Prepubescent and adolescent weight training: Is it safe? Is it beneficial?

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Anatomically and physiologically, the prepubescent and adolescent are recognized as different, but due to the lack of ossification at growth centers, their potential for injury while involved in weight training or other sporting activities is considered similar. It has been determined that injuries can be decreased with proper weight training programs and that bone mass is increased, creating greater shock absorbing capability (11, 13, 23). Do the benefits gained with weight training, however, significantly outweigh any risks involved due to the physical immaturity of the subjects?

Research demonstrates that resistance training of prepubescent and adolescents can cause significant increases in strength. The development of strength will occur, although the quantity is dependent upon the gender and physical maturity level of the participant.

Weight training injuries do occur, but the primary causative factor has been found to be improper technique in an unsupervised setting (17). Weight training has been proven to improve sport performance and decrease sport injuries and rehabilitation time relative to non-weight trained individuals (11). A well-balanced training program for adolescents will aid in strength increases as well as development of motor coordination, balance, timing and familiarity with basic biomechanical principles.

In order for someone to properly instruct prepubescent and adolescent weight trainers, he or she should understand basic concepts such as differences between adults and children in osseous growth structures, and areas of potential injury among prepubescents and adolescents. All too often, the individual responsible for supervising young people is more familiar with weight training principles suitable for adults. This review has been prepared in an attempt to clarify the osseous factors, benefits to be gained and the safety aspect of weight training within this age group to facilitate coaches, trainers and health care educators in their work with young people.

Definitions

Weight training: method of conditioning involving repetitive action against submaximal resistance. The objective is to improve athletic performance and overall muscle tone (3, 8, 15, 18, 21).

Weightlifting: sport in which participant attempts to lift his or her maximal weight (1 repetition maximum—1 RM). Includes the olympic lifts—snatch, clean and jerk (3, 8, 15, 18, 21).

Powerlifting: competitive lifting of maximal lifts with the goal of one maximal repetition. Lifts are restricted to bench press, squat and deadlifts (3, 8, 15).

Bodybuilding: goal is hypertrophy and body form. Strength is achieved with training, but it is not the primary objective (3).

Circuit weight training: this method consists of a number of stations (average of 10) where the individual performs a set of exercises rapidly at approximately
50 to 70 percent of his or her individual maximal repetition. There is a brief rest (15 to 30 seconds) between stations, with the entire circuit repeated one to three times. Circuit training is utilized to obtain cardiovascular improvement as well as strength increases during the same exercise program. The goal is to maintain a target heart rate throughout the circuit (3).

Plyometrics: exercises designed to develop "power." Involves depth jumping and hopping. Theoretically, this style of training overloads the muscle/tendon unit and ligaments. It is generally restricted to fully developed, well-trained athletes. It would not be recommended for any adolescent due to the increased chance of developing avulsions or apophysitis injuries (3).

Apophysis: site of tendon-to-bone junction. Apophysitis is an inflammatory condition at this site due to overuse or chronic irritation of tendon stresses on bone.

Avulsion: a separation of the insertion site of tendon into the bone. Both avulsions and apophyses are prevalent in prepubescent and adolescents due to non-ossified growth cartilage at the apophyseal insertion.

Prepubescence: time from childhood to onset of secondary sex characteristics (21). A male or female up to age 15 or 16 is generally considered prepubescent (18). This can vary significantly between individuals. Sailors determined 13 to 15 to be the onset of puberty and secondary sex characteristics for males; females, one to two years earlier (19).

Adolescence: period after onset of secondary sex characteristics until physical and skeletal maturity. The growth centers of long bones and epiphyseal plates are not yet ossified (21).

Osseous Conditions and Considerations within Adolescent Population

The possibility of injury during resistance training in adolescents is similar to that of adults, but you must add the additional risk of damage to the growth cartilage. Growth cartilage is located at three sites: the epiphyseal plate, the epiphysis or joint surface and the muscle tendon insertion or apophyseal insertions (1, 9, 16, 17). It is possible to damage all three growth cartilage sites by accident, operations, disease or repeated microtrauma. Damage by microtrauma is most commonly seen in the shoulders and elbows of little league pitchers. The continuous induced stress to these non-ossified growth areas compromises the weaker areas. During athletic activity, the greatest load falls on the weakest link during the entire movement. An overload at that point creates a potential injury.

