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REVIEW ARTICLE

Musculoskeletal injuries in bodybuilders: A brief review with an emphasis on injury mechanisms

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Abstract

In this article we reviewed the literature on injuries and their mechanisms in bodybuilders. Bodybuilding is a weightlifting sport where the main goal is to increase muscle mass while maitaining body symmetry. From a biomechanical point of view, it is important to analyse technical performance of exercises to improve sports technique. Compound exercises based on the development of muscle hypertrophy must be included. The training is different before and during season, in pre-season it is based on reduction of body fat to a low level and a high volume of aerobic exercise. Adequate nutrition, use of supplements and banned substances are widespread in the sport. In that case athletes should be very careful for banned substances in accordance with WADA Code. The most commonly performed exercises where injuries happen are the squat, deadlift and benchpress. The majority of injuries (60 %) are acute, with 93 % shoulder joint injuries, 85 % lower back injuries and 80 % knee injuries. The incidence of injuries is low compared to other sports, between 0.24/1000 hours of training or 0.12 injuries per lifter per year. The most common type of injury is muscle strain, followed by tendinitis and cartilage wear. So it is therefore important to identify risk factors to allow the development of appropriate prevention programs. Muscle ruptures are common with high eccentric loads, with pectoralis major tendon being the most vulnerable to be injured. Than followed by a rupture of biceps femoris during the deadlift exercise, during sudden flexion of the hip joint while the knee is extended. Eccentric contraction and rupture also occurs in the quadriceps muscle, which lifters try to avoid by performing low-bar squat. Uncontrolled abdominal pressure during high-weight exercises causes discus hernias, which lifter can prevent by breathing correctly and using strong muscle stabilizers. The most well-known injury of all is elbow burzitis or »Bodybuilders elbow« due to repetitive flexion and extension movements of elbow joint. To prevent this injuries we have to include preventive measures such as medical check-ups, education of athletes, ensuring safety in competitions, appropriate training and load distribution, treating the body as a whole and regular equipment check-ups.

Keywords: bodybuilding · risk factors · biomechanics · prevention strategies

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1. Introduction

Competitive bodybuilding is a weightlifting sport, where the goal is to increase muscle mass, symmetry, and body definition (Siewe et al., 2014). It is a sport that involves performing different positions on stage, where judges rate the aesthetic appearance of each competitor in terms of muscle mass, symmetry, and definition (Alves et al., 2020). The aim is to achieve a perfect body proportion, with as little fat as possible, which is achieved through weight training and a specially designed nutritional programme that varies during the season and off-season (Siewe et al., 2014).

The artistic showing of aesthetic muscularity dates back to Ancient Greece, but with the development of the camera, bodybuilding took on a whole new dimension (Dutton & Laura, 1989). Starting in 1892, Eugen Sandow was considered the first official bodybuilder and he triggered the slow rise of the fitness industry. Europe only came into contact with bodybuilding in the 1980s, during the biggest fitness boom (Giessing & Todd, 2005). For many years, the sport normalised the use of banned performance-enhancing substances, which were only banned in the 1970s, and announced the arrival of natural bodybuilding (Liokaftos, 2018). The almost unrealistic standards set for achieving physical body appearance force individuals to be disciplined and determined to maintain muscle mass. Extremes such as hours spent in gyms, abnormal eating patterns and supplement use lead to a wide range of injuries (Reeves et al., 1998). The majority of research focuses on acute injuries, which typically outnumber chronic injuries, 93 % of which are exclusively shoulder joint pathologies (Raske & Norlin, 2002).

In this review article, we will discuss bodybuilder injuries, focusing on their mechanisms. We will also discuss the analysis of the requirements and loads needed for the sport, the epidemiology and risk factors, and the implications for prevention and rehabilitation which are important for understanding the occurrence of injuries in the bodybuilding world.

2. Method

2.1 Search strategy and selection criteria

To conduct this narrative review on musculoskeletal injuries in bodybuilders, we performed a literature search using multiple databases including PubMed, Scopus, and Google Scholar. The search was limited to articles published in English from January 2000 to December 2023. Keywords used in the search included "bodybuilding", "musculoskeletal injuries", "injury mechanisms", "risk factors", and "epidemiology". We included both peer-reviewed articles and relevant grey literature such as conference papers and expert opinions.

