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ACL Reconstruction with Contralateral Patellar Tendon Grafts

ABSTRACT & COMMENTARY

Synopsis: *Patients reconstructed using contralateral patellar tendon grafts achieved range of motion, quadriceps muscle strength, and return to sport faster than patients reconstructed with ipsilateral patellar tendon grafts.*

Source: Shelbourne KD, Urch SE. Primary anterior cruciate ligament reconstruction using the contralateral autogenous patellar tendon. *Am J Sports Med* 2000;28(5):651-658.

Acl reconstruction is a commonly performed procedure for the orthopaedic surgeon that generally yields good results that allow an athlete to return to activities. Although the most common graft choice remains the ipsilateral patellar tendon, patient complaints related to graft harvest are common and sometimes activity limiting. Shelbourne and Urch have addressed this problem by using the contralateral patellar tendon as a graft source.

Over a three-year period, Shelbourne and Urch reconstructed 434 patients with contralateral patellar grafts and 228 patients with ipsilateral patellar grafts. Patients with revision reconstructions, prior contralateral ACL injuries, or bilateral injuries were excluded from the original number of 831. The patient made the choice of graft after preoperative counseling. Demographics, percentage of patients involved in competitive sports, and associated meniscal and chondral pathology were similar between groups. All patients followed an aggressive rehabilitation protocol without the use of any brace and with immediate weight bearing. All patients stayed one night in the hospital.

Range of motion was about 10° greater in the contralateral group at each time point up until two months postoperatively. Shelbourne and Urch found that quadriceps strength as assessed by isokinetic testing was greatest in the contralateral ACL reconstructed group at one, two, and four months postoperatively. Athletes with contralateral grafts returned to full sports participation at a mean of 4.9 months postopera-

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tively, compared to 6.1 months for athletes with ipsilateral grafts. The subgroup of competitive athletes returned to full sports at a mean of 4.1 months compared to 5.5 months for the ipsilateral group. Stability, as determined by KT-1000 arthrometry, was equivalent between groups. Modified Noyes subjective scores were equivalent among groups at two-year follow-up, while pain scores were slightly worse in the ipsilateral group. Shelbourne and Urch conclude that use of the contralateral patellar graft results in a faster return of quadriceps strength, quicker return of motion, and earlier return to sports.

COMMENT BY DAVID R. DIDUCH, MS, MD

Because of donor site morbidity and complications, alternative graft choices to ipsilateral patellar tendon grafts have been explored. Shelbourne and Urch represent a minority who have chosen to harvest the contralateral patellar tendon. By so doing, they maintain the advantages of bone plug fixation and rapid healing within the tunnels as an advantage over soft tissue grafts. Decreased surgical trauma to the reconstructed knee extensor mechanism preserves muscle strength, motion, and accelerates rehabilitation, as one would expect. This paper effectively and objectively measures these variables. Unfortunately, Shelbourne and Urch do not give us a good measure of the difficulty in recovering from bilateral knee surgery. The addition of outcome measures and short-term assessment of pain with visual analogue scales would have been helpful. Nevertheless, it would appear that the contralateral group did very well, given how quickly they regained motion, strength, and activity. It is amazing that in a group of patients this large that Shelbourne and Urch had no patellar fractures, patellar tendon ruptures, or infections.

What is less clear is what advantage, if any, the contralateral patellar tendon has over the use of hamstring grafts. It has been established that hamstring grafts involve less donor site morbidity and preserve greater quadriceps muscle strength. Return to sports would generally be longer as most surgeons restrict patients greater than four months due to the prolonged healing of soft tissue within the tunnels compared to bone plugs. A prospective study with similar comparisons as found in this paper would be useful. Otherwise, it seems that one could argue that use of a hamstring graft has similar advantages while avoiding trauma to the other knee. In my limited experience involving revisions, it is a tough sell to the patient to operate on the opposite knee. Lastly, I wonder if this could be done as an outpatient? Many of us do ACL reconstructions routinely as an outpatient procedure, and managed care dictates this in many locations.