The cartilage of the epiphyseal plate has the primary function of providing for longitudinal growth of the bone. Because the strength of cartilage is less than that of bone, the growth plate is a weak link in the immature skeleton (5). There are two sites of weakness within the epiphyseal plate. The primary site is the hypertrophic zone of the plate and the secondary site is the metaphysis below the hypertrophic zones (1). The hypertrophic zone refers to the area of rapidly increasing cells that is responsible for the longitudinal bone growth. It is above the zone of matrix calcification. The metaphysis is the transitional zone where the diaphysis (shaft of the bone) and epiphysis are joined (7). The mechanism of plate fragility appears to be the increase in thickness of the hypertrophic zone that occurs during this period of rapid growth (1). Cartilagenous growth occurs, followed by opposition of osseous cells. The cartilage cells continue to multiply with the subsequent osseous development until the growth limit for this individual has been reached. At that time, the epiphysis fuses to the metaphysis and the epiphyseal line becomes a denser line of osseous material.

During a cleavage, the growing cartilage cells usually remain with the epiphysis. If the nutrient source is not damaged, the growth generally is not impaired. Epiphyseal injury does not mean permanent deformity (14). The majority of epiphyseal displacements can be reduced and do not produce any growth disruption. Fractures may occur through the epiphyseal lines, and the epiphysis may be displaced minimally or be reduced spontaneously, dependent upon the force creating the fracture. In cases of damage to one epiphyseal plate that will inhibit future growth, the contralateral limb may be stapled across the epiphyseal line to prevent future growth and subsequent limb length discrepancy.

Utilizing rat tibias, Bright et al. found increasing failure load with age (5). Shear strength of epiphyseal plate is age dependent, due to the change in perichondral cartilagenous complex (10). The average strength of the epiphyseal plate increases with age. Females consistently required greater loads to cause failure than males at a similar maturation stage (5). Interpretations of experimental results indicate that as a structure has absorbed approximately 50 percent of its failure energy, shear cracks begin to occur within the growth plate. If the load is released, the cracks remain and
their presence temporarily weakens the plate. However, if the force continues to increase, a secondary crack becomes the propagating crack and passes through the plate to cause eventual failure. In an intact animal or individual, the periosteum is thought to act as a checkrein on the epiphysis once the plate has failed (5). If the load is sufficient to rupture the periosteal fibers, X-ray evidence of epiphyseal displacement will be evident. This concept is important considering that the clinical evidence of epiphyseal injury can occur without X-ray evidence of displacement. The strength of the fibrous capsule and ligaments around joints is two to five times greater than the metaphyseal-epiphyseal junction (14, 21). Therefore, sprains must be carefully evaluated in children for the possibility of epiphyseal damage. This evidence further validates the necessity to avoid maximal lifts by children.

Those most vulnerable to epiphyseal injury (ages 9 to 15) are also the most active. There is increased evidence that the child's articular surface is more susceptible to shear than adult cartilage (17). The increased epiphyseal displacement injuries within this age group could be due to decreased fragility of the radial shaft as the cortex increases in strength with circumferential growth (1). This theory is suggested due to a decreased number of greenstick and shaft fractures seen within this growth period. The mean period for the peak of the adolescent growth spurt has been found to be 13.5 years for males and 11.7 years for females (1). The male predominance in epiphyseal plate displacements is explained by the more rapid growth seen in males. In addition, without appearing stereotypical, males generally are involved in more contact sports and higher risk activities than females. The combination of increased risk activities, more rapid growth of the hypertrophic zone (1) and less capability to resist shear forces (5) contributes to the greater number of plate injuries seen in males.

