An Overview of Strength Training Injuries: Acute and Chronic

Mark E. Lavallee[1,3] *and Tucker Balam*[2,3]

[1]Indiana University School of Medicine, South Bend, IN; USA Weightlifting, Sports Medicine Committee, Colorado Springs, CO; International Weightlifting Federation, Masters Division, Budapest, Hungary; South Bend Sports Medicine Fellowship Program, South Bend, IN; Indiana University South Bend, South Bend, IN; Holy Cross College, Notre Dame, IN; University of Notre Dame, Notre Dame, IN; [2]Family Medicine, Memorial Family Medicine Residency Program, South Bend, IN; [3]Memorial Sports Medicine Institute, South Bend, IN

LAVALLEE, M.E. and T. BALAM. An overview of strength training injuries: acute and chronic. *Curr. Sports Med. Rep.*, Vol. 9, No. 5, pp. 307–313, 2010. *This article introduces the history of strength training, explains the many different styles of strength training, and discusses common injuries specific to each style. Strength training is broken down into five disciplines: basic strength or resistance training, bodybuilding, power lifting, style-dependant strength sports (*e.g., *strongman competitions, Highland games, field events such as shot put, discus, hammer throw, and javelin), and Olympic-style weightlifting. Each style has its own principal injuries, both acute and chronic, related to the individual technique. Acute injuries should be further categorized as emergent or nonemergent. Specific age-related populations (*i.e., *the very young and the aging athlete) carry additional considerations.*

INTRODUCTION

Increasing numbers of people recognize the importance of exercise as a vehicle to continued health and have turned to various activities to get this benefit. Many have chosen resistance training as either their primary source of exercise or as a secondary regimen in order to improve performance in another desired sport (*i.e.*, cross-training). Since so many athletes now partake in strength training, it behooves the sports medicine physician to be aware of not only common injuries and how to treat them, but also the basics of the sports to further aid in communication, diagnosis, and the development of treatment plans. Additionally, it is important to counsel those patients on how to prevent injuries related to the sport.

BRIEF HISTORY OF STRENGTH TRAINING

Modern strength training can trace its roots back thousands of years. Ancient Chinese texts indicate that prospective soldiers were required to pass feats of strength prior to being conscripted. In their art and sculpture, the Greeks were depicted lifting large stones or weights in their ancient Olympics (35).

The birth of modern weightlifting in its more recognizable form took shape in the latter part of the 19th century with the strongman era. These men would lift hollowed metal dumbbells that could be filled with sand or lead to predetermined weights. These competitions became so popular, they were included, in 1896, in the first modern Olympics, in Athens, Greece. These first games included only two lifts: the one- and two-arm versions of the clean and jerk. Eventually the Olympics added the snatch and the clean and press, which was later eliminated, in 1972 (18,35).

Strength training continues to become more popular as interest in sports has grown, aided by the public's fascination with bodybuilding, starting in the 1970s. Strength training continues to play an integral role in many high-school, collegiate, and professional sports as a way to improve performance and decrease injury (1,29–31).

STYLES OF STRENGTH TRAINING

Many styles of resistance training exist, all with the common goal of improving sport-specific performance and strength. Any of the styles mentioned here can be used by

Address for correspondence: Mark E. Lavallee, M.D., CSCS, FACSM, Memorial Sports Medicine Institute, 111 West Jefferson Blvd, Suite 100, South Bend, IN 46601 (E-mail: mlavallee@memorialsb.org).

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the amateur athlete for maintaining health or recreation. Understanding the different strength training and competition styles will help the clinician recognize the injury patterns common to each.

Strength training (weight training or resistance training) is the broadest category. The general goal of strength training is to add strength and muscle mass for health and fitness. More specifically, this training is used to either improve performance or prevent injury in a particular sport (*e.g.*, football, baseball, soccer, swimming). This is accomplished using free weights (*e.g.*, dumbbells and barbells), machines, bodyweight exercises, or resistance bands. These exercises are used to approximate the motion that the athlete is trying to improve in their particular sport. For example, the shot put requires explosive strength of the shoulder, pectorals, triceps, legs, and hips, as well as stabilization of each of the various joints. Consequently, an athlete participating in the shot put would work on explosive exercises that grossly approximate and use the muscles required in that sport (*i.e.*, clean and jerk).

