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The Effects of Athletics on Spinal Curvature in Kids

ABSTRACT & COMMENTARY

Synopsis: *Greater cumulative athletic training time correlated with greater degrees of thoracic kyphosis and lumbar lordosis.*

Source: Wojtys EM, et al. The association between athletic training time and the sagittal curvature of the immature spine. *Am J Sports Med* 2000;28(4):490-498.

This study from the university of michigan's medsport and the departments of mechanical engineering, biomedical engineering, and kinesiology, as well as the Institute of Gerontology, was inspired by the chairman of the University of Michigan's Section of Orthopaedic Surgery, Dr. Robert Hensinger. Dr. Hensinger, observing his own patient population, felt that there seemed to be an increase in thoracic kyphosis in competitive swimmers and wondered if athletic participation could be associated with a greater tendency toward saggital spinal curvature. It is known that not only can compressive loading of the spine affect vertebral apophyseal development and hence vertebral shape (as seen in Scheuermann's kyphosis), but also mechanical loading can affect disk shape and hence spinal curvature. Furthermore, intense athletic training can, depending on the sport, result in repetitive high muscle forces about the spine that ultimately can cause significant compressive, shear, and bending loads on the vertebral endplates. Hence, Wojtys and colleagues formulated two related null hypotheses for their study. First, large angles of thoracic kyphosis or lumbar lordosis are not associated with increased exposure to athletic training, as quantified by the number of annual training hours. And second, that these angles would not differ by age, sex, or primary sport.

Two thousand two hundred and seventy children (407 girls and 1863 boys) between 8-18 years of age were enrolled in the study. Inclusion criteria for the athletic group required self reported participation in regular extracurricular athletic training and competitive sport a minimum of four days a week, three months out of the year. Youngsters in the control

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group denied any participation in competitive sport or physical training programs. The medial sagittal curves in the study population were measured in the upright standing position using an optical rasterstereographic method. The degree of curve was correlated with age and sex of the child and the sport in which he or she participated.

No significant differences were found between the measured sagittal angle of the thoracic and lumbar spine and the age or sex of the study population. However, both thoracic and lumbar angles of curvature increased with the number of annual training hours. The increase in curvature of the thoracic spine was proportional to training time, but the increase in curvature of the lumbar spine remaining fairly constant per training time under 400 hours per year. Additionally, curves appeared to vary according to the child's primary sport. Curves were lowest in the sedentary controls. Those children participating in football, gymnastics, hockey, swimming, and wrestling had significantly greater thoracic and lumbar curves than those participating in track and volleyball.

COMMENT BY LETHA Y. GRIFFIN, MD, PhD

This study is another well-organized and executed study from the Michigan group. It reminds us that, although moderate physical activity has a positive effect on bone development, excessive forces placed on immature bone (and in this particular case, intervertebral disks) may be detrimental. Wojtys et al enumerate the limitations of their study, which include a nonrandomized sampling technique, a "self-reported" time of athletic participation, and lack of objective measure of the magnitude of the spine loads involved. While not using conventional radiographs for quantifying the degree of thoracic kyphosis and lumbar lordosis, Wojtys et al do cite literature in which their technique for curve measurement was found to correlate with radiographic measurements with a correlation coefficient of 0.7. ❖

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Chondroprotection with Glucosamine and Chondroitin Sulfate

ABSTRACT & COMMENTARY

Synopsis: *The use of glucosamine and chondroitin sulfate in combination provide chondroprotective activity for hyaline cartilage in the rabbit instability model.*

Source: Lippiello L, et al. In vivo chondroprotection and metabolic synergy of glucosamine and chondroitin sulfate. *Clin Orthop* 2000;381:229-240.

Lippiello and colleagues in an industry supported study report on a well-designed animal study evaluating the cartilage reparative effects (chondroprotection) of a combination of glucosamine, chondroitin sulfate, and manganese ascorbate. A total of 42 New Zealand rabbits randomized to various treatment groups (control, combination of glu/chond/Mg, glucosamine alone, chondroitin alone, Mg alone) underwent an arthrotomy and transection of the ACL and PCL producing a well-described instability model for osteoarthritis (OA). Articular damage was analyzed by histology and immunohistochemistry. Biochemical evaluation included proteoglycan synthesis by 35-Sulfate incorporation, and degradative activity by IL-1 induced collagenase activity.