The greater the force, the greater chance of disruption of the epiphyseal cartilage. The plate is much more vulnerable to shear force than compressive force. Ages for epiphyseal plate closures are variable, but the following are most commonly acknowledged: elbow—18, shoulder/wrist—20, hip/ankle—18 and knee—20 (16).

Epiphyseal fractures in young weightlifters are documented, but each case involved poorly performed overhead lifts (8) or maximal lifts (8, 9). During the growth spurt, the hypertrophic zone has four changes occurring: increased rate of cell division, increased length of replicating columns, increased number of columns and increased size of cells (1). These increase the thickness of the plate, but the matrix and collagen needed to protect from shear and compressive forces are not yet available. Thus, an increased weakness occurs. This physiologically explains the absolute value in youth abstaining from maximal lifts (3). Maximal lifts create extreme shear and compressive forces. The keys to prevention are supervision in adolescent lifting and education of the child on the importance of avoiding maximal lifts.

Increases in bone thickness by growth of cortical bone occurs when bone is deposited around the outer surface of the shaft by the periosteum as the inner surface of the marrow cavity is absorbed (16). Exercise training increases the internal stresses in bone. This in turn produces an increase in cortical thickness and a narrowing of the medullary canal (13, 23). The size and shape of bones will alter, depending on the external forces put on them (Wolff's law) (7). Testing of femurs on moderately exercised swine showed the quality or mechanical properties were unchanged, but the quantity, in cortical thickness and volume, increased with exercise (23). This significant bone hypertrophy allowed the subject to carry more load and absorb more energy before failure. A study by Woo evaluated weight-bearing femurs and their response to exercise stresses (23). Five immature swine were subjected to 12 months of exercise training consisting of treadmill running. Upon biomechanical evaluation of the femurs of experimental and control subjects, significant increases were found in the experimental group. The maximum load of exercised animals increased 35 percent. The cortical thickness of the femurs showed an average increase of 17 percent. The clinical significance of these results shows that exercise can not only maintain homeostasis, but produce actual hypertrophy of bone.

The continuing question is whether bone must be weight bearing before an increased bone deposition occurs. What about non-weight bearing osseous structures? Jones et al. conducted a study of 84 active adult professional tennis players (mean playing years: males, 18; females, 14). They further verified the evidence of hypertrophy of bone due to exercise with statistically significant increases in unilateral cortical bone (13). This study is indicative of cortical increase in a non-weight bearing bone when subjected to stress. Weight training
is subjecting non-weight bearing bones to increased stress when working many of the upper body muscle groups. No research was found dealing with osseous changes directly related to weight training adolescents in non-weight bearing bones. However, utilizing Wolff’s law, it can be postulated that some osseous response will occur due to stresses upon the bones utilized in supporting resistive weights. What is the significance of bone mass increase? A greater bone mass can prevent injuries and increase the capability to absorb stress.

A final area of consideration in osseous structure in the adolescent is the tendon/bone junctions. The tendon/bone junction is one of the normal sites of relative weakness in a growing child. The strength of the muscle/tendon is greater than the bone during this stage. There is increasing evidence that tiny avulsion fractures occur when excessive force is exerted by a muscle on the non-osseified epiphysis. The most common site of this occurrence is the patellar tendon apophysis complex, causing a condition known as Osgood-Schlatter’s disease. Osgood-Schlatter’s disease is a true epiphysitis (inflammatory process) of the anterior aspect of the upper tibial epiphysis (1, 14, 17). Generally it is not caused by any specific injury, but has a gradual onset with gradually increasing pain. This can be seen in adolescents performing weightlifting techniques such as squats and clean and jerk, where excessive knee flexion is followed by forced extension. The union of the tendons and ligaments to the bone are by Sharpey’s fibers, which skewer the outer lamellae (16). With excessive exertion, these fibers can begin to tear from the periosteum and create a complete avulsion or develop a chronic irritation and subsequent osseous reaction (avulsion tendonitis).

Compression fractures of vertebral end plates (Schmorl’s node) peak during adolescence (1). These compression injuries are also explained as a heightened fragility of the end plate due to the adolescent growth spurt. Overhead lifts and excessive weight increase the chance of sustaining such an injury. Older individuals become susceptible to vertebral end plate fractures, but this is due to increased osteoporotic conditions.