Bodybuilding, on the other hand, uses many of the same techniques found in other aspects of strength training. However, the goal in bodybuilding is much less about strength and more about adding size, symmetry, and muscular definition. Bodybuilding is a visual sport, so muscular "beauty" is judged subjectively. In bodybuilding, nonballistic resistance training along with strict nutrition are the hallmarks for success.

Power lifting is a sport that evolved with and then separated from Olympic lifting. The goal of power lifting is to lift a maximal weight for one repetition. This is accomplished using three lifts: the squat, the dead lift, and the bench press, with the maximum weight of each lift added together to get a final score (Fig. 1). The squat is performed by placing a loaded barbell across the upper back and shoulder, flexing the hips/knees until the thighs are parallel to the floor, and then pressing the weight back to the upright starting position. In the dead lift, the weighted barbell starts on the floor. The athlete then grips the weight and extends the hips and knees until the weight is lifted and resting against the thighs and the back is in full extension. The bench press requires the athlete to take a loaded barbell off the rack on a bench while laying supine, then to lower the weight to the chest and finally press the bar to its starting position. In competition, lifters have three attempts at each lift.

Similarly, Olympic weightlifting requires the athlete to attempt a lift of maximal weight in order to achieve the highest combined total of two lifts, which are the clean and jerk and the snatch (Fig. 2). Both lifts use weighted barbells resting on the ground, similar to the dead lift. In the clean and jerk, the barbell is gripped by a shoulder width grip and then accelerated by the athlete and caught on the athlete's anterior upper chest and shoulders. The weight is finally "jerked" into an overhead position in a controlled fashion. The snatch starts and finishes in the same position as the clean and jerk, except it uses a much wider grip and involves a singular, more fluid motion from the floor to an overhead position (2,16,26,29).

Other strength-related sports include those in the track and field realm, like shot put, discus, hammer throw, and javelin, as well as the Highland games and strongman competitions.

The Highland games, which originated centuries ago as a Celtic festival of athletic competition, food, and music in Scotland, now take place around the globe, with the two largest located in the United States (San Francisco and North Carolina).

Figure 1. This figure demonstrates the three powerlifting events: squat (A, B), dead lift (C, D), and the bench press (E, F). On display are the start/end positions and the position where momentum of the weight changes direction in each of the three lifts.

The strength component of the Highland games includes the caber toss, stone put, Scottish hammer throw, weight throw, and weight over bar. The caber toss involves the athlete holding a large pine log vertically, running forward and attempting to hoist/throw the log end-over-end. The stone put is very similar to Olympic shot put but differs in the use of a heavy "Braemar" stone or the smaller "open" stone. The Scottish hammer toss uses a round metal ball at the end of a 4-foot-long shaft. The athlete's feet are firmly planted on the ground, often using long blades in their shoe to anchor them, while the hammer is rotated overhead and thrown. The weight throw (or weight for distance) involves either a light (26 lb) or heavy (56 lb) metal ball attached to a short chain and handle. The athlete holds the handle with one hand, spins around, and releases the weight for distance. The weight over bar event involves a 56-lb weight (same as in weight throw), and the athletes attempt to throw the weight over a bar one-handed. If successful, the bar is raised, and the athlete attempts again. Many of these activities involve not only

Figure 2. This figure demonstrates the Olympic weightlifting lifts. This series displays the key points in both the clean and jerk (upper) and the snatch (lower). Injuries are most prominent in the acceleration, catch, and stabilization phases of each lift.

strength but coordination, rotation, and speed (*i.e.*, ballistic in nature).