Articles were included if they met the following criteria:

- Focused on bodybuilding as a sport or physical activity.
- Discussed musculoskeletal injuries, including types, mechanisms, and risk factors.
- Addressed injury prevention and rehabilitation strategies.
- Published in peer-reviewed journals or as conference proceedings.

The exclusion criteria were:

- Studies not directly related to bodybuilding (e.g., general weightlifting or other sports).
- Articles not available in English.
  Publications before the year 2000 to ensure relevance to current practices and trends.
- Studies focus on nutritional supplements and performance-enhancing drugs without linking them to injury mechanisms.

2.2 Data extraction and synthesis

Two authors independently screened the titles and abstracts of all identified articles. Full-text versions of potentially relevant studies were retrieved and assessed for inclusion. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer. Data extracted from each study included study design, sample size, population characteristics, types of injuries, mechanisms of injury, risk factors, and recommendations for prevention and rehabilitation.

A thematic analysis approach was adopted to synthesize the data. This involved identifying key themes related to the types and mechanisms of injuries, risk factors, and prevention strategies. Themes were derived from the patterns observed in the data and were cross-validated by both reviewers. This approach allowed for the identification of recurring patterns and critical insights into musculoskeletal injuries in bodybuilders.

3. Analysis of requirements and loads

3.1 Biomechanical aspect, loads, and physiological requirements

In bodybuilding, the analysis of technical performance is important to optimise exercise techniques and improve muscular symmetry (Burdukiewicz et al., 2020). Bodybuilding involves a series of exercises that contribute towards the over-development of muscles, which allows hypertrophy and needs to be developed evenly with muscle mass (Blanco-Díaz & Quitian-González, 2020). If the strength deficit is small, hypertrophy should be stimulated by submaximal loading followed by maximal efforts with heavy loads (Reggiani & Schiaffino, 2020). In addition, bodybuilders sometimes use the preload principle to achieve stronger concentric muscle contraction and therefore lift heavier loads. In doing so they start the movement from the initial position that causes an intense stretch of the muscles, hold it for a few seconds, and then push themselves out of that position as hard as possible. Panayotov et al. (2020) have found strong and significant correlations between body measurements and exercise performance in all strength tests in bodybuilders. These findings are somewhat expected as although the main goal in bodybuilding is to achieve muscle hypertrophy, larger muscles are stronger, so in bodybuilders, absolute strength increases with body mass. Height contributes to maximal strength as tall bodybuilders are stronger than short ones (Panayotov, 2020).

Improving the training process by optimising loads is one of the main issues in bodybuilding. The search for an effective combination of strength exercises and training programmes is ongoing (Chernozub et al., 2023). The most prominent adaptive changes of the body during the specialized basic training phase occurred during high-intensity training loads and anaerobic-galactate mode of energy supply (Chernozub et al., 2023). Exercises on machines contributed more than free weight exercises to the increase in morphological functional indicators of athletes (Chernozub et al., 2023).

3.2 Movement patterns, motor skills, and training variables

Bodybuilders often perform compound movements where several muscle groups are trained at the same time. To increase muscle fatigue, isolation exercises are performed before compound exercises (Helms et al., 2015). Mobility limitations are often present in the hip joint and lumbar region (Prokop et al., 2022). Bodybuilding is currently gaining popularity worldwide, as it is a discipline that has great potential capabilities in the physical performance and motor skills development of athletes of different ages (Viorel et al., 2019). It can be concluded that subjects with greater thigh and chest circumference and no abdominal fat tissue had greater lower limb static strength than subjects lacking such morphological characteristics (Popo et al., 2018). A study by Hooper and colleagues (2013) showed that after a high-intensity short rest protocol, there are lasting residual effects on motor performance. Therefore, strength and conditioning coaches need to be attentive in monitoring movement and exercise techniques after such training sessions to prevent injuries and optimise further training protocols.

