There Is No Need to Avoid Resistance Training (Weight Lifting) Until Physeal Closure

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Abstract: The physis, or *growth plate*, is relatively weaker than the surrounding bone; as a result, individuals with immature skeletons are at risk for growth plate injury from forces that would not harm an adult. Based on the knowledge that immature growth plates are weaker than adult growth plates, it is not known with certainty whether or not adolescents can participate safely in resistance training programs. Because medical literature does not definitively answer if it is safe for adolescents to pursue strength-training programs, we previously surveyed 500 experts in sports medicine to determine whether they agreed with the statement "resistance training ('weight lifting') should be avoided until physeal closure." Overall, respondents answered that "this statement is very likely false." In this article, we interpret the experts' survey responses by reviewing the basic and clinical sciences implicit in the question, as well as the literature regarding adolescent outcomes. Although the avoidance of resistance training by adolescents is theoretically appealing, we found that the data indicate properly supervised weight programs are not associated with increased risk of acute injury. However, the literature offers no insight about the long-term implications of weight lifting on growth plates. In sum, the expert consensus from our survey that strength training is safe for individuals with immature skeletons is consistent with data from medical literature.

Keywords: resistance training; physis; injury; skeletal immaturity; sports medicine

Introduction

Should resistance training (ie, weight lifting) be avoided by adolescents until physeal closure? What are the risks, if any? Because the literature does not provide a definitive answer to this question, we surveyed 500 experts in sports medicine and asked if they agreed with this statement: "resistance training ('weight lifting') should be avoided until physeal closure."[1] Respondents were asked to register agreement or disagreement according to a 7-point, centered, and symmetrical scale, which ranged from "the statement is false" (1 point) to "the statement is true" (7 points). For the statement about the avoidance of resistance training, the mean score was 2.0, which corresponds to the answer "this statement is very likely to be false." The distribution of survey responses to this question is contained in Table 1.[1] This article reviews the responses to this question about resistance training in individuals with immature skeletons and attempts to interpret expert responses in context. We also reviewed the available literature to summarize the evidence on this topic.

The Question

The increasing popularity of organized youth sports has led to a recent rise in both the number of pediatric athletes and the expectation that these young athletes perform at

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Table 1. Distribution of Responses to the Survey Statement "Resistance Training ('Weight Lifting') Should Be Avoided Until Physeal Closure"[1]

Group mean[a]	Orthopedic surgeon mean[a]	Non-surgeon mean[a]	"The statement is false," % (1)	"The statement is very likely to be false," % (2)	"The statement is probably false," % (3)	"The statement may be true/ false; 50-50," % (4)	"The statement is probably true," % (5)	"The statement is very likely to be true," % (6)	"The statement is true," % (7)
2.0	2.4	1.9	54	19	12	5	5	3	2

[a]Means are presented on a 7-point scale.
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a high level. In turn, resistance training has become a central part of many younger athletes' work-outs.[2] However, some children and adolescents are discouraged from participating in strength-training routines due to a number of perceived risks: acute musculoskeletal injury; decreased flexibility; increased blood pressure; and chronic growth plate damage with subsequent stunted growth.[3]

Damage to the long bone physis is a particularly relevant concern in the pediatric population because of the relative weakness of the growth plate. At the physis, chondrocytes proliferate, mature, and secrete extracellular matrix, which eventually ossifies. However, prior to matrix mineralization at the interface between the physis and the metaphysis, the still uncalcified growth plate lacks the strength of adjacent ossified bone and is also more fragile than surrounding soft tissue structures.[4] That is because the physis must be "soft" enough to allow longitudinal bone growth—yet this also makes the physis malleable enough to be injured from forces that "hard" bone can easily withstand.