This paper effectively validates the option of using the opposite knee for graft harvest and gives the surgeon helpful information on which to base a decision and counsel the patient. We can conclude that the contralateral patellar graft is a safe, effective graft choice alternative. Obviously, there is more than one way to do things in orthopaedic surgery. ❖

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Tunnel Expansion with EndoButton in Hamstring ACLs

ABSTRACT & COMMENTARY

Synopsis: *In a comparative study, 1-incision hamstring ACL reconstruction with femoral EndoButton fixation was associated with more tunnel expansion than a 2-incision technique fixed proximally with a screw and spiked washer.*

Source: Simonian PT, et al. Tunnel expansion after hamstring anterior cruciate ligament reconstruction with 1-incision EndoButton femoral fixation. *Arthroscopy* 2000;16(7): 707-714.

Although we are unclear regarding the clinical significance of tunnel expansion seen on post-

operative radiographs, its recognition has raised a great deal of concern among ACL surgeons. In the present study, Simonian and colleagues report that a 1-incision technique using EndoButton fixation on the femoral side resulted in more tunnel expansion (especially on the femoral side) than historical control group in which they used a 2-incision technique with screw and spiked washer fixation. They attribute this to micromotion (sometimes referred to as the "bungee-cord" effect) of the graft within the tunnel. Twenty consecutive patients who underwent hamstring ACL reconstruction with a 1-incision EndoButton technique were compared with 20 consecutive patients who had a 2-incision technique (retrospective control group). Radiographs were obtained at three and 12 months postoperatively, and tunnel measurements were made using calipers on a horizontal light box. The following approximate average tunnel expansion at three months postoperatively was recorded (*see Table*).

Table

Tech	AP proxT	LatproxT	AP dist T	Lat dist T	AP Fem	Lat F
1-in*	3 mm	7 mm	3 mm	2 mm	6 mm	6 mm
2-in	1 mm	0.5 mm	1 mm	0.3 mm	1 mm	1 mm

*in = incision

These differences did not change significantly at 12 months. All other clinical parameters were similar between the two groups. Simonian et al offer two explanations for this phenomenon. The first issue implicates that EndoButton-creep and micromotion may occur with this device. The second issue involves eccentric drilling required with a 1-incision technique. This basically involves additional drilling of the back wall of the tibial tunnel when passing the drill bit for accurate placement of the femoral tunnel using a 1-incision technique. This of course would explain the increased lateral dimension of the proximal tibia tunnel (the most likely explanation) but not the femoral expansion. Simonian et al do emphasize that although tunnel expansion is significant, the clinical outcome was not affected by these findings.

COMMENT BY MARK D. MILLER, MD

Although tunnel expansion is concerning, it does not appear to affect clinical results, at least in the short term. It is unclear whether graft incorporation is adversely affected. Other researchers have noted this phenomenon, and there is still room for additional study on this issue. Tunnel expansion is a concern when revision ACL reconstruction is contemplated. In these cases, it is necessary to consider bone grafting these defects, either in a one- or two-stage reconstruction.

There may be some technical considerations that would reduce the incidence and amount of tunnel expansion associated with the use of the EndoButton and 1-incision technique. Simonian et al typically placed 25 mm of graft into the femoral tunnel. Perhaps if the graft was placed farther into the tunnel, as close to the cortex as possible (a technique that I have adapted with this device), less expansion will occur. Second, and perhaps more important, the second-generation EndoButton is a continuous loop (CL) and does not require a knot to be tied. This will likely result in less creep and micromotion. Unfortunately, the smallest CL device available is 20 mm, and this may affect the first suggestion. Although I have not recognized a problem with tunnel expansion using these two techniques, careful measurement of postoperative radiographs, as was accomplished in the present study, will be necessary to determine if we can reduce the incidence of this concerning finding in the future. ❖

Early Postoperative Refracture of the Fifth Metatarsal (Jones Fracture)

ABSTRACT & COMMENTARY

Synopsis: *The fifth metatarsal is at risk for delayed union and stress fractures. Wright and colleagues note a risk of refracture despite operative intervention.*

Source: Wright RW, et al. Refracture of proximal fifth metatarsal (Jones) fracture after intramedullary screw fixation in athletes. *Am J Sports Med* 2000;28(5):732-736.

Wright and colleagues from several medical centers describe their experience with a serious postoperative complication of intramedullary fixation of the Jones fracture of the proximal fifth metatarsal. Wright et al report refracture in six athletes who were initially diagnosed with an acute fracture of the proximal fifth metatarsal without evidence of prodromal symptoms, medullary canal sclerosis, or cortical thickening (as would be seen with a stress fracture commonly seen in this anatomic site). In three of the patients released to activities at seven, eight, and 11 weeks postoperatively, an acute refracture occurred the day after release! Four of the six patents with a refracture had fixation with a cannulated screw that was 4.5 mm or smaller. Interestingly, no fracture of the internal fixation occurred.