It is common to divide training into two different phases: off-season and pre-season. In the off-season phase athletes do workouts divided by muscle groups. In general, the pre-season phase starts 20-12 weeks before the competition, with the main focus on reducing body fat to an extremely low level and high volume of aerobic exercise (Alves et al., 2020). The hypertrophy associated with bodybuilding is the result of training with moderate loads performed with eight to 12 repetitions. Muscle groups should be trained twice or more per week, although a higher frequency is beneficial in high-volume exercises to ensure that the volume does not become too high in a single session. The quantity of sets should be 3 to 6, with repetitions ranging from 6 to 12, using 70-80 % 1 RM. Traditional rest intervals of 1 to 3 minutes are appropriate, but longer intervals can be used. The tempo should allow muscular control of the load; 1 to 2 seconds concentric and 2 to 3 seconds eccentric tempo (Helms et al., 2015).

3.3 Issues with food, supplements, and banned substances

Calorie intake should be such that body weight is reduced by about 0.5 to 1 % per week to preserve as much muscle as possible. Within this calorie intake, most will respond best by eating 3 to 6 meals per day with 2.3-3.1 g/kg of protein per lean body mass, 15-30 % of calories gained from fat, and the rest of calories from carbohydrates (Helms et al., 2014). Popular supplements include creatine monohydrate, caffeine, and beta-alanine, which have beneficial effects in preparation for competition (Hoffman et al., 2006). Dehydration and electrolyte manipulation in the last days and hours before competition can be dangerous. Athletes need to be aware of the increased risk of

developing eating disorders and body image in sports, so they should have access to appropriate mental health professionals (Helms et al., 2014). In addition, we need to be alert to substances banned under the WADA Code, as they may provide benefits or be dangerous to athletes (Sánchez-Oliver et al., 2019). Anabolic steroids and growth hormones are most commonly abused and can cause serious side effects (El-Reshaid et al., 2018).

4. Injury epidemiology and risk factors

The incidence of injury is between 0.24/1000 training hours, or 0.12 injuries per lifter per year, which is explained by a strong discipline and motivation to continue training regardless of any pain or injury (Dudagoitia et al., 2021). The movements are performed in a slow and controlled manner, and if symptoms occur in one area of the body, the exercise can be modified or easily modified so that this part is isolated and can recover, which explains the low incidence compared to other sports (Siewe et al., 2014). Muscle strains are the most common type of injury, followed by tendinitis and cartilage wear and tear (Keogh & Winwood, 2017). On average athletes recover only 11.5 days from competition and training (Brown & Kimball, 1983).

Significant gender differences have been observed, namely, female bodybuilders had a significantly lower overall injury rate (1.3 vs. 2.1 injuries per lifter per year) (Keogh and Winwood, 2017). In relation to age, the incidence of injury increases over the years, due to unrealistic body visualisation and a harder time reaching standards with age (Siewe et al., 2014). Namely, more than 40% of athletes complain of pain during training, which has been accepted as part of high-intensity bodybuilding training (Aasa et al., 2017).

Athletes involved in weight training are prone to various external and internal risk factors. Identifying relevant modifiable risk factors therefore enables the adjustment of specific injury prevention programmes for weightlifting sports. Describing relevant non-modifiable risk factors is useful for individuals intending to participate in these sports (Keogh & Winwood, 2017). Internal risk factors include gender, competition level, age, the weight class in which they compete, physiological factors, and physical fatigue. All internal factors have a relatively small impact on the epidemiology of injury in weight training sports, with the exception of gender (Keogh & Winwood, 2017). External risk factors include the type of training, rules of the sport, training environment, consumption of excessive protein diet and use of anabolic steroids, incorrect technique, failure to follow the principle of progression, overload, inadequate warm-up, and poorly maintained equipment (Xie, 2022).

5. Injury mechanisms

The most commonly performed movements where injuries occur in the bodybuilding world are the squat, deadlift, and bench press (Siewe et al., 2011). The average weight of the movements performed is around 156 ± 65.8 kg for the squat, 135.2 ± 44.8 kg for the deadlift, and 145.3 ± 70.9 kg for the bench press (Siewe et al., 2014). Overall, approximately 93 % of injuries are to the shoulder, 85 % to the lower back, and 80 % to the knee (Raske and Norlin, 2002). Of these, 60 % of injuries are acute, and the rest are chronic nature (Keogh et al., 2006).