During the growth spurt of adolescents, the rapid longitudinal growth creates a deficit in flexibility until the muscles and connective tissues can catch up. This is primarily evident in hamstring tightness, thus increasing the lordotic curve. This decreased flexibility can be a precursor to injury. Acute trauma to the lumbar musculature and vertebral bodies can be caused by lifting maximum or near maximum resistances. This excessive weight, accompanied by the decreased flexibility and improper form, will increase stress on an already compromised area (18). The muscle/tendon unit generally will catch up with the longitudinal growth with maintenance of a stretching program.

There is limited research in the area of flexibility in weight training, but the consensus seems to be that flexibility of weightlifters and weight trainers is the same or better than that of nonlifters (3). Of primary importance is educating the lifter (adult or child) about the importance of training through his or her entire range of motion. A common myth is that weight training creates a muscle-bound condition and a subsequent loss of flexibility. Stretching exercises must be incorporated into a strength training program to ensure that range of motion is maintained (3, 8).

**Strength Gains**

The use of resistive weight training to improve strength has been proven to enhance sport performance and decrease susceptibility to injury for adults. The use and safety of strength training for prepubescents and adolescents remains a controversial subject. A primary question to be asked is whether these children are capable of making strength gains while remaining injury free. As discussed in the previous section, weight training in a submaximal, controlled situation is beneficial to bone deposition. There are psychological benefits as well, which will be discussed later.

Opposition to strength training is based on three contentions: Prepubescents are incapable of decreasing strength due to inadequate circulating androgens; strength gains do not improve motor performance or decrease risk of injury in sports; and resistance weight training is dangerous, with an unacceptable risk of injury (2, 8).

In a study by Sewall and Micheli, strength responses, flexibility and injury rate were evaluated. Eighteen boys and girls (10 to 11 years of age), 10 in experimental and eight in control groups, were followed for nine weeks of three progressive resistance training sessions per week. Changes in strength for knee flexion/extension and shoulder flexion/extension were calculated. The test group recorded greater strength gains in each motion compared to the controls (+42.9 percent to +9.5 percent). Of all motions, shoulder
flexion strength gain within the experimental group was statistically significant (p < 0.05). There was no loss of flexibility and no injuries sustained during the training period (20). Although no injuries occurred during this study, that does not negate the potential for injury with use of resistive exercise equipment in youth. A primary concern when developing a program should always be the amount of stress upon the growth cartilage areas.

Weltman et al. studied the effects of a 14-week strength training program for prepubertal males. They reported a significant increase in strength of 18.5 to 36.6 percent within the experimental group for eight motions tested (p < 0.05). The strength trained subjects also demonstrated significant improvements over the control group in vertical jump (+10.4 percent to -3.0 percent), flexibility (+8.4 percent to -1.2 percent) and VO₂ max (19.4 percent to +13.8 percent). In addition, musculoskeletal scintigraphy indicated no evidence of damage to epiphyses, bone or muscles as a result of training. There was only one weight training-related injury during the 14-week period with 16 subjects. Also, increased flexibility was found in the weight trained individuals, which can aid in injury prevention during sporting events (22).

This research demonstrates that resistance training of prepubescent males and females can cause significant increases in strength. These increases in strength can be achieved without injury in a well-organized and supervised program. The data presented by these two studies do not support the contention of the American Academy of Pediatrics that weight training should not be attempted by prepubescent males because no

strength gains are possible due to an insufficient level of circulating androgens, as do females. Yet, strength gains without hypertrophy by females have been demonstrated. A healthy, untrained woman who begins weight training can show a 25 to 35 percent increase in strength during a 10- to 20-week period, without any hypertrophy (3).

Other factors, such as number of motor units recruited as well as improved synchronization, may account for development of neuromuscular power increases. This neural adaptation without hypertrophy accounts for strength increases in both females and prepubescent boys (20). Increased neural response will facilitate injury prevention in other sports and activities of daily living.