Histologically, all groups had some degree of articular damage; however, the combination of glucosamine, chondroitin sulfate, and manganese led to the least severe articular lesions. Combination therapy also produced the greatest increase in proteoglycan synthesis (+96%) as compared to control. Chondroitin sulfate alone, combination therapy, and manganese ascorbate all produced statistically significant decreases in degradative enzyme activity. Glucosamine alone did not produce a change in

degradative activity.

COMMENT BY ROBERT C. SCHENCK, Jr., MD

The culture of nutritional supplementation requires definition of commonly used terms with which physicians may not readily be familiar. Most agents used initially in the management of OA are nonsteroidal antiinflammatory drugs (NSAIDs) and these medications function to limit or ameliorate the breakdown products from articular degeneration.[1] Chondroprotection is used to describe any medication or "compound" that can block progression of degenerative joint disease and stimulate repair of damaged articular cartilage. The theoretical basis of chondroprotection is providing substrate or components of the hyaline matrix, thereby providing a stimulus to increase the synthesis of complete aggrecan macromolecules.

Only recently has interest in glucosamine and chondroitin sulfate increased such that clinical and basic science studies are being performed.[2-4] Three recent studies at the Orthopaedic Research Society have focused on the mechanism of glucosamine and chondroitin sulfate on a molecular level. Recent mechanistic studies have given further credence to the use of nutritional supplementation in the management of mild to moderate OA. Mimms and colleagues recently showed increased production of proteoglycans when bovine cartilage explants were cultured with glucosamine and chondroitin sulfate alone and in combination. Mimms et al noted that combination therapy demonstrated the greatest proteoglycan synthesis compared to glucosamine or chondroitin sulfate alone. Mimms et al went on to show the ability of nutritional supplements to prevent interleukin-1 (IL-1) induced aggrecan depletion. Mimms et al concluded that dietary supplementation may play a role in promoting cartilage health, maintenance, and repair. In another study, Sandy and colleagues evaluated the mechanism by which one component of nutritional supplements may affect chondroprotection. Glucosamine was shown to block the aggrecanase response of chondrocytes to IL-1 in an *in vitro* model using rat chondrosarcoma cells and bovine cartilage explants. These studies are the first independently funded investigations to show a mechanism by which glucosamine and chondroitin sulfate both influence the production of proteoglycans as well as inhibit the degradation of aggrecan, the important components of normal cartilage metabolism. Currently, both European and American nutraceutical companies are carrying out clinical studies on the effectiveness (symptom modification vs disease modification) of nutritional supplementation for (OA) and articular injury, as performed in this study by Lippiello et al. This investment will pay off, as a mechanism of function for nutraceuticals will support their use among skeptical allopathic physicians.

Finally, the concept of disease modification vs. symptom modification is an important distinction when using nutritional supplements.[5,6] Disease modifying aspects of glucosamine and chondroitin sulfate, alone or in combination, have been claimed by industry and researchers alike. Symptom modification is generally accepted with the use of these compounds for mild to moderate OA, but independent nonindustry supported studies are still needed. Disease modification in noninflammatory OA would be a significant finding in the use of glucosamine and chondroitin sulfate clinically, and the study by Lippiello et al is a well-designed attempt to show basic science evidence of disease modification.[5,7]

The true difficulty in sports medicine today is the treatment of articular lesions in the young adult athlete. Currently, when I reconstruct an ACL deficient knee and find an osteochondral contusion (seen in more than 80% of acute ACL injuries), I use a course of glucosamine and chondroitin sulfate for the articular injury as an adjunct to any surgical repair required. Side effects of glucosamine and chondroitin sulfate appear to be minimal and it is well tolerated. Until there are other tested chondroprotective agents, it is a relatively harmless option that has credibility based on long-term clinical studies as well as the basic science evaluations discussed in this review. The use of glucosamine and chondroitin sulfate is currently not included in most treatment algorithms. In the young athlete with an osteochondral injury, chondroprotection is the right treatment direction as there are relative contraindications with NSAIDs. However, only with further study (including independent funding sources) will we know the true efficacy of such nutritional supplements.[1] ❖

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7. Kreder HJ. Glucosamine and chondroitin were found to improve outcomes in patients with osteoarthritis. *J Bone Joint Surg Am* 2000;82:1323.