5.1 Muscle ruptures

5.1.1 Rupture of pectoralis major

The pectoralis major has a complex structure whose tendon is bilaminar, with anterior and posterior layers. It serves as a major source of strength when performing upper limb exercises and is the area of desired hypertrophy. The most common mechanism is an indirect injury during the eccentric phase, when lifting weights in the supine position (SantAnna et al., 2022).

The majority of muscle ruptures, 40-70 %, are during the bench press. During the movement, a forced abduction occurs at the point of maximal eccentric contraction. The injury is recognised by the possible appearance of ecchymoses, a palpable defect in the anterior axillary region, weakness and painful adduction, or a sensation of fullness in the area of the muscle that is not under tension (Golshani et al., 2017). Rarely, but also possible, rupture can occur due to an uncoordinated movement in the face of fatigue or weakness of the performer who performs weight transfer to one side. Sudden contraction of the pectoralis major muscle under high pressure causes injury (Gupton & Johnson, 2019).

Treatment, due to loss of adduction strength, requires surgical management, both for acute and chronic injury. The acute intervention is performed in the inserted area of the adductor to the humeral head, while the chronic one requires reconstruction of the muscle using flexor tendons (Pochini et al., 2018). Complete tears (20%), where there is a tear at the myotendinous junction, are treated conservatively and only in the absence of weakness. Rehabilitation initially requires 3 weeks of

immobilisation in the position of internal rotation of the humerus and symptomatic treatment. In the sixth week, passive and active exercises are performed, progressing to strengthening exercises over the next few months. Regardless, surgical treatment is still more effective than conservative treatment (Bak et al., 2000).

5.1.2 Rupture of biceps femoris

The injury is caused by a sudden, forceful flexion of the hip joint while the knee is extended and the posterior thigh muscles are severely contracted. The movement described is a deadlift, which requires lifting the bar off the ground until the lifter is standing upright. The starting position is occupied by flexion of the ankles, knees, and hips, with the arms straight, aiming to lift the bar to the upright position. Knee extension occurs before the bar is lifted, as the segments reach the optimum angle to exert maximum force, the potential to lift the bar increases (the action of the force-length relationship and the pulling angle of the muscle), excessive trunk tilt reduces quadriceps effort and elicits a large hip extensor moment (Hales, 2010). In doing so, the hip, knee, and back extensors are stressed. Specifically, the most stressed muscles are the gluteus, hamstrings, erector spinae, latissimus dorsi, infraspinatus, teres minor, and major (Bengtsson et al., 2018). The long head of the biceps femoris is the most commonly injured muscle as it is subjected to a greater force to complete the extension than the other thigh muscles (Hsu et al., 2023).

With a quick diagnosis and surgery, the final functional results are good. In the case of delayed diagnosis, primary muscle suture to the ischial bone cannot be achieved and additional surgery is required to restore function (Orava & Kujala, 1995).

5.1.3 Rupture of quadriceps

Squats are divided into high-bar and low-bar and the front squat. The names of the techniques are related to the placement of the bar on the back. The bar is either centered across the shoulders just below the spinous process of the C7 vertebra, "high-bar", or further down on the back across the spine of the scapula, "low-bar". It has been shown that the low-bar squat is characterized by a more forward lean of the trunk (Illmeier, 2023). In the high-bar squat, there is a higher risk of quadriceps rupture due to the larger knee lever (Wretenberg et al., 1996). Specifically, bilateral quadriceps rupture is typically present in older individuals but now is also seen in younger individuals with the excessive use of anabolic steroids. The injury occurs due to eccentric contraction of the muscle during knee flexion or landing on a flexed knee (Alrashedan et al., 2023).

Thus, lifters avoid mechanical loads to the knees by performing low-bar squats. In doing so, the trunk tilt before lifting is greater, resulting in a shift in the centre of gravity, less knee torque, and patellofemoral forces of lifting that increase with the flexion angle and produced moment of force (Wretenberg et al., 1996). In the squat, dorsiflexion and anterior translation of the knee occurs, the knee lever is smaller and the hip lever, or lumbar spine lever, is larger than in the high-bar squat, which reduces the action of the extensors of the knee (Keogh & Winwood, 2017). To avoid common patellar tendon ruptures, lifters use knee bandages, which restrict the patellar motion and are potentially one of the risk factors for developing injury.

