# Eminence-Based Medicine Versus Evidence-Based Medicine: Is Anterior Cruciate Ligament Reconstruction Optimally Performed With the Double-Bundle Technique?

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**Abstract:** The anterior cruciate ligament (ACL) comprises 2 distinct bands or bundles—the anteromedial bundle, which is tighter in flexion, and the posterolateral bundle, which is tighter in extension. Traditional ACL reconstruction uses 1 graft. A new technique, known as the double-bundle technique, uses 2 tendon grafts to more closely approximate normal anatomy. Because the medical literature does not provide a definitive answer as to which reconstruction method is better, we surveyed 500 experts in sports medicine in a previous study to determine whether they agreed with the statement "ACL reconstruction is optimally performed with the double-bundle technique." Respondants were inclined to answer "This statement is probably false." Our article interprets the expert responses by reviewing the basic and clinical sciences implicit in the question and reviewing the literature regarding outcomes. We found that double-bundle ACL reconstruction is theoretically appealing, but evidence proving that it improves clinical outcomes is unavailable. High-quality studies are under way on the topic, which may provide a definitive answer. However, until such data are available, the expert consensus from our survey was that the double-bundle technique is not necessarily the optimal approach.

**Keywords:** anterior cruciate ligament; reconstruction; graft failure

## Introduction

Should reconstruction of the anterior cruciate ligament (ACL) use 2 tendon grafts (ie, the double-bundle technique) or should a 1-tendon graft (ie, the traditional technique) be used? Is one superior to the other? 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 the statement "ACL reconstruction is optimally performed with the double-bundle technique."[1] Respondents were asked to register agreement or disagreement according to a 7-point, centered, and symmetrical scale ranging from "The statement is false" (1 point) to "The statement is true" (7 points). For this particular statement, the mean score was 3.4, which inclines toward "This statement is probably false." The responses to the statement followed the distribution in Table 1. This article reviews the responses to the question about use of the double-bundle ACL reconstruction technique in order to summarize the literature, and attempts to interpret the expert responses in context. We also review the available literature.

## The Question

Two distinct bands or bundles of the ACL have long been recognized in orthopedic sports medicine literature—the anteromedial bundle and posterolateral bundle.[2,3] This macroscopic division acknowledges the fact that the ACL does not behave

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**Table 1.** Distribution of Responses to Survey Statement

| Statement | Group mean | Orthopedic surgeon mean | Non-surgeon mean | "The statement is false," % | "The statement is very likely to be false," % | "The statement is probably false," % | "The statement may be true/false; 50–50," % | "The statement is probably true," % | "The statement is very likely to be true," % | "The statement is true," % |
|---|---|---|---|---|---|---|---|---|---|---|
| "ACL reconstruction is optimally performed with the duble-bundle technique." | 3.4 | 2.5 | 3.6 | 20 | 10 | 11 | 42 | 9 | 6 | 3 |

Scores are on a 7-point scale.
**Abbreviation:** ACL, anterior cruciate ligament.

like a single strand, but rather, has distinct regions that are preferentially stressed as the knee flexes. In particular, the anteromedial bundle is tighter in flexion, whereas the posterolateral bundle is tighter in extension.[4]

Possibly due to issues regarding technical feasibility, original attempts at ACL reconstruction ignored this anatomic nuance. A single-bundle ACL graft was placed, with a single point of attachment near the apertures of the tibial and femoral tunnels. Although single-bundle ACL reconstruction is used successfully by many orthopedic surgeons,[5] it is understood that a single-bundle graft does not reconstitute normal anatomy. Because normal anatomy is not established, single-bundle grafts are likely to have abnormal biomechanics. In turn, perfect stability and protection of the articular surfaces and meniscus are not attained.

Double-bundle ACL reconstruction aims to more closely recreate the normal anatomy. Instead of placing 1 graft, this procedure places 2 grafts. The first attemps to replicate the anteromedial bundle and the second emulates the posterolateral bundle.[6] However, even the double-bundle ACL graft technique is not a true reconstitution of normal anatomy, as the classification of the ACL region is simplified. The ACL comprises thousands of fibers of collagen, each with its own point-to-point connection between the femur and tibia, and therefore distinct biomechanical profile. Furthermore, securing 2 grafts under the correct tension is technically more difficult.