ACUTE INJURIES

By definition, acute injuries occur with rapid onset secondary to a traumatic event. This definition, however, is limited in usefulness beyond this scope as it cannot relate information regarding severity or type of tissue involved. Sudden injuries account for approximately 60%–75% of all injuries observed, when comparing football and power lifters, and often vary widely in type and severity (2,30). New data suggest that sprains/strains account for approximately 46% of injuries, and the most common mechanism is dropping of a weight (65%). This study also suggests that free weights account for more than 90% of these injuries (17). These injuries were brought to the attention of the mainstream media by the recent injury of a high profile athlete at a major NCAA Division I football program, in which a weight was dropped on the athlete's neck, causing serious injury. The goal of this article is not to be all inclusive but to provide the reader with an understanding of the breadth of acute injuries that one may encounter in clinical practice.

Acute injuries can be further subcategorized into nonemergent and emergent types. Emergent injuries include acute herniated discs, fractures, dislocations, myocardial infarction, and spontaneous pneumothorax. These often require further work-up and/or transfer to a medical facility. These injuries usually result in significant time off for sport (>5 d). Nonemergent acute injuries, by contrast, are the most common chief complaint at competitions and often either do not stop an athlete from continuing (*e.g.*, small lacerations, mild strains) or result in only a brief respite from lifting (<5 d).

By far, the most common acute, nonurgent injuries are muscular strains and ligamentous sprains, accounting for 46%–60% of all acute injuries in strength training (2,17). There is, however, some disagreement as to the most common injury sites. Research indicates that, as expected, there are differences among the various strength sports. For example, power lifters more commonly injure their shoulders, while weightlifters more commonly injure their elbows and knees. Both power lifters and Olympic weightlifters seem to experience low-back muscular strains at a higher rate than bodybuilders. However, most of these injuries are not severe and require very little time away from the inciting activity (2,26,31). This is in contrast to a study of the 2008 summer Olympic athletes in which almost 50% of injuries were associated with inability to train or compete in their sport. However, it should be noted that these articles use different definitions as to what constitutes time lost (2,16,26,31).

Less common in occurrence are the acute, emergent injuries. These include both musculoskeletal and nonmusculoskeletal injuries. Nonmusculoskeletal acute, emergent injuries that occur during resistance training include subarachnoid hemorrhages (13), spontaneous pneumothorax, hernias, myocardial infarction, stroke, and epistaxis. Fractures, dislocations, and tendon ruptures are the most commonly encountered musculoskeletal acute injuries. These usually result from loss of control of the weight during positions of vulnerability, for example, the overhead portion of the clean and jerk or snatch, where the shoulder is flexed/abducted and the elbow is extended to extremes. It is the author's (M.E.L.) personal experience that more shoulder and elbow dislocations occur in the snatch compared with the clean and jerk due to two factors, the wider

TABLE 1. Acute tendon rupture or joint dislocations in resistance training.

Tendon Ruptures	
Triceps tendon	Shot put, bench press, javelin throw
Bicep tendon	Snatch, bodybuilding
Quadriceps tendon	Squat, clean, jerk, snatch
Patellar tendon	Squat, clean, jerk, snatch
Achilles tendon	Jerk, split snatch, Highland games, shot put, discus
Pec major tendon	Shot put, discus, bench press, bodybuilding
Dislocations	
Gleno-humeral joint	Jerk, snatch, javelin, hammer toss, shot put, dead lift
Elbow joint	Snatch, javelin
Acromio-clavicular joint	Clean, bench, squat (back), military press, shot put
Sterno-clavicular joint	Clean, javelin
Patellar joint	Shot put, discus, Highland games
Hip joint	Jerk, split snatch
Ankle joint	Squat, split snatch, jerk

nature of the grip and the more aggressive rotation or over-rotation of the shoulder. Patellar dislocation and acute meniscal tears rarely are reported in resistance training, probably due to the very controlled nature of the lifts. It appears that acute emergent injuries account for 2%–3% of all injuries in adolescent power lifters (29,30). Injury surveillance data reported from emergency departments report that most acute injuries in the adult (>18 yr) population related to strength training were accidental or related to overstraining.

Acute tendon and ligament ruptures have been noted in resistance training. Ligament ruptures seem to be most associated with inappropriate movement of a joint (*e.g.*, misplacement of foot in squat causing lateral ankle sprain or in the bottom of the snatch causing a medial collateral ligament [MCL] injury to the knee). Tendon ruptures seem to be less associated with inappropriate movement of a joint and more from overloading the tensile strength of the tendon. These ruptures seem to occur more frequently in those using certain muscle-enhancing products (*e.g.*, creatine monohydrate, anabolic steroids, or human growth hormone [HGH]), those recently having used fluoroquinolones, or those over 40 yr old.

