (15).

Although there is evidence to support the relationship between the excessive uses of the arm and the development of shoulder pain, there is a weakness in the documents which examine how overuse of the arm plays an important role in shoulder pain. One of the biomechanical mechanisms that may explain this association is changes in the kinematics of the scapula and arm secondary to fatigue of the shoulder girdle muscles. Studies have shown that when shoulder muscles fatigue, the joint mechanism changes, thereby leading to pathologies such as tendon inflammation, impingement, and even partial dislocations or dislocation (16-19). In addition, shoulder muscle fatigue directly affects how the scapula and arm move. Hence, kinematics of the shoulder largely depends on the surrounding muscles. Fatigue in any of these muscles can lead to a change in normal kinematics of the arm and shoulder (16, 20). Therefore, the aim of this study was to investigate the effect of exhaustive fatigue on flexor, extensor, elevator, depressor, retractor, and abductor shoulder muscles in young bodybuilders.

Materials and Methods

Participants

The present study was a quasi-experimental study with a pre-test and post-test design without control group registered in the Ethics Committee of Islamic Azad University - Tehran Shargh (IR.IAU.ET.REC.1400.025). The total number of 25 professional bodybuilders from Tolo-E-Dobareh located in Tehran-Pakdasht, at the age of 18-30, were selected as the statistical sample calculated by G*Power software (Statistical power 0.8, P value 0.05, effect size 0.24) (21). Inclusion criteria were having professional bodybuilding record at least 5 last years, having a history of at least 2 provincial tournaments, age range of 18 to 30 years, and lack of orthopedic damage in shoulder area. The exclusion criteria were using non-permitted supplements on the day of test, and any pain and injury in the neck, shoulder, upper breast area, back, and arm. The present study was carried out with only one experimental group (25 individuals). The force amount was measured by a portable tension and compression machine (JTECHOn Site commander) before starting the exercise and it was also redone after the fatigue protocol was completed. Due to the Covid-19 Pandemic in the process of the study, all health care tips were performed.

Assessment of **force**

After marking anatomical points which identify the location of tension and compression machine (including midpoint of inner edge of scapula, acromion appendage, elbow appendage, and pisiform wrist bone), providing details on how to perform the test, and explaining the individuals to apply maximum force for 10 minutes(22), the individuals were warmed under the observer's control. Afterward, the fatigue protocol was implemented and then the person was laid on the bed to measure the force amount. The forces were measured by the researcher using a portable tension and compression machine. In this way, before recording the force amount in each motion, the person was asked to perform the motion in sub-maximum state once. Next, the force of each motion was measured by two repetitions two repetitions maximum for 4 seconds and 2 seconds of rest between two iterations. The first iteration (training repetition) was removed in the data registration process (23). The selected motion for measuring the force were movements of elevation, depression, protraction, flexion, extension and abduction in both shoulders.