In short, double-bundle ACL reconstruction requires more surgical effort, yet still may fail to recreate the normal anatomy. Therefore, the question remains: Which technique is better? Some argue that though a single-bundle technique is imperfect, it is good enough, and that the theoretical advantages of the double-bundle technique may not justify its complexity. On the other hand, proponents of the double-bundle technique state that this technique comes closer to the aim of restoring the native anatomy, and therefore must be the preferred method.

## The Literature

Most patients who currently undergo single-bundle reconstruction return to normal stability with respect to International Knee Documentation Committee (IKDC) criteria.[7] Woo et al[8] reported that the single-bundle technique restores anterior tibial translation to 78% to 100% of normal stability in response to a 134-N anterior tibial load. In a systematic review of 1024 single-bundle reconstructions, Lewis et al[5] found negative pivot-shift test results in 81% of patients. Moreover, the investigators found a 6% complication rate and a 4% graft failure rate.

Radford and Amis[9] validated the double-bundle technique in cadaveric knees, stating that "the double-bundle reconstruction [gives] practically normal anterior stability at both 20 degrees and 90 degrees," closely recapitulating intact ACL physiology.[9] In the early 2000s, a more complete understanding of force distribution between the anteromedial and posterolateral bundles in response to anterior tibial load was achieved and was found to be reciprocal. In particular, the force of the anteromedial bundle is greater in flexion, whereas the posterolateral bundle is tighter in extension.[8] The distinctive bundles also resist valgus and rotary loads, serving to validate further interest in anatomic ACL reconstruction.[8] Many authors view the latter to be the principal theoretical advantage of double-bundle reconstruction.[8,10] With this understanding of intact ACL function, many authors were able to demonstrate good clinical outcomes using a variety of double-bundle reconstruction techniques.[11] In 2004, Yasuda et al[12] published their study on 57 patients who underwent arthroscopic double-bundle reconstruction. Investigators found superior clinical results in manual knee laxity and KT-2000 testing compared with the authors' previous experience with conventional single-bundle reconstruction.[12]

When comparing the 2 techniques, it is important to consider the rationale for ACL reconstruction. In the short-term, the goal of surgery is to return patients to pre-injury physical activity as quickly as possible. This task, based on normalizing subjective knee symptoms and anterior tibial translation, has been largely achieved by current methods of ACL reconstruction.[7,8,13–15] The second goal (ie, the prevention of late complications of ACL rupture, such as meniscus tear and osteoarthritis [OA]) has not been met.[16] A 2004 Swedish study of female soccer players who had sustained ACL injuries more than a decade prior found that nearly half had radiographic evidence of OA in the affected knee and that 75% had persistent knee-related symptoms.[17] Some studies have demonstrated radiographic evidence of OA in as many as 60% to 90% of patients who sustained ACL ruptures.[16] These persistent effects of ACL injury are hypothesized to occur secondary to the subtle knee instability that remains after ACL reconstruction.[8] Focal, abnormal forces can damage the meniscus, articular surface, and other soft tissues.[8]

Attaining only 1 of the 2 operative goals underlies the current debate regarding the double-bundle technique. Perhaps a better ACL repair (ie, one that more closely reconstitutes normal knee anatomy) may be better at preventing degenerative changes.[7] To date, however, there has been no correlation between how an ACL rupture is treated (ie, operative vs nonoperative) and the development of OA in late follow-up.[11,18] Thus, there is opportunity for improving ACL reconstruction outcomes.