Rehabilitation is individualised according to the injury and recovery is short. The most effective surgical repair of the quadriceps tendon is with an anchor suture (Sherman et al., 2016).

5.2 Discus hernia

Discus hernia is a common condition that occurs with age, due to a degenerative process. In the world of bodybuilding, herniation occurs due to uncontrolled abdominal pressure (IAP) during high-weight exercises, more specifically, excessively elevated intra-abdominal pressure (Smith et al., 1999).

The two most common exercises that cause this pathology are the squat and the deadlift. The erectors' inability to overcome the substantial forces produced by the hip extensors in the initial phase of the lift results in a reduced ability to maintain lumbar lordosis when handling heavier loads. The kyphotic thoracic curve is increased, causing strain on the spinal ligaments and compressive forces on the discs (Hales, 2010). Although IAP reduces compressive forces on the spinal discs by 40 %, breathing must be properly controlled during the performance of the exercise. Also related to pressure is the strength of the entire abdominal wall, which when increased, together with the erectors, will provide stabilisation to the trunk (Hagins et al., 2004).

Many people prevent herniated discs by using belts between lifts, which have been shown to reduce the compression forces on the discs. The disadvantage of belts is the negligible action of the deep trunk stabilisers, and therefore regular wearing of a belt during training is not recommended for all lifters (Harman et al., 1989).

5.3 Elbow burzitis

Olecranon bursitis, also called "Bodybuilder's Elbow", is caused by repetitive movements that cause friction and increase the volume of fluid in the bursal cavity. The bursa is a poorly vascularised synovial membrane with a low coefficient of friction and is damaged by the olecranon during elbow flexion and extension (Blackwell et al., 2014). The elbow often experiences pain during commonly performed exercises such as bench presses, elbow extension exercises, and push-ups, as well as any other exercises that cause overload on the elbow joint (Williams et al., 2023).

Burzitis is frequently described predisposing factor for triceps tendon tear or any triceps abnormality and is often associated with local steroid injection or a history of anabolic steroid use (Koplas et al., 2011). Successful treatment requires commitment from the physician; well-conditioned professional athletes can be rehabilitated more quickly and more aggressively than others, but the treatment concepts are the same – knowing the correct form during exercises leads to a risk of bursitis (McCarthy, 1989).

6. Implications for prevention and rehabilitation

The injury risk in bodybuilding primarily arises from the incorrect handling of high physical loads, leading to various injuries (Jassim & Alessa, 2023). Identifying modifiable risk factors is crucial for adapting injury prevention programs, allowing for the mitigation of these risks (Keogh & Winwood, 2017). Additionally, recognizing non-modifiable risk factors is valuable for individuals considering participation in the sport (Keogh & Winwood, 2017). Coaches should closely monitor movement and technical performance to prevent injuries (Hooper et al., 2013). Preventive measures should include regular medical check-ups, enhanced athlete education on exercise injury prevention and substance use, ensuring safety and protection during competitions, appropriate training and load management, holistic treatment approaches, and regular equipment inspections (Jassim & Alessa, 2023).

Data mining techniques, such as cluster analysis and the C4.5 algorithm, have been shown to be effective in identifying injury patterns and risk factors in fitness and bodybuilding (Xie, 2022). By analyzing large datasets, these techniques can uncover hidden patterns that help in designing better injury prevention strategies. For instance, frequent exercisers, defined as those who exercise more than three times per week, have been identified as a high-risk group, highlighting the need for targeted preventive measures (Xie, 2022). Rehabilitation programs should be tailored to the specific deficits of each individual (Shaw et al., 2016). Resistance exercises should be an integral component of any exercise program aimed at preventing and rehabilitating musculoskeletal injuries (Shaw et al., 2016). The use of data mining can also aid in monitoring the effectiveness of rehabilitation protocols, ensuring that they are adapted to the evolving needs of the athlete (Xie, 2022).

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