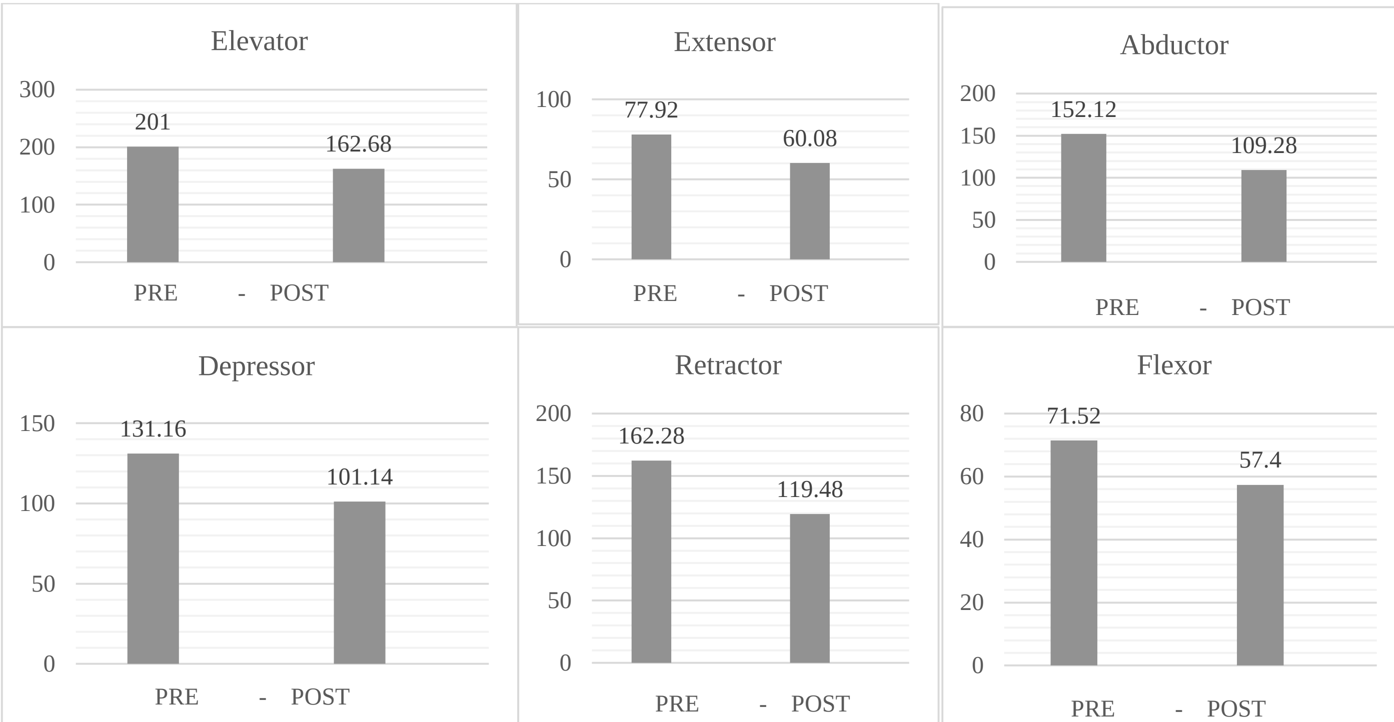

Figure 1. Pre- Post test results of force in the experimental group

Front barbell shoulder press | Lat Pulldown | Pullups | Back barbell shoulder press | Dumbbell shoulder press

Figure 2.Fatigue training protocol

Motion for measuring the force was elevation, depression, protraction, flexion, extension, and abduction in both hands. The status of the force measurement was as follows:

The attached belt was placed on the top of the elbow Olecranon process to measure the exercise force of the flexion, extension, and abduction. In the elevation motion, the push pad was placed right at the inner side of the acromion process (23, 24). In the depression and retraction exercises the experimenter dragged the loop attached to the machine using the examiner to keep the fingers closed. This aid was designed to reduce the fatigue interaction between the fingers and wrists flexor muscles in order to catch the device loop (23, 24). Due to the fact that this study was conducted during the Covid-19 epidemic, each device was disinfected by the researcher once it was used.

Since the data distribution was normal, the paired sample t-test was used in the present study indicated in Table 1 and Figure 1.

Fatigue protocol

The fatigue protocol was carried out by a weight including Lat Pulldown training, shoulder with barbell from front and back, shoulder press, and horizontal bar. For all items, the maximum strength in each move (Lat Pulldown, shoulder with barbell from front and back, shoulder press) was calculated for each person, and then the maximum strength of 60% was repeated 6 times. The final exercise of bar (Pullups) was carried out and the person had to do the exhaustive movement. The break time between each move was 30 seconds (25).

The order of execute training with weights to create the fatigue protocol is shown in Figure 2.