Specifically, the physis tends to be the first structure to fail when force, especially tensile force, is applied to a growing bone. As a result, mechanisms of injury that would cause ligament sprains in adults might cause growth plate injuries in individuals with immature skeletons. Moreover, physeal blood supply is tenuous; even nondisplaced physeal injuries carry an increased risk of blood supply interruption if they are not adequately treated. Further, even a properly treated acute growth plate injury may impede future growth of the patient's bone, which results in diminished or asymmetrical axial proliferation that may lead to stunted growth or angular deformities in patients.[4] It has also been proposed that the physis may experience occult damage from the repetitive microtrauma of resistance training.[5] This could further weaken the physis and therefore lead to premature physeal closure and stunted growth or increased fracture risk.

The Literature

Despite the theoretical plausibility of the dangers of resistance training prior to physeal closure, there is little evidence to suggest that the pediatric population should avoid weight lifting. The original data describing acute traumatic injuries to growth plates contains a low level of evidence. During the 1970s and 1980s, the National Electronic Injury Surveillance System of the US Consumer Product Safety Committee reported data from several US emergency departments that showed a trend of pediatric injuries attributed to resistance training.[6,7] The committee extrapolated this data to make national predictions, which led experts to discourage weight lifting in the pediatric population.[3,5] At approximately the same time, multiple case reports were published that described adolescent physeal injuries caused by resistance training.[8–10] Ryan and Salciccioli[10] reported fractures of the distal radial epiphysis in adolescent weight lifters, and Gumbs et al[8] described 2 cases of bilateral radius and ulnar fractures. Jenkins and Mintowt-Czyz[9] described a 13-year-old boy who experienced bilateral fracture-separations of his distal radial epiphysis during weight training and fractured his distal tibial epiphysis as he played football 2 weeks later. The largest and highest quality study that showed growth plate injuries among young athletes was a retrospective review of 43 subjects with weight training injuries from 1976 to 1980; the authors related 6 of those injuries to the growth plate by characterizing the injuries as anterior iliac spine avulsions.[11]

These data showing acute traumatic physeal injury in adolescents were misinterpreted by the experts who discouraged resistance training in the pediatric population.[10] A closer inspection of 2 years of National Electronic Injury Surveillance System data (1979 and 1987) revealed that most physeal injuries now can be attributed to athletes failing to have qualified supervision, lifting excessively heavy weights, using improperly designed equipment, and employing poor technique.[5] For example, Jenkins and Mintowt-Czyz[9] and Gumbs et al[8] each attributed the physeal injuries that they reported to unsupervised technique. In 2009, Myer et al[12] reviewed individuals with weight lifting injuries who presented to emergency rooms. They found that the proportion of accidental injuries related to dropped weight or improper equipment use was inversely correlated to age; two thirds of the injuries sustained in the 8- to 13-year-old age group were related to "dropping" and "pinching." Although these conclusions still suggest that unsupervised and inappropriate use of weight lifting equipment may be dangerous to a child's or an adolescent's relatively weak growth plates, the findings cannot be extrapolated to mean that adequately designed and supervised pediatric–resistance-training programs are harmful to a child's health.

In fact, no prospective youth–resistance-training research study has reported any acute injury to youth growth plates.[5,13] Malina[13] performed an evidence-based review that analyzed the effects of resistance-training programs on youth response, growth, maturation, and injury; as of 2006, Malina found 10 studies that had systematically monitored youth injuries. Of the 10 studies, only 3 reported acute injuries to individuals that were significant enough to require cessation of training. Malina estimated that injury rates were only 0.176, 0.053, and 0.055 per 100 participant-hours in the 3 studies and determined that none of the reported injuries involved the physis. Lillegard et al[14] noted only 1 male shoulder muscle strain in a group of 36 pre- and post-pubertal males and females who lifted 3 sets of 10 repetitions at a 10 repetition maximum for 6 exercises 3 times per week for 12 weeks. Rians et al[15] also reported 1 clinically defined male shoulder strain in a group of 18 prepubertal males who were undergoing a 45-minute routine of a 10-station hydraulic machine circuit 3 times per week for 14 weeks; however, a scintigraphy of the injured child's bone, epiphyses, and muscle indicated no evidence of damage. The only other reported injury was nonspecific thigh pain associated with the bar falling after a lift in a 21-month study of 60 males aged 9- to 10-years-old, who performed 150 repetitions for 3 to 6 exercises 2 times per week.[16] Seven of the 10 controlled, prospective studies tracking injuries in Malina's review[13] collectively followed an additional 141 children and adolescents who underwent various weight-training regimens for durations ranging from 8 weeks to 9 months and found no injuries.[17–23]