Psychological benefits, such as improved self-esteem and body image, are demonstrated effects of resistive weight training (8, 11, 18). Proper lifting technique involves concentration at a maximal level. Development of the discipline and concentration needed for weight training has been shown to affect other activities. In the study by Weltman et al., parents reported that in the hours following weight training, their children were more attentive to homework and other activities than they were on nontraining days (22).

**Weight Training Injuries and Injury Prevention**

Many weight training programs have been developed on the theory that if some training is good, more is better. However, overtraining often leads to injury. The more common injuries are lumbo sacral (6), patellofemoral joint (20) and ASIS (anterior, superior iliac spine) avulsions from hyperextension back exercises and dead-weight lifting (3, 4). Dead-weight lifting refers to lifting a weighted barbell from floor level to an overhead position, creating an increased stress at the lumbo-sacral junction. The most common fractures are seen in the distal radius and/or the ulna of adolescents (3). This is caused by sudden, forceful hyperextension of the wrists, and may occur during a near fall while performing a clean and jerk (10). A near fall refers to an unbalanced position of the barbell with the weight too far posterior to the axis of the wrist, causing a hyperextension of the wrist in an attempt to control the weight. The importance of spotters, even in submaximal lifts, cannot be overemphasized. As muscles fatigue, the chance of a fall increases due to the inability to maintain proper technique. Three improper positions that increase lumbar hyperextension and the chance of developing spondylolisthesis are:

1. holding weight against gravity with back rounded and flexed,
2. pressing weight overhead while leaning back,
3. holding weight overhead; this causes a hyperlordotic position, creating a greater shear force on L₅-S₁ (12).

The Leaper was a causative factor for 59 percent of lumbo-sacral and cervical spine injuries in one high school study (4). The number of injuries from the use of the Leaper is indicative of two potential problems: students used improper technique and the machine is too dangerous for skeletally immature lifters to use. It creates a lumbar hyperextension force, aggravating any spondylolitic condition (3, 4). Incorrectly performed military press and bench press create an increased lumbar...
stress on the lifter also.

Epiphyseal fractures of young lifters have been reported, but after careful evaluation of the mechanism of action, each case involved poorly performed overhead lifts (8). When an overhead lift is performed, a forward thrust of the hips is necessary to bring the total body into alignment, because the weight has a tendency to pull the body forward. This hip thrust puts the low back into a hyperextended, lordotic position, creating a sheer force on the lumbar vertebra and L5–S1 junction. This movement is sudden and forceful. Adolescents generally should avoid similar type movements until ossification of growth centers is complete.

Jesse is an advocate of adolescent development of the deep seated spinal rotators (semispinalis, multifidus, rotatores) by rounded back, rotation and lateral flexion exercises prior to any type of overhead lift (12). These muscles, along with the short interspinous ligaments, maintain the basic stability and alignment of the spine. This stability is needed to protect the spine during lifting and supporting overhead weight. These muscles generally are developed through the childhood activities of tumbling and wrestling, and work such as digging and shoveling. Observing the sedentary lifestyle of so many preadolescents, the proper development of these deep, rotational stabilizers may be deficient. There has been no objective study, to date, to verify this theory, but it is something to consider when beginning an adolescent on any weight training program.

In a study involving 43 individuals with definite weight training injuries, it was found that 15-year-olds are the most frequently injured (4). Evaluating the strength and growth patterns in boys 7 to 17, it was found that the greatest rate of change peaked between 13 and 15 (19).

High school athletes on a comprehensive weight training program had nearly one-third fewer sport injuries and 50 percent less time in rehabilitation than athletes without any weight training (11). Those students who trained with weights had an injury rate of 26 percent versus 72 percent for untrained individuals. Numerous adolescent sporting teams were evaluated (girls' volleyball, boys' and girls' basketball, football and wrestling). The participants were categorized as maximal weight training background, moderate background and no weight training background. There was slight variation between sports, but overall, those athletes with weight training backgrounds suffered injuries at a rate almost one-third that of their non-weight trained counterparts. Also, rehabilitation ratios (amount of time lost to participation by injury per number of participants) showed that those with maximal backgrounds lost the least amount of time to injury, while control subjects showed greater time lost. The rehabilitation ratios ranged from 2:1 to 3:1 in time lost from nontrained to maximally trained. This would indicate the value of preseason conditioning in injury prevention. This is significant due to the large number of students evaluated and involved in weight training related to the number of injuries requiring a trip to the hospital emergency room. Within this study, only one injury was from weight training alone.