Laboratory evidence demonstrates a sharp difference in knee mechanics produced by single- versus double-bundle reconstruction. Single-bundle reconstruction does not recapitulate normal knee kinematics. Boyer and Meislin[19] have stated that knees repaired by single-bundle reconstruction are "universally abnormal" in tibial translation and tranverse motion compared with normal knees. In cadaveric knees, Yagi et al[20] demonstrated that double-bundle reconstruction yielded an in situ force of 97% of normal versus 89% of normal in single-bundle reconstruction when grafts were exposed to anterior tibial loads, and even more drastic differences, of 91% and 66%, respectively, when exposed to rotary forces. Yagi et al[20] theorized that the contribution of the posterolateral bundle, which was largely ignored in single-bundle reconstruction, contributed to the improved kinematics of the double-bundle reconstruction. The exaggerated difference in rotational loading was validated by Hemmerich et al[21] in anthropometric data on patients randomly assigned to either single- or double-bundle ACL reconstruction.

Clinical outcomes have yet to match the enthusiasm generated by laboratory data for comparing single- and double-bundle reconstruction techniques; they have also been largely conflicting. The largest prospective cohort study on the topic was conducted by Kondo et al.[22] In 328 patients, investigators found a significant difference ($P < 0.0001$) in both side-to-side KT-2000–measured anterior tibial translation (ATT) and manual pivot-shift testing in double- versus single-bundle reconstruction. However, there was not a statistically significant difference in subjective outcome, as measured by IKDC scoring.[22] These findings are largely consistent with the literature. When significant differences are found in various prospective studies between single- and double-bundle reconstruction, (eg, Longo et al[23] published a systemic review on this topic), the differences are often related to objective variables, such as KT-2000–measured ATT and manual pivot-shift testing. However, when patients are asked to subjectively relate their postoperative experience, the differences between double- and single-bundle reconstruction are largely rendered null.[23] Like Kondo et al,[22] Aglietti et al[24] demonstrated significantly better results in KT-2000–measured ATT in double- versus single-bundle reconstruction and demonstrated significantly improved results in manual pivot-shift testing; however, there were no differences in IKDC score.[24]

Other studies have shown nonsignificant results, demonstrating no significant difference in either objective measures or IKDC. In fact, the systematic review by Longo et al[23] described 8 of 17 recent prospective studies in which no difference in anterior knee stability was found, while 8 showed a positive result. Of the 14 studies in which pivot-shift test results were reported among the data of Longo et al,[23] 7 found an insignificant difference between double- and single-bundle reconstruction, while 7 showed that patients were more likely to have a normal pivot-shift test with double-bundle technique. Of the 13 studies reporting IKDC subjective scores, only 3 reported a significant difference. A meta-analysis by Meredick et al[10] is strikingly similar in its conclusion. In both the primary and secondary analysis, Meredick et al[10] found a small statistically significant difference in KT-2000 arthrometer results favoring double-bundle over single-bundle technique, which the authors referred to as having "no clinical significance."[10] The meta-analysis found a greater chance of a normal pivot-shift test with double-bundle repair, but concluded that such a difference was not clinically significant.

A separate meta-analysis, which relied on many of the same studies, was conducted by van Eck et al.[25] Investigators found that the double-bundle technique showed less anterior and rotational laxity compared with single-bundle technique, but they noted no differences in result based on patient-reported outcome.[25]

In summary, meta-analyses and systematic reviews of the literature generally demonstrate a small, statistically significant difference in objective measures of anterior knee stability, no difference in manual pivot-shift test results, and no difference in clinical outcome.[10,23] There was no reported difference in complication rates for either intraoperative or postoperative problems for either procedure. None of the comparative studies between single- and double-bundle reconstruction have prospectively followed patients for long enough to determine differing rates of OA between treatment groups; however, these data should be forthcoming.[26]

## The Experts

The mean score for the statement "ACL reconstruction is optimally performed with the double-bundle technique" was 3.4, which inclines toward "this statement is probably false." Orthopedic surgeons, as a subgroup within our group of experts, were even more likely to deem the statement to be false. It is also worth noting that many of the experts were uncertain; 42% labeled this directly as uncertain, with an additional 20% in the categories adjacent to that. One way of interpreting these data is that the community of experts is not convinced that double-bundle reconstruction is necessarily better, but is keeping an open mind, implicitly saying "Show me; I am willing to be convinced." This is indeed how medical knowledge should advance—by using theory to propose new approaches, but demanding that outcome studies validate the theory before the new approach is accepted as standard.