Cervical Spine Injured Hockey Player: Helmet on or Helmet off?

ABSTRACT & COMMENTARY

Synopsis: *Helmets and shoulder pads should be kept on the unconscious or potential spine injured hockey player.*

Source: Laprade RF, et al. Cervical spine alignment in the immobilized ice hockey player. A computed tomographic analysis of the effects of helmet removal. *Am J Sports Med* 2000;28(6):800-803.

Helmets and shoulder pads are standard gear for the ice hockey player. The purpose of this article was to determine if removal of the ice hockey helmet would increase the lordosis of the cervical spine if the shoulder pads remained on. Ten adult male volunteers averaging 22 years of age without a history of c-spine injury underwent computed tomography (CT) scans of the c-spine. Each individual was studied under three conditions 1) helmet and shoulder pads on; 2) helmet and shoulder pads off; 3) helmet off and shoulder pads on.

The results showed a significant increase in lordosis between C-2 and C-7 when the helmet was removed compared to when the helmet and pads were left on. Additionally, the C 6-7 segmental level revealed an increase in lordosis when compared to other levels if the helmet was removed compared to when the pads and helmet were left on.

COMMENT BY JAMES R. SLAUTERBECK, MD

Although lots of literature addresses how to handle the football player with a cervical spine injury, little literature addresses how to best protect the cervical spine in the hockey player. Laprade and colleagues point out that c-spine injury occurs three times more often in hockey than in football.[1] Similar but less bulky shoulder pads and a helmet protect the hockey player. However, the shoulder pads are large enough to potentially harm the cervical spine if an injured hockey player has the helmet removed and the c-spine increases in lordosis.

Intuitively, I have established a protocol with our hockey players that the helmets are not to be removed unless the shoulder pads are removed at the same time. This is only to be done if an airway cannot be established or if the transport of the patient cannot be safe because of poor fitting equipment. The shoulder pads should then be removed together with the helmet with some type of stable padding placed around the head to keep the shoulders and neck in constant and stable alignment. If for some reason the helmet is ever removed without removing the shoulder pads, then the head must be supported with firm padding to maintain proper alignment.

This article will now be the landmark article defining what precautions need to be performed to maintain alignment of the c-spine in the unconscious or c-spine injured hockey player. The same rule applies that we know works with football players—the helmet and shoulder pads should be on or off as a unit and are best left on if possible. ❖

Reference

1. Tator CH, et al. Spinal injuries in ice hockey players, 1966-1987. *Can J Surg* 1991;34:63-69.

Commotio Cordis

ABSTRACT & COMMENTARY

Synopsis: *A history of warning symptoms for commotio cordis should be obtained during the preparticipation physical exam to help reduce the risk of sudden cardiac death.*

Source: Vincent GM, McPeak H. Commotio cordis. *The Physician and Sportsmedicine* 2000;28(11):31-39.

Commotio cordis, or cardiac concussion, is a rare cause of sudden death in athletes that results from "blunt, nonpenetrating, precordial chest impact that causes arrhythmias or sudden death without evidence of heart injury at autopsy". It has been most frequently reported in baseball, softball, and ice hockey. According to the U.S. Commotio Cordis Registry in Minneapolis, 70% of those affected have been younger than 16 years of age, 99% have been male, and 87% have been white. The precipitating event is generally a blow to the precordial area, but left-lateral chest trauma can precipitate an event as well. Young athletes are felt to be more susceptible to commotio cordis because of the narrower anteroposterior diameter of their thorax and the greater compliance of their chest wall. Other factors suggested for the increased susceptibility of young athletes include their lack of awareness of risk factors and their less frequent use of protective gear compared with collegiate and professional athletes.

The pathophysiology of commotio cordis is not well understood, but from experimental work in pigs and evaluation of survivors of this incident, it appears that a blow

delivered at precisely the right time in the cardiac electrical cycle can result in a fatal arrhythmia. Ventricular fibrillation is the most common arrhythmia seen. The true incidence of this cardiac catastrophe from which only 10% survive, despite resuscitation efforts, is unknown, but 70 cases have been reported to the registry as of June 1998.

Prevention measures include chest protectors for those at risk, elimination of the on-deck circle in baseball, further evaluation of the effectiveness of softer-core baseballs, and education of players and coaches regarding these measures.