Wright et al noted clinical and radiographic healing

prior to release to activities, and the return to functional activity was relatively rapid with light jogging by four weeks postop; two weeks after that, full running was allowed. Several recommendations were made concerning this injury: 1) use a larger screw, depending upon the size of the medullary canal; 2) functional bracing in the immediate season after fixation; 3) question standard assessment of healing, and consider CT, MR, or sonography to fully evaluate fracture healing.

COMMENT BY ROBERT C. SCHENCK, Jr., MD

The treatment of the proximal fifth metatarsal fracture is not without controversy. Certainly, the philosophy of management of the acute fracture (no prodromal symptoms, no evidence of sclerosis on plain radiographs) has changed from a nonweightbearing, nonoperative approach, to an operative approach with intramedullary fixation due to the increased demands placed on the athlete to return to competition. Nonetheless, this report of acute refracture after operative treatment is concerning and makes the orthopaedic surgeon reassess the choice of internal fixation, assessment of healing, and timing of return to sport.

Wright et al have critically assessed the failure mechanisms involved in the six patients and suggested the use of an orthotic to provide support for early return to sport. I believe two additional factors need to be considered: 1) fracture personality; and 2) fracture healing. The personality of the Jones fracture is different from most acute fractures. The Jones fracture is slow to heal based on its limited vascularity and continued stresses once healed. Clearly, the healing time for this fracture is different, and time lines based on other fractures won't translate to this injury pattern. The return to sport is best determined by presence of healing clinically (physical and plain radiographic examination) in conjunction with time. Other imaging modalities may be of use in evaluating healing, but the presence of an implant will make use of CT or MRI difficult. The use of a larger intramedullary fixation device will provide a stronger internal splint with additional support during the slow healing period and return to activities. Although more difficult to place, I prefer a noncannulated, 6.5 mm AO screw. Careful intraoperative imaging is critical with any intramedullary device to ensure proper placement. Although not reported in this series of six patients, smaller cannulated screws have been associated with breakage. The larger cannulated screws are routinely 7.0 or 7.3 mm in diameter and can be too large for the canal.

The management of Jones fractures requires a different approach, and the exact time to return to sport and clinical healing is still being determined. Rapid return to sport in all likelihood requires larger internal fixation devices. ❖

Strength Training Increases Tennis Serve Velocity in Women Athletes

ABSTRACT & COMMENTARY

Synopsis: *Women college tennis players who participated in a periodized multiple-set strength training program produced greater muscular strength for the upper and lower body, increased lean body mass, and increased serve velocity better than single set circuit training.*

Source: Kraemer WJ, et al. Influence of resistance training volume and serialization on physiological and performance adaptations in collegiate women tennis players. *Am J Sports Med* 2000;28(5):626-633.

The purpose of this study was to compare strength and performance between a multiple and a single repetition resistance strength-training program tailored for the tennis athlete. Twenty-four collegiate tennis players matched for ability were randomly placed into one of three groups: 1) no strength training, control group; 2) single set circuit training group; and 3) periodized, multiple set resistance training group. The groups trained 2-3 days per week depending on matches for nine months. Both resistance-training groups used the same exercises, but differed in the number of repetitions. The circuit group performed one set of 8-10 repetitions, whereas the multiple set group did four sets of 4-15 repetitions. The control group performed all tennis drills but no weight lifting.

The study design was carefully prepared to allow testing on the same day with similar pretesting rest periods. Body composition was tested by skin fold measurements. Cycle ergometer and vertical jump height measured anaerobic power. Muscular strength was determined by single set maximum for leg press, shoulder press, and bench press. The maximum serve velocity was determined with high-speed digital photography.

The results showed that a multiple repetition, periodized, resistance program yielded significantly superior increases in upper and lower body strength, lean body mass, and tennis serve velocity when compared to a single set or control program. Although both strength-training programs showed increases in body strength and serve velocity over the first four months, only the periodized group continued to show improvement over the nine-month period.