## Future Research

There are various limitations in the literature that make direct comparisons between double- and single-bundle reconstruction difficult. First, the level of evidence across the literature on ACL reconstruction is generally low.[27] A close review of the clinical trials comparing double- and single-bundle techniques reveals significant differences in operative technique, including differences in graft material, fixation devices, and methods of graft tensioning and fixation, such that few studies can truly be compared side by side.[7] Furthermore, there is a current lack of agreement in the literature on how outcomes should be measured altogether. Some studies, for example, fail to report manual pivot-shift test results, which is a key measure in a surgical procedure designed to minimize rotary instability. Others fail to administer critical subjective IKDC surveys.[23] Additionally, there is a great deal of both patient and surgeon heterogeneity when comparing the 2 procedures. A conclusion in the recent meta-analysis by van Eck et al[25] is instructive to the inconsistency of current comparative studies: "The majority of the included studies had a least one major limitation in study design that decreased the quality of the study."

A recent editorial by D'Agostino et al[28] discussed the future of the single- versus double-bundle reconstruction debate. The authors described the need for well-designed, definitive studies on the topic, stating that the current literature "frequently reach[es] conclusions that are unconvincing if not inconclusive because of limitations in study design."[28] D'Agostino et al[28] calls for a trial with 1) standardized surgical protocols, 2) patient randomization, 3) patient blinding, 4) blinding of assessing clinicians, 5) standardized outcome measures including quality-of-life surveys, and 6) multiple institutions and multiple surgeons. D'Agostino et al[26] very well may get their wish. A group led by Dr. Freddie Fu at the University of Pittsburgh has initiated a clinical trial with National Institute of Arthritis and Musculoskeletal and Skin Diseases funding that meets many of the specifications detailed by D'Agostino et al.[26]

Because it may take 10 years to see differences between the 2 techniques as they relate to arthritic symptoms, and because the prevention of OA is germane to ACL repair, it will be helpful to establish markers that can serve as surrogates for the true outcome of interest. In doing so, it will also be useful to validate proxy outcomes (eg, measured laxity or biochemical markers of chondrocyte viability) that relate to joint preservation. This may allow answers to be found faster than in clinical outcomes trials.

If the promoters of double-bundle reconstruction could demonstrate that at least in highly selected patients they can attain outcomes that exceed those of historical controls, then other surgeons may be emboldened to use the technique and in turn help generate additional data. On the other hand, if the outcomes in even this select group are suboptimal, strong evidence suggests that double-bundle reconstruction is not ready for widespread use.

## Conclusion

Double-bundle ACL reconstruction is theoretically appealing, but evidence proving that it improves clinical outcomes is not currently available. High-quality studies are under way on the topic, which may well render a definitive answer. Until such data are available, the expert consensus from our study is that the double-bundle reconstruction is not superior to single-bundle repair.

## Conflict of Interest Statement

Paul R. Massey, Fotios P. Tjoumakaris, MD, and Joseph Bernstein, MD, disclose no conflicts of interest.

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# 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.
Reprinted from *The Physician and Sportsmedicine*, 39, Tjoumakaris FP, Ganley TJ, Kapur R, Kelly J, Sennett BJ, Bernstein J. Eminence-based medicine versus evidence-based medicine: level V evidence in sports medicine, 124–130, 2011, with permission from JTE Multimedia.

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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# Eminence-Based Medicine Versus Evidence-Based Medicine: Level V Evidence in Sports Medicine