The tendons most likely to rupture often are dictated by the sport. Achilles tendons rupture more in basketball players and Olympic weightlifters and much less in power lifters. While triceps tendon ruptures are more prevalent in power lifters because of focus on the bench press, bicep tendon ruptures seem to occur more often with Olympic weightlifters and bodybuilders. Tears of the pectorals major almost never are seen in Olympic weightlifters, because they do not bench, but are more common in powerlifters, because of maximal lifts in bench, and bodybuilders, due to the high rate of anabolic steroid, supplement use, and emphasis on heavy bench routines (Table 1). Case reports of traumatic triceps tendon rupture have been reported, and all were associated with anabolic steroid use or corticosteroid injection in the recent past from the injury (33). Advanced age also may be a risk factor for tendon rupture. The authors have noted three cases of triceps tendon ruptures over a 13-yr period covering World Masters weightlifting championships where triceps tendon ruptures occurred in Masters over the age of 55 and in the jerk component to their lift. None had admitted to using anabolic steroids, fluoroquinolone use, or recently having a cortisone injection. Other case reports show pectoralis major rupture with dips (3).

Nonmusculoskeletal acute emergent injuries can run the gamut of life-threatening to serious. The literature reports cases with the following conditions associated with strength training (Table 2).

A case series of subarachnoid hemorrhages associated with weightlifting has been reported, with all patients requiring surgery, but all doing well postoperatively (13). Other literature includes a case report of cardiac rupture and one of an acutely herniated lumbar disc (31).

CHRONIC INJURIES

In contrast to acute injuries, chronic injuries are insidious in onset and therefore give us more insight into the tissues that likely are to be involved. Chronic injuries often are the result of repetitive stress being placed on tissue that has insufficient time or recuperative ability. This can happen in entry-level athletes trying to increase their lifting too fast or in high-level athletes where a premium is placed on performance and training. Chronic type injuries tend to be of the overuse type, and account for approximately 30% of injuries associated with strength training (2,26).

Tendinopathies are the most common chronic injury to be encountered. Accounting for 12%–25% of all strength training injuries, tendinopathies (*e.g.*, acute tendonitis or chronic tendinosis) can have a significant impact on training time. The knee and shoulder are the most commonly injured locations, especially among the weightlifting and power lifting styles. Patellar tendon more frequently is mentioned over quadriceps tendon as an injury site in power lifting and weightlifting due to the deep loaded knee flexion required in the cleans, snatch, and squats. Due to the repetitive nature of bodybuilding, we also can infer that tendonitis of the knee would be a relatively common occurrence in that sport as well. Other common chronic injuries include arthritis of the

TABLE 2. Nonmusculoskeletal acute emergent injuries.

Gross Hematuria	Status Asthmaticus	Retinal Detachment	Tongue Laceration
Hypertensive crisis	Tracheal crush injury	Concussion	Epistaxis
Aneurysm rupture	Cerebral vascular accident	Subarachnoid hemorrhage	Spontaneous pneumothorax
Myocardial infarction	Ventral hernia	Rectal prolapse	Inguinal hernia
Hematuria	Incontinence	Cardiac rupture	

major joints related to the repeated stresses placed upon those joints during training and competition over years or even decades of performing the same motion.

More severe chronic type injuries include stress fractures. Stress fractures occur at sites of repetitive loads. Over time, stress fractures can lead to overt fractures and significant loss of training and competition time. Stress fractures are seen in a variety of sports with locations varying by sites of repeated stress (*e.g.*, the shins and feet of runners and soccer players). In the strength sports, stress fractures are not found in the long bones as seen in the running sports but located in the spine (*i.e.*, spondylolysis) secondary to the repeated excessive loads placed on the axial spine. This especially is prominent in lifts such as the clean and jerk, snatch, squat, and dead lift, although any exercise with increased flexion-to-extension of the lumbar spine under load has a significant risk. This was particularly evident with the clean and press, an event which was in the Olympic Games prior to 1972. The press portion of the lift positioned the athlete in extreme lordosis, placing a great deal of stress on the lumbar spine and vertebrae (2). In addition, a stress fracture of the radius has been reported in a 36-yr-old athlete who was a competitive bench presser (12).