After the publication of Malina's meta-analysis in 2006, several more recent highly controlled, prospective studies also have reported injury-free resistance training by children and adolescents at a variety of physical fitness levels. In a 2008 analysis of the effect of resistance training on adiposity in children, Benson et al[24] reported no acute injuries to the subjects during 284 maximal strength tests and 405 hours of progressive resistance training. Similarly, Sgro et al[25] and McGuigan et al[26] reported no injuries in overweight or obese prepubescent children who engaged in 8 to 24 week resistance-training programs. In a more fit patient population, Christou et al[27] exposed 9 predominantly pubescent male high school soccer players to supplemental semi-weekly strength-training programs for 16 weeks without evidence of injury. In a similar population of 62 Chinese males who were high-level regional U-14 soccer players and underwent supplemental resistance-training programs, 3 out of 31 players quit the team due to injury or illness. However, the authors[28] noted that these injuries or illnesses did not occur during the training program; more importantly, a larger number of players (8 out of 31) in the control group quit the team for similar reasons. The authors do not detail the players' reasons for quitting the team, but this study was highly controlled and the 2 groups were matched on body mass, height, and age, which may suggest that resistance training is indeed protective against the musculoskeletal injuries that may force players to quit.

Just as many studies have shown that resistance training is not acutely dangerous to a youthful physis, there is limited clinical evidence that suggests weight lifting does not alter linear growth in the short term. The meta-analysis by Malina[14] combined data from highly controlled, prospective studies to reveal that although experimental subjects were on average taller than control subjects at the start of training programs, there were no differences in height changes between resistance training and control groups; however, these 9 studies followed children for durations ranging from just 6 to 21 months.[13] Alvarez-San Emeterio et al[29] also suggests that growth spurts are not altered by weight lifting; they report that the combination of strength training and Alpine skiing for a period > 2 years does not alter height gains experienced by 20 predominantly pubescent adolescents compared with sedentary controls.

It must also be noted that studies supporting the safety of youth resistance training were performed in highly controlled environments. Consequently, the importance of proper supervision has been repeatedly emphasized in published pediatric weight-lifting guidelines: 5 of the 16 suggestions by Nettle and Sprogis focus on supervision, instruction, and demonstration,[3] and Faigenbaum and Myer's first pediatric resistance-training guideline is to "provide qualified instruction and close supervision."[2] Supervisors should stress that proper technique is the goal of training—not maximum-weight lifts.[2,3,16] Adequate rest and training on nonconsecutive days is also important when training young athletes.[2,3] Some authors suggest that athletes should practice slow, controlled movements and avoid Olympic-style ballistic exercises[16]; however, other authors emphasize the importance of progressing from relatively simple movements to advanced multi-joint exercises that target balance and coordination.[2,3] Regardless of skill level, children should not be shamed if they are unable to perform an exercise nor should children be compared with each other—training should remain an enjoyable, yet serious, activity that is driven by positive reinforcement.[3] Therefore, ideal supervisors should understand both the physical and the psychosocial uniqueness of youth to optimally advance program design over time and to ensure that training is both musculoskeletally and emotionally stimulating for young athletes.[2]