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**Abstract:** Through extensive survey analysis, we investigated expert opinion in sports medicine. The study had 3 purposes: to provide clinical guidance for cases in which the correct action is not necessarily apparent, to examine expert opinion itself, and to delineate areas of future study. A total of 500 members of the American Medical Society for Sports Medicine and the American Orthopaedic Society for Sports Medicine evaluated a set of 25 statements on unresolved issues in sports medicine. The following 10 statements were deemed false: "It's okay for 12-year-old pitchers to throw curve balls; it's the pitch count that matters"; "Resistance training ('weight lifting') should be avoided until physeal closure"; "Jogging during pregnancy is to be avoided"; "At an athletic event, if sideline coverage is offered by an emergency medical technician and athletic trainer, there is little additional benefit from having a physician present"; "Contact sport athletes who sustain a second concussion should be excluded from contact sports permanently"; "The utility of pre-season medical screening is derived from the history; as such, student-athletes should complete a questionnaire, with physical examination reserved for only those with a positive relevant history"; "Femoroacetabular impingement is a myth—the designation of anatomic variation as disease"; "An AC (acromioclavicular) separation in a contact athlete should not be treated surgically if the athlete won't give up the sport; it will fail"; "Ankle taping induces weakness and atrophy of the dynamic stabilizers of the ankle"; "Only autografts should be used in ACL (anterior cruciate ligament) surgery, as allografts have an unnecessary high failure rate in clinical practice." One statement was accepted as true: "Surgery to treat anterior (patello-femoral) knee pain in a patient with normal patellar mechanics and stability is contraindicated." In short, expert opinion may be a helpful adjunct to clinical practice. Expert opinion cannot replace individual judgment and certainly does not trump the primary medical literature. Yet when better evidence is lacking, expert opinion is valuable for even the staunchest practitioner of evidence-based medicine.

**Keywords:** evidence-based medicine; expert opinion; level V evidence

## Introduction

The practice of evidence-based medicine is based optimally on sources that provide the highest levels of evidence. Wright[1] has noted, "The essence of levels of evidence is that, in general, controlled studies are better than uncontrolled studies, prospective studies are better than retrospective studies, and randomized studies are better than nonrandomized studies." Prospective, randomized, controlled trials stand atop the evidence hierarchy.[2] At the base is the lowest level of evidence—level V, or expert opinion. Placement of expert opinion somewhere within the hierarchy of evidence-based medicine relies on the intuitive argument that however limited it is, expert opinion is better than nonexpert opinion. However, cultural history is littered with numerous examples of experts being wrong—from the Decca Records executive who declined signing The Beatles to a contract in 1961 because "guitar groups are on the way out,"[3] to the perhaps apocryphal head

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of the patent office who advocated closing it in 1899 because "everything worthwhile has already been invented."[4] Thus, the apt role of expert opinion is not clearly defined.

The correct use of expert opinion should be based on recognition of its strengths and weaknesses. To that end, we investigated by survey analysis the nature of expert opinion in sports medicine. Our primary purpose was to provide clinical guidance in areas in which the correct action is not necessarily apparent. Our secondary purpose was to study the nature of expert opinion and thereby highlight its strengths and weaknesses. Our final charge was to identify areas of controversy within the larger sports medicine community and between orthopedic and nonoperative sports medicine practitioners. This delineation may help to guide future study in clinical decision making.

## Methods

Statements regarding unresolved issues in sports medicine were presented to members of the American Medical Society for Sports Medicine and the American Orthopaedic Society for Sports Medicine (AOSSM) (Table 1). Results were collected electronically until 500 completed surveys were received. Respondents were asked to agree or disagree with a given statement according to the following 7-point, centered, symmetrical scale:

1. "The statement is false."
2. "The statement is very likely to be false."
3. "The statement is probably false."
4. "The statement may be true/false; 50–50."
5. "The statement is probably true."
6. "The statement is very likely to be true."
7. "The statement is true."

For each question, the mean and distribution of the responses were noted. The respondents were classified as "orthopaedic specialists" (AOSSM members) and "non-orthopaedic specialists" (all others).

The group's responses were interpreted according to the following arbitrary scheme:

- If the mean response was $\leq 3.0$, a consensus that the statement is false was said to have been reached.
- If the mean response was $\geq 5.0$, a consensus that the statement is true was said to have been reached.
- If the mean response of the orthopedic sports specialists group differed from the mean of the nonorthopedic sports specialists by $\geq 1.0$, this difference was deemed significant.
- If $\geq 50\%$ the responses were "probably false," "may be true/false; 50–50," or "probably true" (the center groups), we inferred from the data that the experts were uncertain about this statement.
- A given statement was deemed controversial if it simultaneously received $\leq 20\%$ support for "false" or "very likely to be false" and $\leq 20\%$ support for "very likely to be true" or "true."