COMMENT BY LETHA Y. GRIFFIN, MD, PhD

Fortunately, sudden death in athletics is extremely rare. The most common cause in athletes older than 35 is coronary artery disease; whereas, the most common cause of sudden death in younger athletes is inherited structural abnormalities of the heart (e.g., hypertrophic cardiomyopathy and structural malformations of the coronary arteries). Sudden death can also result from myocarditis triggered by a viral infection or cardiac abnormalities caused by drug abuse.

Unfortunately, most causes of sudden death in young athletes cannot be detected during routine medical athletic screening examinations. However, since many young athletes at risk for fatal cardiac events often experience warning symptoms during exercise, including questions in the preseason examination specific for these symptoms as well as questions pertaining to a family history of cardiac disease and a history of drug use by the athlete is mandatory. These warning symptoms include chest or stomach pain or discomfort, dizziness, palpitations, or fainting episodes. The physical examination should also include auscultation of the athlete's heart with the athlete standing and lying and a seated brachial artery blood pressure. ❖

Pain Management in Arthroscopic Surgery

ABSTRACT & COMMENTARY

Synopsis: *Preemptive analgesia and postoperative multimodal analgesic techniques should be used to minimize pain for patients undergoing arthroscopic surgery of the knee.*

Source: Reuben SS, Sklar J. Pain management in patients who undergo outpatient arthroscopic surgery of the knee. *J Bone Joint Surg Am* 2000;82-A:1754-1766.

Although arthroscopic knee surgery is a commonly performed procedure, perioperative pain management varies widely among surgeons. Many surgeons still perform anterior cruciate ligament (ACL) reconstruction with an inpatient hospital stay. Advances in perioperative analgesia techniques allow this procedure now to be done as an outpatient routinely and also help to minimize pain in all patients undergoing arthroscopic knee surgery. Strategies to help minimize pain in the safest and most efficient manner are outlined in a recent "Current Concepts Review" by Sklar and Reuben.

Many factors contribute to pain following arthroscopic knee surgery, including surgical trauma with direct input to the central nervous system (CNS). Prolonged inflammation can contribute to hypersensitivity of the nerve endings in the area and subsequent reduction in the threshold of the afferent nerve terminals. Central sensitization can also result from persistent exposure to painful input from the peripheral neurons. Together, the peripheral and central sensitization can lead to a postoperative hypersensitivity state or "spinal wind-up" that is most unpleasant for the patient and the surgeon.

To help prevent this, preemptive analgesia with intra-articular local anesthetics or morphine can be very helpful. Studies have demonstrated that even one to two milligrams of morphine injected intra-articularly can provide effective postoperative analgesia for several hours without any systemic side effects. The mechanism of action appears to be through binding specific receptors in the nerve terminals within the joints. A low level of inflammation appears to increase the affinity for binding and the effect. The addition of an oral nonsteroidal antiinflammatory agent can suppress benefits of the intra-articular morphine administration, but the downside of this is probably outweighed by the benefit of reduced inflammation and potential for the hypersensitivity state. Combining intra-articular morphine with long-acting bupivacaine is an effective way to block patient's pain for the initial four to eight hours after surgery. The addition of intra-articular Ketorolac provided similar benefit in analgesia but no additive effect when combined with intra-articular morphine. Intra-articular corticosteroids can be used in similar fashion but there are safety concerns regarding potential infection. Adding intra-articular clonidine to bupivacaine and morphine appears to potentiate the effects of these drugs when used individually.

Regarding oral narcotic administration, long-acting opioids with controlled release formulations provide increased convenience as well as pain relief for the patients, especially during sleep. Side effects including sedation, sleep disturbance, and vomiting are also reduced. This in combination with a potent anti-inflammatory agent such as ketorolac can be very beneficial in the first few days following outpatient ACL reconstruction. The newer Cox-2 inhibitors are also effective at

reducing pain while avoiding gastrointestinal side effects. It appears that the Cox-2 pathway is specific for pain, whereas, the Cox-1 pathway, which is also addressed by other anti-inflammatory drugs, is responsible for more of the toxicity. Additional modalities include administration of a femoral nerve block intraoperatively with a long-acting agent such as ropivacaine or bupivacaine. The maximum safe dose of bupivacaine for peripheral nerve block is 2 mg/kg of body weight. Lastly, cryotherapy can decrease pain, swelling, inflammation and bleeding postoperatively. Cooling can also depress the neuronal pain signal transmission and reduce muscle spasm. Ideally, the skin temperature should be lowered to about 20°C to obtain measurable changes in intra-articular temperature.