COMMENT BY JAMES R. SLAUTERBECK, MD

The old adage, "Practice makes perfect," may not strictly apply to our high performance athletes. In-season strength training in addition to practice increased performance in tennis players more than just practice alone. Additionally, the in-season circuit-training methods advocated by many trainers and coaches may not achieve the results one may need by the end of a long season.

This is a nicely designed study looking at the effect of multiple sets vs. a single set resistance training method vs. sport participation only on strength and performance. Clearly, the results show the benefits of in-season strength training programs and further show the positive effects of a multiple set program for improved long-term results.

Tennis is a demanding sport requiring strength, agility, grace, and endurance over a long season. A strength-training program must address short- and long-term athlete and team goals. Although strength training needs to improve the athlete's overall strength and conditioning, a clear increase in serve velocity would be a major benefit to the individual and to the team. This study convincingly demonstrates that multiple sets of resistance exercise training translated to increased function and performance in the sport as evident by a significant increase in serve velocity.

Although one can argue that the results here could be sport and gender specific, I am convinced that a multiple repetition, periodized strength-training program is beneficial to increasing individual performance and strength. It is my opinion that one should carefully adjust strength programs to take advantage of this information and have our athletes work out in season with a multiple set and repetition resistance program. Over-training may cause injury also; therefore, performance in other sports and with male athletes should be prospectively monitored. ❖

Glenohumeral Joint Laxity and Stiffness in Healthy Men and Women

ABSTRACT & COMMENTARY

Synopsis: *Shoulder arthrometry finds differences in glenohumeral joint laxity and stiffness in males and females.*

Source: Borsa PA, et al. Patterns of glenohumeral joint laxity and stiffness in healthy men and women. *Med Sci Sports Exerc* 2000;32(10):1685-1690.

Borsa and colleagues used a shoulder arthrometer to measure glenohumeral joint laxity and stiffness in 51 physically active and healthy men and women. The subjects were free from history of shoulder injury and had not participated in regular physical activity involving upper-extremity overhead throwing motions. Prior to participation in the study, each subject was screened by an orthopaedic surgeon for hyperlaxity and pathology involving joint instability. No subjects had greater than 1+ laxity of the glenohumeral joint in any direction.

Joint laxity was defined as the amount of humeral head translation from the glenoid in response to 67, 89, 111, and 134 N of force. Joint stiffness was measured as the slope of the force-displacement curve using least squares regression. The instrumented arthrometer applied force to the glenohumeral joint using a custom applicator. Two linear displacement transducers individually measured linear motion of the humeral head and the acromion. Subjects were seated and secured in a test chair, with the humerus positioned and secured in 20° of abduction and neutral rotation, flexion, and extension. Generalized joint hypermobility was also measured with a standard plastic goniometer. For all measurements, both shoulders were tested in random order.

The women were found to have more anterior joint laxity than men (11.4 vs 8.3 mm), and the men had more posterior than anterior joint laxity (9.6 vs 8.3 mm). The women had less anterior joint stiffness than the men (16.3 vs 20.5 N/mm), and the women had less anterior than posterior stiffness (16.3 vs 22.1 N/mm). The women also had more generalized joint hypermobility than the men (2.9 vs 1.0°).

COMMENT BY DAVID H. PERRIN, PhD, ATC

Joint arthrometry is commonly used to assess anterior and posterior laxity of the knee (tibio-femoral) joint and compliance of the ACL. These assessments are undertaken for purposes of pre-season screening of athletes, to aid in diagnosis of injury to the cruciate ligaments, and to assess the success of surgical reconstruction. Borsa et al have developed a model that permits easy assessment of anterior and posterior glenohumeral joint displacement. From these measures, one can determine not only absolute values of laxity but can calculate joint stiffness as well. Borsa et al previously reported on the reliability of the device,[1] and now they provide us with baseline comparative values for males and females.

It is interesting that the glenohumeral joint laxity and stiffness findings in males and females are relatively consistent with values reported for the knee. It would be interesting to determine if laxity of the shoulder reacts the same as the knee in response to training and the

influence of female hormones. It will also be interesting to determine through prospective longitudinal studies if the increased anterior laxity and decreased joint stiffness in females predispose them to joint instability and injury. As with knee arthrometry, a practical method of assessing glenohumeral joint laxity and stiffness has endless potential for advancing our understanding of this complex joint in both athletes and nonathletes. ❖

Reference

1. Borsa PA, et al. In vivo assessment of AP laxity in healthy shoulders using an instrumented arthrometer. *Journal of Sport Rehabilitation* 1999;8:157-170.