A total of 554 sports specialists clicked on the link for the electronic survey, and 500 (the arbitrary point for closing the survey) completed it, yielding a completion rate of 90%. Of them, 112 respondents were orthopedic sports specialists.

The consensus identified the following statements as false:

- "It's okay for 12-year-old pitchers to throw curve balls; it's the pitch count that matters."
- "Resistance training ('weight lifting') should be avoided until physeal closure."
- "Jogging during pregnancy is to be avoided."
- "At an athletic event, if sideline coverage is offered by an emergency medical technician and athletic trainer, there is little additional benefit from having a physician present."
- "Contact sport athletes who sustain a second concussion should be excluded from contact sports permanently."
- "The utility of pre-season medical screening is derived from the history; as such, student-athletes should complete a questionnaire, with physical examination reserved for only those with a positive relevant history."
- "Femoroacetabular impingement is a myth—the designation of anatomic variation as disease."
- "An AC (acromioclavicular) separation in a contact athlete should not be treated surgically if the athlete won't give up the sport; it will fail."
- "Ankle taping induces weakness and atrophy of the dynamic stabilizers of the ankle."
- "Only autografts should be used in ACL (anterior cruciate ligament) surgery, as allografts have an unacceptably high failure rate in clinical practice."

Only 1 statement was deemed true:

- "Surgery to treat anterior (patello-femoral) knee pain in a patient with normal patellar mechanics and stability is contraindicated."

**Table 1.** Survey Responses

| Statement | Group Mean Agreement Value | Orthopedic Surgeon Mean Agreement Value | Nonsurgeon Mean Agreement Value | Indicating "The statement is false," n % |
|---|---|---|---|---|
| 1. It's okay for 12-year-old pitchers to throw curve balls; it's the pitch count that matters[7] | 2.9 | 3.6 | 2.7 | 36 |
| 2. For patients with an acute ankle injury, the ability to hop on the sidelines is sufficient evidence to allow the athlete to return to the field | 3.2 | 3.6 | 3.0 | 32 |
| 3. ACL reconstruction is optimally performed with double bundle technique[8] | 3.4 | 2.5 | 3.6 | 20 |
| 4. Resistance training ('weight lifting') should be avoided until physeal closure[9] | 2.0 | 2.4 | 1.9 | 54 |
| 5. In a patient with impingement syndrome of the shoulder to be treated surgically, 'the acromion is innocent' and unless there is a focal spur, no bone has to be removed[10] | 3.7 | 4.4 | 3.6 | 13 |
| 6. Platelet-rich plasma injections, to the extent they offer any benefit at all, are placebos | 3.3 | 3.6 | 3.1 | 12 |
| 7. Reconstructing a torn and deficient ACL will prevent meniscal tears[11] | 4.3 | 5.4 | 4.0 | 15 |
| 8. Proximal hamstring ruptures in athletes require repair, distal ones don't[12] | 3.2 | 3.8 | 3.0 | 20 |
| 9. The etiology of medial joint line knee pain in a 50-year-old can be deduced by the location: pain anterior to the medial collateral ligament is apt to be arthritis, and not a meniscus tear | 3.2 | 3.8 | 3.0 | 18 |
| 10. Subacromial decompression is contraindicated in patients who did not get relief with a lidocaine injection test[13] | 3.6 | 4.3 | 3.4 | 15 |
| 11. Ruptures of the Achilles tendon, in the setting of tendinopathy, can be prevented with physical therapy and cushioning shoe inserts[14] | 3.2 | 2.9 | 3.2 | 19 |
| 12. Jogging during pregnancy is to be avoided[15] | 1.7 | 2.1 | 1.5 | 62 |
| 13. The rising popularity of surgical fixation of clavicle fractures[16] represents the triumph of marketing over reason and experience | 3.9 | 3.1 | 4.1 | 14 |
| 14. At an athletic event, if sideline coverage is offered by an emergency medical technician and athletic trainer, there is little additional benefit from having a physician present[17] | 2.2 | 2.6 | 2.0 | 52 |
| 15. Arthroscopic debridement for arthritis of the knee, to the extent it works at all, works by a placebo effect[18] | 4.4 | 3.7 | 4.6 | 7 |
| 16. Contact sport athletes who sustain a second concussion should be excluded from contact sports permanently[19] | 2.0 | 2.7 | 1.7 | 57 |
| 17. Surgery to treat anterior (patello-femoral) knee pain in a patient with normal patellar mechanics and stability is contraindicated[20] | 5.3 | 5.0 | 5.4 | 6 |