Table 1. The Paired T-test results in force of shoulder muscles

Variable	Mean (SD) Pre-test	Mean (SD) Post-test	% Change	T	DF	P
Flexor (N)	71.52 (11.40)	57.40 ± 8.85	- 19.05± 0.09	8.16	24	0.001*
Extensor (N)	77.92 (10.31)	60.08 ± 12.65	- 23.17 ± 0.10	10.44	24	0.001*
Elevator (N)	201.00 (20.20)	162.68 ± 20.73	- 18.53 ± 0.11	7.65	24	0.001*
Depressor (N)	131.16 (12.25)	101.14 ± 10.04	- 22.35± 0.10	10.74	24	0.001*
Retractor(N)	162.28 (18.07)	119.48 ± 22.28	- 26.87 ± 0.10	13.42	24	0.001*
Abductor (N)	152.12 (26.14)	109.28 ± 13.50	- 26.53 ± 0.09	10.10	24	0.001*

** Significant level was ≤0.01, Df: Degree of freedom*

Table 2. The results of the demographic data of individuals (n=25)

Variables	Mean (SD)
Age (years)	26.12 (2.78)
Height (m)	1.82 (0.03)
Weight (kg)	78.92 (4.23)
BMI (kg/m^2)	23.71 (1.40)
Sport History (years)	2.96 (0.97)

Statistical analysis

In this study, descriptive statistics was used to report the characteristics of individuals' demographic. Shapiro-Wilk normality test was utilized to determine the variables normality. The paired sample t-test was utilized for within-subject comparison and also the Paired T-test and the percentage of changes were calculated for comparison of within subjects. SPSS 26 software was used in this study. Significant level was ≤0.01.

Results

The results for the descriptive data are reported in Table 2.

The results of Paired T-test in all factors for force evaluation showed that fatigue protocol had an significant effect on the amount of force in people and decreased the amount of force in flexion ($P \leq 0.01$), extension ($P \leq 0.01$), elevation ($P \leq 0.01$), depression ($P \leq 0.01$), retraction ($P \leq 0.01$) and abduction ($P \leq 0.01$) of shoulder. Therefore, the selected fatigue protocol in the present study significantly affected the shoulder muscles force after the intervention. By observing the means in the above chart, we can see the changes after the intervention.

Discussion

The purpose of this study was to determine the fatigue effect on the force of shoulder muscles in the young bodybuilders after one-moment exhaustive training. The strength of flexor, extensor, elevator, depressors, retractor, and abductor shoulder muscles was evaluated before and after the exhaustive fatigue exercise. The results indicated that fatigue was associated with a significant reduction in the muscle force of the flexor (P=0.001), extensor (P=0.001), elevator (P=0.001), depressor (P=0.001), retractor (P=0.001), and the abductor (P=0.001) of shoulder.

The findings of the present study indicated that fatigue can be associated with reduced muscle force in bodybuilding athletes. These results were consistent with the findings of the Andrade et al. who pointed to the effect of fatigue on reducing the strength of shoulder muscles in handball athletes (26), study of Umehara *et al.* who noted the effect of fatigue on reducing muscle strength and increasing muscle frequency to compensate the weakness caused by fatigue, and also Rosemeyer *et al.* who noted the effect of fatigue in the central zone on reduction of shoulder muscle strength (16, 27).