The Experts

The mean score was 2.0 for the statement "resistance training ('weight lifting') should be avoided until physeal closure"; this value is equivalent to the scoring of the phrase "this statement is very likely to be false." As a whole, the subgroup of orthopedic surgeons in our survey was slightly less likely to deem the statement false, with a mean agreement value of 2.4. It is important to note that 85% of all experts surveyed thought the statement was false; 54% of the experts directly labeled the statement false and an additional 31% of surveyed experts believed the statement was "very likely" or "probably" false. Only 5% of the experts surveyed directly labeled the statement uncertain and the remaining 10% of experts leaned towards declaring the statement true. In other words, approximately half of the community of experts is convinced that resistance training is safe for individuals with immature skeletons and the other half of the experts is keeping an open mind, although they are more likely to believe the statement is false. Perhaps this is the correct attitude towards medical knowledge. Doctors should require that high quality research support hypotheses before accepting even the most theoretically plausible theories as true.

Additionally, asserting the permissibility of weight lifting in adolescents is not tantamount to saying that weight lifting is completely risk-free; rather, the contention is that weight lifting is not harmful on balance—risk is involved with many athletic activities, but serious injury occurs rarely enough that youth athletics on the whole are not avoided. Therefore, completely valid reports in the literature of *some* patient complications from weight lifting should not necessarily be used as evidence to ban the practice, just as papers describing the medical consequences of traffic accidents should not be used as evidence to ban driving.

Future Research

There is high quality evidence suggesting that properly supervised resistance training is safe for youthful growth plates in the short term; a number highly controlled, randomized, prospective studies tracked weight lifting regimens in patients without evidence of physeal injury.[13–16,18,20–28] Although these studies individually analyzed small numbers of patients, they collectively assessed $>$ 300 age-matched children and adolescents.

However, there is one glaring limitation with the current literature which makes the questioned statement in our survey difficult to answer: duration of follow up. All studies that assessed the impact of resistance training on individuals with immature skeletons did so for a relatively short period of time, which ranged from 6 months to 2 years. We were unable to identify any papers that explore the relationship between resistance training before physeal closure and height at maturity; we were likely unsuccessful because most papers assess the relationship between resistance training and growth peripherally and focus on other patient outcome measures that are more applicable to the short term. Of course, it would be expensive to continue resistance training for such an extended period of time. It would also be difficult, and perhaps unethical, to obtain such a long-term commitment from the already vulnerable study population of children and adolescents.

The optimal study assessing the theory that growth plates are susceptible to damage from the repetitive microtrauma of resistance training must continue to evaluate study patients until they reach skeletal maturity. That ideal study should of course be a randomized, controlled trial that exposes experimental patients to supervised resistance training of substantial duration before assessing several patient parameters when patients maturity. The patient parameters measured should include longitudinal growth in terms of vertical height as well as individual bone lengths. The ideal study should also quantify any rotational or angular deformities in patients that are due to asymmetrical occult growth plate injury. Ethics committees are unlikely to approve radiographic imaging of growth plates either at the start and end or throughout such a study, but the emergence of ultra-low dose radiation modalities like the EOS machine[30] may make this possible in the future. A large sample size of patients will also need to be studied because of the high variability of human height,[31] which may further impede the viability of the ideal study.

Authors of the larger highly controlled short-term studies described in this article[17,25] may be able to follow-up with their former subjects to assess growth parameters because these subjects now have mature skeletons. Although a detailed quantification of bone length and angular deformities in patients would be difficult, a simple phone call inquiring about patient height may

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also provide more long-term information than present in the current literature.

Conclusion

Although scientific theory suggests that resistance training—now often encouraged for youths involved in competitive athletics—may be deleterious to a child's growing physis, properly supervised training regimes emphasizing lighter weights and slow, controlled movements have been shown to be safe in the short term. There are no data assessing the long-term effects of weight lifting on youth growth, but the expert consensus from our study is that resistance training is safe prior to physeal closure. But absence of evidence is not evidence of absence, so further studies are needed to address this question.

Conflict of Interest Statement

Michael T. Milone, BA, Fotios P. Tjoumakaris, MD, Kevin B. Freedman, MD, MSCE, and Joseph Bernstein, MD, MS, disclose no conflicts of interest.

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