VELOCITY-RELATED INJURIES

Just as acute and chronic injuries often are related to a particular style, injuries related to velocity of movement are also associated with a given exercise. Nonballistic styles are those that move the weight in a controlled, often slower (>2–3 s) fashion. Ballistic styles, on the other hand, accelerate the weight to a much greater degree and thus are at greater risk for momentum and inertia related injuries.

Nonballistic strength training includes power lifting and bodybuilding. These styles have their own associated injuries, in large part due to the significant and extreme stress placed on particular joints or structures. The nature of the movement places significant load on certain joints (such as the acromioclavicular and sternoclavicular joints, causing clavicular osteolysis).

Ballistic-type training styles, which include Olympic weightlifting, discus, hammer toss, shot put, and most Highland games events (*e.g.*, caber toss), fall into this category. In these events, the athlete must accelerate a weight, possibly the athlete's own body weight, very quickly while generating great amounts of power and force. Dislocations, tendon ruptures, and fractures are somewhat more common due to the jerking and rotational movements of these styles. In addition, these sports frequently rely on the shoulder being in an "at risk" position, that is, extreme flexion and abduction. This accounts for more traumatic-type injuries, but also places great stress on the active stabilization and control by smaller supporting muscles leading to strains and rotator cuff injuries.

SPORT-SPECIFIC INJURIES

Some injuries are seen uniquely in one particular type of strength sports. Injuries such as clavicular osteolysis are almost exclusive to the world of power lifting due to the heavy loads of the bench press, which can reach four times an athlete's body weight. Other unique strength, sport-related injuries are listed in Table 3.

TABLE 3. Sport-specific strength sports injuries.

Power Lifting	
Bench press	Clavicular osteolysis, triceps tendinosis, pectoralis major tears
Dead lift	Callous tears, shin abrasions
Squat	Rectal prolapse, SI joint dysfunction
Olympic Weightlifting	
Snatch	Callous tears, shin abrasions, biceps tendon rupture
Clean and jerk	Sternoclavicular abscess or hematoma, callous tears, dorsal wrist osteophyte at DRUJ, thumb injury from hook grip
Bodybuilding	Skin issues due to tanning and/or spray-on tan, megorexia (body dysmorphia); eating disorders, tendon rupture due to anabolic steroid use
Highland Games	
Caber toss	Splinters, crush injuries, finger dislocations
Stone put	Triceps rupture
Scottish hammer toss	Achilles transection, lacerations or penetrating trauma from bladed-anchors in shoes
Weight throw	Crush injury
Weight over bar	Crush injury
Track and Field	
Shot put	Carpel tunnel syndrome, collision with shot
Hammer throw	Dequervain's tenosynovitis, triangular fibrocartilage complex wrist injury, collision with hammer
Discus	Collision with discus
Javelin	UCL injuries, Penetrating wound in chest/abdomen/limb from javelin

DRUJ = distal radial ulnar joint, SI = sacroiliac, UCL = ulnar collateral ligament.

AGE-RELATED AND MEDICAL ISSUES

Strength training athletes who are in particular age groups can sustain unique age-associated injuries. These groups include the skeletally-immature (*i.e.*, pre-adolescents and adolescents) and our aging/Masters athletes.

A frequent concern in the health of young weightlifters is the theoretical risk to the growth plates and growth velocity. The literature only supports a decrease in growth velocity in athletes who also had significant calorie restriction or were using specific behavior-modification drugs (*i.e.*, methylphenidate, dextroamphetamine) (6–11,14,19,20,23,25,28,32,38). The young lifter has a greater risk of injury due to accident or lack of supervision rather than injury to growth plates. A study of 1109 elite lifters (12–20 yr) who were competing in a national or international event over a 4-yr period reported no physeal injuries or serious injuries requiring surgery or hospitalization (19,27).