Bodybuilding exercise is one of the most popular and powerful sports that include the continuous movements of the upper limb in different situations and angles. Weakness and the reduction of muscular endurance and the cause of joint damage are due to fatigue of muscles and the creation of repetitive movements (15). This causes micro trauma, ultimately leading to macro trauma in the different tissues of this organ, especially during the tournament (28). One of the important muscles involved in the dynamic strength of this joint is the rotator cuff, deltoid muscles as well as the supporting muscles of the shoulder. These muscles play an important role in the maintenance of the arm bone the dynamic strength of the shoulder joints, and the fluid and coordinated movement of the shoulder bone on the chest (28-30). On the other hand, free and smooth motion of the shoulder is closely related to the position and exercise of the shoulder bone on the chest (24). In fact, there is a multidimensional relationship between muscular imbalance and shoulder impingement with malfunction or change in the function of the shoulder bone (30, 31). In general, it can be concluded that positioning inconsistency of the shoulder bone and its true mobility changes occur following fatigue which is generally associated with shoulder injuries, impingement, tear and rotator cuff tendon damage, lack of joint strength of the glenohumeral bone, shoulder adhesive capsule, and shoulder joint dryness (32). Shoulder joint stability and muscle strength are the most important factors for proper shoulder exercise(33), that several authors have studied these factors(18, 34-36). Joint fixation and muscle strength are also of vital importance to prevent joint damage (37). According to this force component, recent findings indicate that some athletes have a muscle imbalance between internal and external rotator muscles of the shoulder, resulting the weak stability of the joint is indicated (38, 39). In order to reduce this imbalance of strength, the main stability exercises are proposed (40). Another interesting finding from literature is that there is a greater damage at the end of the competition than at the beginning (41). Therefore, muscular fatigue resulting from repeated movement may be more evident in agonist muscles than antagonist muscles. Selected fatigue protocol can affect the balance of muscle strength and thus stabilize the shoulder joint, thereby causing more damage in the late training and competition. Involvement of most elastic tissues in the presence of muscle fatigue, which reduce the need for muscle activation, also may be associated with joint damage(26). In addition, this fatigue may be a factor that disrupts person's performance (42). In this context, reduced performance and increased injuries in the late training and competition compared to the early one, proposed by Hawkins and Fuller(41), may be caused by loss of muscle balance due to fatigue. As a result, it is likely that rehabilitation programs or damage prevention programs aimed at increasing the endurance of shoulder muscles can be useful to prevent the loss of muscle strength and thus lack of muscle joint balance at the end of exercise.

Regarding the ways in which fatigue affects the function of the expressed muscle, it has been stated that when multiple muscles simultaneously contract, the voluntary activation of a muscle decreases(43). This is likely to occur from inhibiting feedback to alpha-spinal motor neurons through the spinal Oligosynaptic pathways (44). Loss of neuromuscular function measured by the combined potential of muscles rarely causes pathological or physiological fatigue (45). Before physiological fatigue, people experience more effort to maintain their own task. The augmentation of perceived effort increases faster just before failure in work, because the central drive is increased with muscle fatigue to maintain force. Therefore, the speed of doing repetitive tasks, such as walking, is reduced and the time of doing the work is lengthened by fatigue (46).

On the other hand, fatigue interferes with force generation (47) and muscle movement control capabilities, increases the likelihood of work-related musculoskeletal disorders (48), and decreases the nerve movement to motor units (49). Muscle fatigue may occur at the surface of muscles (peripheral) or central nervous system (central fatigue). In neuromuscular connectivity, the central fatigue can occur as voluntary reductions in motor neurons due to neural drive failure, signal propagation failure, partial activation of motor unit (50), and unmotivated or pain tolerance (51). On the other hand, Environmental fatigue, is a decrease in the capacity to produce energy despite the optimal activation of muscle fibers by motor neurons (51). In peripheral fatigue, the nervous system is sufficiently stimulated; however, muscle fibers are unable to respond maximally (51). Environmental fatigue is caused by differences in lean muscle cross-sectional area, muscle contractile properties and oxidative muscle metabolism, or impaired excitation-contraction coupling (52) Decreased maximal muscle contraction following the fatigue protocol is considered a sign of environmental fatigue (51). Generally, it can be said that fatigue is associated with a decrease in shoulder muscle strength, and this decrease in strength can interfere with optimal athletic performance.

One of limitations of the study was the non-use of other factors such as range of motion, shoulder proprioception. Therefore, it is suggested that a future study investigate the fatigue effects on the shoulder proprioception and function of bodybuilding athletes. The researchers suggest studying the effects of fatigue on the deep sensation and shouldering function of the bodybuilding athletes, and also the muscular activity after fatigue, with more accurate laboratory instruments. Moreover, it is suggested to conduct other studies to determine the effects of fatigue on specific exercise performance in other sports such as volleyball and swimming.

Conclusion

The results of the present study indicated the fatigue effect on reduction of strength of flexor, extensor, elevator, depressor, retractor and abductor muscles. This reduction in strength can be a factor in performance reduction during fatigue conditions and increase of injury risks in bodybuilding athletes.

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All authors made substantial contributions to the conception, design, analysis, and interpretation of data.

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