| Indicating "The statement is very likely to be false," n % | Indicating "The statement is probably false," n % | Indicating "The statement may be true/false; 50–50," n % | Indicating "The statement is probably true," n % | Indicating "The statement is very likely to be true," n % | Indicating "The statement is true," n % |
|---|---|---|---|---|---|
| 19 | 9 | 7 | 13 | 9 | 5 |
| 15 | 9 | 10 | 18 | 11 | 5 |
| 10 | 11 | 42 | 9 | 6 | 3 |
| 19 | 12 | 5 | 5 | 3 | 2 |
| 19 | 16 | 15 | 14 | 15 | 8 |
| 17 | 25 | 33 | 7 | 5 | 1 |
| 7 | 10 | 12 | 26 | 24 | 7 |
| 22 | 15 | 17 | 15 | 8 | 3 |
| 22 | 14 | 24 | 11 | 9 | 1 |
| 16 | 19 | 16 | 15 | 14 | 4 |
| 23 | 19 | 14 | 15 | 7 | 3 |
| 20 | 12 | 4 | 1 | 0 | 1 |
| 14 | 13 | 14 | 24 | 13 | 7 |
| 20 | 10 | 7 | 7 | 3 | 2 |
| 11 | 16 | 15 | 16 | 19 | 15 |
| 18 | 9 | 8 | 2 | 4 | 1 |
| 6 | 6 | 7 | 16 | 29 | 30 |

**Table 1.** (*Continued*)

| Statement | Group Mean Agreement Value | Orthopedic Surgeon Mean Agreement Value | Nonsurgeon Mean Agreement Value | Indicating "The statement is false," n % |
|---|---|---|---|---|
| 18. The utility of pre-season medical screening is derived from the history; as such, student-athletes should complete a questionnaire, with physical examination reserved for only those with a positive relevant history[21,22] | 2.7 | 3.4 | 2.6 | 42 |
| 19. Femoroacetabular impingement is a myth—the designation of anatomic variation as disease[23,24] | 2.4 | 2.5 | 2.3 | 37 |
| 20. An AC separation in a contact athlete should not be treated surgically if the athlete won't give up the sport; it will fail[25] | 2.7 | 2.6 | 2.7 | 34 |
| 21. Ankle taping induces weakness and atrophy of the dynamic stabilizers of the ankle[26] | 2.5 | 2.3 | 2.6 | 33 |
| 22. A patient with bilateral spondylolysis is cleared to play contact sports as long as he or she can tolerate the symptoms[27] | 3.8 | 4.2 | 3.6 | 20 |
| 23. Patients whose age multiplied by their body mass index exceeds 1,200 can be presumed to have some component of their knee pain explained by arthritis[28] | 4.1 | 4.1 | 4.1 | 9 |
| 24. Physician ownership of surgi-centers and PT facilities creates conflicts of interest that can never be completely resolved if the physician refers his or her own patients there[29] | 4.5 | 3.5 | 4.8 | 14 |
| 25. Only autografts should be used in ACL surgery, as allografts have an unacceptably high failure rate in clinical practice[30] | 2.5 | 2.4 | 2.5 | 38 |

**Abbreviations:** AC, acromioclavicular; ACL, anterior cruciate ligament; PT, physical therapy.

For some statements, the responses clustered toward the middle; we labeled these statements as "uncertain." These were as follows.