Open vs. Arthroscopic Treatment of Elbow Arthritis

ABSTRACT & COMMENTARY

Synopsis: *Although both arthroscopic and open debridement procedures were successful for patients with osteoarthritis, the arthroscopic group showed somewhat better pain relief and the open group showed somewhat better motion comparatively.*

Source: Cohen AP, et al. Treatment of osteoarthritis of the elbow: A comparison of open and arthroscopic debridement. *Arthroscopy* 2000;16(7):701-706.

This study examines the efficacy of open debridement of elbow osteoarthritis (OA) (Outerbridge-Kashiwagi procedure) vs. arthroscopic debridement including fenestration of the olecranon fossa.[1] Patients were allocated to treatment based on the hospital where they presented. The two study groups were similar: mostly middle aged males with primary OA. Preoperative radiographs showed typical osteophytes in the olecranon fossa and coronoid process. Loose bodies were visualized in 55% of cases. The majority of patients complained of pain, stiffness, and locking.

The open procedure was performed through a triceps splitting approach with olecranon osteophyte excision, loose body removal, olecranon fossa fenestration, and coronoid osteophyte excision. The arthroscopic procedure consisted of debridement, loose body removal, synovectomy if necessary, and fenestration of the olecranon process. No osteophyte excision was performed. The results were then compared using the Mayo Clinic Elbow Function Chart at a mean 35 months. Both groups showed a significant increase in range of motion, and an improvement in symptoms of pain and locking. There were no significant complications. Only one patient out of 44 required further surgery. Cohen and colleagues concluded both arthroscopic debridement with fenestration of the olecranon fossa and the open O-K procedure are effective in improving pain, flexion and extension, and result in satisfied patients.

COMMENT BY STEPHEN B. GUNTHER, MD

To my knowledge, this is the first comparative study of arthroscopic vs. open debridement procedures for primary elbow arthritis. In this short-term study (mean follow-up, 35 months), the majority of patients were satisfied with their procedure. The results show moderate improvements in motion (average 8° increase in arthroscopic group and 19° improvement in open group) and excellent short-term improvement in pain. No soft tissue procedures (contracture release) were performed. Also, no radial head excisions were performed. This is an important addition to the literature since a defined group of patients with primary OA of the elbow were prospectively randomized by treatment center to arthroscopic vs. open procedures which both produced successful results.

Further research will be necessary to evaluate arthroscopic procedures in combined groups of patients such as post-traumatic arthritis with contractures. Also, arthroscopic techniques have been expanded significantly since this series was performed (1988-1993).[2-4] For example, many surgeons now routinely perform osteophyte excision arthroscopically as well as radial head excision when necessary. Capsular release may also be performed arthroscopically by experienced surgeons. Future studies will be necessary to determine the efficacy and safety of these more aggressive surgical procedures as well as document the long-term results. ❖

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arthritic elbow: Indications, technique, and results. *J Shoulder Elbow Surg* 1999;8:214-219.

Risk of Injury in Skiing and Snowboarding

ABSTRACT & COMMENTARY

Synopsis: *By developing a new assessment for injury rates that takes into account distance skied, Ronning and colleagues find that snowboarding is more than three times the injury risk of skiing.*

Source: Ronning R, et al. Risk of injury during alpine and telemark skiing and snowboarding. *Am J Sports Med* 2000; 28(4):506-508.

Ronning and colleagues present a novel way to assess injury risks in skiing, which they term the distance-correlated injury index (DCI). Traditionally, injury rates for alpine skiing have been estimated as injuries/1000 skier days, with skier days estimated on the basis of the number of lift tickets sold. However, Ronning et al argued that estimates based on skier days are erroneous since the hours skied by each lift ticket purchaser are markedly varied (i.e., some skiers ski for less than one hour a day, while others ski from the time the lifts open until they close).

Ronning et al feel that to calculate more accurately the risk of injury, one should assess the number of injuries per 100,000 km skied. Ronning et al's pilot study addressing the effectiveness of such an injury reporting system was conducted at the Hafjell Alpine Center, the third largest alpine area in Norway (averaging 240,000 guests each season). This mountain is unique from many alpine areas in that skiers ascending the mountain on a lift can only descend on a slope of a defined length. This is in contrast with most ski resorts in which skiers can descend from a lift on one of several runs of varying lengths.