The aging or Masters strength athlete also has a unique set of medical concerns and injuries (21). Many of the advanced-age athletes have been competing in the same discipline for many decades. Degenerative joint disease is quite common and is more prevalent but not universal as the age of the athlete increases. Chronic medical conditions like hypertension, diabetes mellitus, coronary disease, and stroke seen commonly in older nonathletic populations also can be seen in our aging athlete population. When working with aging athletes, providers should attempt to be medically supportive but acknowledge when an individual has a condition that may make competing or participating potentially injurious or life-threatening. The rate of tendinopathies and tendon ruptures seems to increase in prevalence in Masters athletes up to the age of 65–70 yr. At this point, a decrease in these injuries is seen because the rate of decline in muscular strength exceeds the rate of decline in the tendon strength (22,23).

SUPPLEMENT-RELATED ISSUES

As athletes search for improvements to their strength performance, they often utilize many sources to gain knowledge. The Internet, friends, coaches, and magazines seem to top the list of sources, while nutritionists, registered dieticians, exercise physiologists, certified strength and conditioning specialists, and physicians seem to rank much lower. Those athletes seeking to change their diet, start using supplements, or change their body weight greater than 10% should consult with a professional, such as a nutritionist, registered dietician, exercise physiologist, certified strength and conditioning specialist, and/or sports medicine physician.

Strength athletes often want to take in large amounts of protein in order to gain muscle mass. Recommendations range between 1.2 to 2 $g \cdot kg^{-1} \cdot$body weight^{-1} in multiple divided doses. Creatine monohydrate has been studied extensively and has been shown to increase power and strength in short-burst exercises (4,24,34). Although controversial, there are some concerns in use of creatine during increased heat environments (football two-a-days) because of heat cramps (34), and in those new to strength training because of increased rate of tendon injuries (5,34).

Anabolic steroids and HGH have been associated with strength sports for over 40 yr. These cause a plethora of medically-related issues, which are beyond the scope of this article but deserve mention because of the numerous temporary and permanent conditions that can stem from their use. Other anabolic agents such as insulin, testosterone precursors like Terrestris tribulus, dehydroepiandrosterone (DHEA), and androsteindione have been cited in the literature as having both anabolic properties and some of its side effects, but have not actually been shown to improve performance (15).

One antibiotic class, the fluoroquinolones (*e.g.*, ciprofloxin, levofloxacin, and ofloxacin), seem to be related to tendon injuries including tendon ruptures and tendinopathies at a higher rate than other classes. All members of this antibiotic class may increase the risk of these tendons injuries, although ofloxacin and ciprofloxacin seem to have higher associated risks (36,37). The tendon problems appear from 7 d up to 12 months after a single course of treatment. In general, the use of fluoroquinolones should be avoided in strength athletes, especially if other effective antibiotic regimens are available.

CONCLUSION

In conclusion, strength training has been accepted by many athletes as a method of cross-training or as their primary sporting endeavor. Because so many athletes partake in this activity, it behooves the sports medicine physician to be aware of the basic rules, lifts, common injuries, and how to treat them. When evaluating those injured strength athletes, it is imperative to know which of the many disciplines of strength sport the athlete is involved in, his or her age and duration of involvement in the sport, and use of ergogenic aids or certain antibiotics, as well as the acute or chronic nature of the athlete's injury. Emergent injuries are uncommon in strength sports, but those sports medicine physicians who choose to cover these events should be prepared for them. Also, it is important to counsel those patients involved in strength training either as their primary or secondary activity on how to prevent injuries related to the sport.

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Fueling the Vegetarian (Vegan) Athlete: Corrigenda

In the print version of the article appearing on pages 233–41 of the July/August issue, an error was detected. On page 236, in column 2, paragraph 3, line 13, the text should read: "…which elongates the ALA to EPA and DHA…" The posted online version of the article is correct. Also, a disclosure omission was detected. The lead author, Joel Fuhrman, MD, profits financially from the sale of supplements promoted in the article.

Reference:

Fuhrman J, Ferreri DM. Fueling the vegetarian (vegan) athlete. *Curr Sports Med Rep.* 2010; 9:233–41.