- 62% uncertain: "ACL reconstruction is optimally performed with double bundle technique."
- 65% uncertain: "Platelet-rich plasma injections, to the extent they offer any benefit at all, are placebos."
- 50% uncertain: "Subacromial decompression is contraindicated in patients who did not get relief with a lidocaine injection test."
- 51% uncertain: "The rising popularity of surgical fixation of clavicle fractures represents the triumph of marketing over reason and experience."
- 70% uncertain: "Patients whose age multiplied by their body mass index exceeds 1,200 can be presumed to have some component of their knee pain explained by arthritis."

Some statements attracted strong responses on both extremes and were labeled as controversial. The responses and statements are as follows.

- 32% false; 23% true: "In a patient with impingement syndrome of the shoulder to be treated surgically, 'the acromion is innocent' and unless there is a focal spur, no bone has to be removed."
- 22% false; 31% true: "Reconstructing a torn and deficient ACL will prevent meniscal tears."
- 28% false; 20% true: "The rising popularity of surgical fixation of clavicle fractures represents the triumph of marketing over reason and experience."

(*Continued*)

| Indicating "The statement is very likely to be false," n % | Indicating "The statement is probably false," n % | Indicating "The statement may be true/false; 50–50," n % | Indicating "The statement is probably true," n % | Indicating "The statement is very likely to be true," n % | Indicating "The statement is true," n % |
|---|---|---|---|---|---|
| 13 | 12 | 8 | 13 | 9 | 3 |
| 23 | 19 | 12 | 4 | 3 | 1 |
| 20 | 17 | 12 | 9 | 5 | 2 |
| 26 | 19 | 10 | 7 | 5 | 1 |
| 16 | 10 | 11 | 18 | 15 | 10 |
| 7 | 8 | 41 | 21 | 12 | 3 |
| 7 | 8 | 11 | 22 | 18 | 19 |
| 21 | 14 | 13 | 8 | 3 | 2 |

- 36% false; 25% true: "A patient with bilateral spondylolysis is cleared to play contact sports as long as he or she can tolerate the symptoms."
- 21% false; 37% true: "Physician ownership of surgi-centers and PT (physical therapy) facilities creates conflicts of interest that can never be completely resolved if the physician refers his or her own patients there."

The following statements attracted significantly different mean responses based on the respondent's specialty.

- Surgeons' mean, 2.5; nonsurgeons' mean, 3.6: "ACL reconstruction is optimally performed with double bundle technique."
- Surgeons' mean, 4.3; nonsurgeons' mean, 5.4: "Reconstructing a torn and deficient ACL will prevent meniscal tears."
- Surgeons' mean, 3.1; nonsurgeons' mean, 4.1: "The rising popularity of surgical fixation of clavicle fractures represents the triumph of marketing over reason and experience."
- Surgeons' mean, 2.7; nonsurgeons' mean, 1.7: "Contact sport athletes who sustain a second concussion should be excluded from."
- Surgeons' mean, 3.5; nonsurgeons' mean, 4.8: "Physician ownership of surgi-centers and PT facilities creates conflicts of interest that can never be completely resolved if the physician refers his or her own patients there."

## Limitations

Surveys such as this have inherent limitations. In this study, subjects may have produced different results had the statements been phrased differently. As Tversky and Kahneman[5] have famously shown, the framing of alternatives deeply influences responses. In the present study, the statement "Femoroacetabular impingement is a myth—the designation of anatomic variation as disease" might have secured greater support with more neutral phrasing, such as "The findings that produce femoroacetabular impingement might be found among many asymptomatic patients, just as disc bulges in the spine are known to be prevalent in patients without complaints."

In addition, this study did not allow the expert to state a level of certainty. For instance, 38 pediatricians were in the study sample, and each provided responses to the technical statements about surgery. Yet, the survey did not allow them to indicate how confident they were about their opinions.

## Conclusion

Expert opinion may be a helpful adjunct to clinical practice, but cannot replace individual judgment, and certainly does not trump the primary medical literature. Yet as Sackett et al[6] has noted, "Evidence-based medicine is the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients." When better evidence is lacking, expert opinion is valuable for even the staunchest practitioner of evidence-based medicine.

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## Conflict of Interest Statement

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