This defined length slope allows Ronning et al to estimate the number of kilometers skied by each skier based on the frequency and location of the lifts ridden by skiers. Ronning et al further subdivide their injury risk factors on the basis of the equipment used (i.e., alpine skis, telemark skis, snowboarding, or "others"), thus establishing the equipment-specific distance-correlated injury index (ESDCI). By this technique, they found the ESDCI alpine was 3.9, the ESDCI snowboard was 13.5 and the ESDCI telemark was 3.0. These data are in contrast with those of others who have reported injury rates in alpine skiing to be similar to those of snowboarding.[1,2]

COMMENT BY LETHA Y. GRIFFIN, MD, PhD

This study emphasizes a frequent limitation of injury data—that is, determining the denominator. The National Collegiate Athletic Association (NCAA) in their Injury Surveillance System reports injury rates as number of injuries per 1000 athletic exposures, defining "athletic exposure" as one athlete playing in one practice or competition. The limitation of this calculation is that, in many sports, all players in any one competition or practice do not play the same amount of time. For example, player A who plays 90 minutes of soccer in a game is assumed to have the same injury exposure as player B who plays only five minutes of the game.

Similarly, Ronning et al thought it inappropriate to use skier days as the denominator for their injury rate analysis, opting instead to use distance covered by the skier or snowboarder. While their argument is logical, the ability to adopt their scheme as a standard would necessitate developing a system to record distances traversed by skiers and snowboarders. In most ski areas, lifts lead to runs of variable distances and, therefore, distance cannot be estimated from the lift ridden by the skier as was done in this study.

A major limitation of Ronning et al's study and hence their comparison of injury rates in alpine skiing and snowboarding is the manner in which they differentiated the number of skiers and snowboarders. Their numbers were obtained by extrapolating counts of those "using the lifts in a pre-designated random fashion in periods of twenty-minutes, observing each lift thirteen times." Registering the primary equipment to be used by each individual (skis or boards) at the time of lift purchase may result in a more accurate numerator for the authors' study, although admittedly the lift purchaser might elect to change equipment during the course of the day, skewing the data somewhat. Despite this limitation, Ronning et al's method for injury calculation in skiing and snowboarding is an intriguing one and merits further consideration. ❖

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1. Bladin C, McCrory P. Snowboarding injuries. An overview. *Sports Med* 1995;19:358-364.
2. Pino EC, Colville MR. Snowboard Injuries. *Am J Sports Med* 1989;17:778-781.

CME Questions

1. **Tunnel expansion following ACL reconstruction with Hamstring grafts:**
   a. is associated with clinical laxity.
   b. is insignificant.
   c. is more likely with a 2-incision technique
   d. is more likely with a 1-incision technique
   e. is less significant than tunnel expansion following patellar tendon grafts.
2. **Refracture of the proximal fifth metatarsal is most probably related to:**
   a. time of healing.
   b. small diameter fixation devices.
   c. functional requirements post-surgery.
   d. All of the above
3. **Compared to ipsilateral grafts, patients with contralateral patellar grafts for ACL reconstruction had:**
   a. better quadriceps strength.
   b. better motion at early time points.
   c. earlier return to full sports.
   d. All of the above
4. **Which of the following correctly describes joint laxity and stiffness in males and females as determined by shoulder arthrometry?**
   a. Men have more anterior laxity than women.
   b. Women have more anterior stiffness than men.
   c Women have more anterior laxity than men.
   d. Men have more generalized joint hypermobility than women.
5. **A college female tennis player can best increase her serve velocity by:**
   a. attending practice and performing technique drills.
   b. attending practice and performing technique drills and participating in a resistance-training program, which uses single set circuit training.
   c. attending practice and performing technique drills and participating in resistance training program which uses multiple sets with multiple repetitions.
   d. None of the above
6. **Primary elbow OA commonly presents with all of the following *except*:**
   a. locking.
   b. pain.
   c. loss of motion.
   d. osteophytes.
   e. instability.
7. **Injury rates in alpine skiing:**
   a. are typically reported based on the number of hours skied.
   b. have been reported to be 5 times greater than for telemark skiing.
   c. have decreased markedly in the last two years because of the new hyperbolic skis.
   d. might be more accurately reported as the rate per distance covered by the skier rather than per days skied.

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