These statistics show strong evidence of the value of weight training for injury prevention in adolescent sports. As is true with most statistics, other variables must be taken into account. It is difficult to separate the effects of training from individual motivational factors. One might expect a highly motivated, aggressive athlete to miss fewer days of practice from an injury because of a willingness to endure more muscular or skeletal discomfort. The athlete with less desire may be willing to sit out of the sport longer for recovery. This same athlete is the type less willing to devote the necessary dedication to a proper weight training conditioning program. On the other hand, the aggressive participant may be utilized more in competition, increasing the chance of injury or re-injury.

Physical therapists are valuable and necessary in rehabilitation from injury, but more valuable to athletics and adolescent patients is the education that should be provided to them. A physical therapist has the anatomical, physiological and biomechanical background to properly advise coaches, trainers and participants in proper conditioning and lifting techniques, intensity and stretching programs. Developing sport-specific weight training protocols for adolescents is a valuable tool therapists have to offer high schools. Preparticipation screening should be emphasized with the goal of detecting any muscular/skeletal problems and developing a program to make corrections before the stress of athletic participation creates an injury situation. Physical therapists are rehabilitation experts, but more importantly they must assume responsibility for prevention educators. Whenever an adolescent presents joint pain, injury to any of the growth centers must be suspected.

Improper technique in an unsupervised setting has been a
primary causative factor to injury. In 1979, the Injury Surveillance System estimated that 35,512 weightlifting injuries required hospital visits. One-half were in the 10- to 19-year-old group, and the majority occurred in the home (2).

The importance of adequate supervision in weight training of children for the prevention of injury cannot be overemphasized (3, 4, 7, 9, 11, 15). Correct form should be the primary emphasis, not the amount of weight lifted.

The majority of resistive weight training equipment is manufactured to accommodate adult bodies. It is recommended that children interested in weight training be taught proper form utilizing free weights through the full range of motion and the use of their own body weight as resistance. Use of their own body weight via push-ups, chin-ups and sit-ups is an effective and safe form of muscle strengthening.

Supervision during any weight training activity with prepubescents and adolescents is of paramount importance. Ideal supervision would entail an individual with training in basic anatomy and biomechanics and a knowledge of the types of weights and their usage (i.e., free weights versus machines). All too often, though, the individual responsible for supervising is the coach or a parent who does not necessarily have a working knowledge of weights or training techniques. In that situation, emphasis should be placed on preventing maximal lifts, requiring spotters, preventing heavy overhead lifts and preventing horseplay or careless use of weights. It is also the responsibility of this individual to seek qualified advice regarding proper and optimal usage of the weights available.

Strength training can be a valuable mode of fitness, but coaches, parents and health care providers must stress that it is only one aspect of a child's physical development.

Growing prepubescents and adolescents must incorporate a wide variety of activities to develop agility, coordination, cardiovascular health and strength. Most important is retaining the fun of this activity for this age group. Encourage weight training for a child that is interested and mature enough to properly perform the techniques, but don't force it upon an individual not desiring it.

References


Summary

The benefits gained by weight training for prepubescents and adolescents include increased strength (quantity dependant upon physical maturity level), increased protection from potential athletic injuries, increased mental concentration and the development of personal discipline. There are potential risks involved due to the relative fragility of the osseous growth structures; however, by properly instructing the participants in lifting technique and reinforcing the absolute necessity of avoiding maximal lifts, training-related injuries can be avoided. The key to optimizing the benefits and minimizing injuries is direct supervision during any weight training.

Editor's note: At the time this article was written, Shafer was a student at the University of Wisconsin-La Crosse.
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