COMMENT BY DAVID R. DIDUCH, MS, MD

Optimal pain relief allowing normal function is difficult to achieve with a single drug or single method. It is currently recommended that combined regimens or multimodal analgesia be used following arthroscopic knee surgery. This is especially important following ACL reconstruction to allow this procedure to be performed as an outpatient. Preemptive analgesia can include administration of the Cox-2 anti-inflammatory agents, which do not have any antiplatelet or bleeding effects. This in combination with femoral nerve blocks and intra-articular administration of bupivacaine plus morphine is very effective in the immediate postoperative period. Multi-modal oral medications to include long acting opioids plus an anti-inflammatory preparation and cryotherapy are also important additions in the postoperative phase. This combination can help us keep our patients comfortable, happy, and deliver care in a cost efficient manner. ❖

Meniscal Repair in Patients Older than 40

ABSTRACT & COMMENTARY

Synopsis: *Noyes and Barber-Westin emphasize that congruent reduction of the meniscus, closely placed vertical mattress sutures, and nonaggressive rehabilitation are keys to success.*

Source: Noyes FR, Barber-Westin SD. Arthroscopic repair of meniscus tears extending into the avascular zone with or without anterior cruciate ligament reconstruction in patients 40 years of age and older. *Arthroscopy* 2000;16(8):822-829.

It is only within the last part of the 20th century that we have appreciated the importance of the meniscus for long-term function of the knee. Meniscal repair has been advocated in a variety of forums, but unfortunately it is still not a routine procedure for most orthopaedic surgeons. To their credit, Noyes and Barber-Westin have been among the most prominent advocates of meniscal repair. In a recent article, they reported successful results with repair of meniscal tears that extended into the avascular zone.[1] In the present article, they report success with repair of these same tears in an older population.

Noyes and Barber-Westin report the clinical results of meniscal repairs performed in 30 patients who were 40 years of age or older. Of note, 72% of these patients also had concomitant ACL reconstruction. Important points regarding their surgical technique include rasping and placement of multiple stacked vertical mattress sutures using an inside-out technique. Partial weight-bearing and early restricted flexion was emphasized postoperatively. Follow-up at two years or longer demonstrated excellent or good results in 88% of these patients. Almost all patients returned to their same level of sports activity.

COMMENT BY MARK D. MILLER, MD

Successful results of meniscal repair in tears that extend into the avascular zone, an area that until recently has been considered incapable of healing, is tremendous! Extending these results to a population older than 40 years of age is even more amazing! Those readers who do not routinely perform meniscal repairs should take heed. However, several words of caution are appropriate. First, note that the senior author is very experienced in meniscal repair. Careful technique cannot be overemphasized. The meniscus must be reduced to its normal position, prepared, and then repaired with multiple vertical mattress sutures on both the top and the bottom of the meniscus. These results cannot be extrapolated to shooting a couple of arrows into the meniscus. Note also that the majority of these tears were fixed at the time of ACL reconstruction. Numerous studies have highlighted that concurrent ACL reconstruction enhances the success of meniscal repair. Finally, note that the rehabilitation program is anything but aggressive. Nevertheless, these results are encouraging and should inspire all of us to "push the envelope" regarding meniscal repair! ❖

Reference

1. Rubman MH, et al. Arthroscopic repair of meniscal tears that extend into the avascular zone. *Am J Sports Med* 1998;26:87-95.

Lightning Safety for Athletics and Recreation

ABSTRACT & COMMENTARY

Synopsis: *Lightning casualties can be reduced with implementation of a lightning-safety policy and emergency action plan.*

Source: Walsh KM, et al. National Athletic Trainers' Association position statement: Lightning safety for athletics and recreation. *Journal of Athletic Training* 2000;35(4):471-477.

Lightning presents a significant risk for physically active people participating in both organized and recreational sports. The National Athletic Trainers' Association has released a position statement on lightning safety for athletics and recreation that can serve as a model for sports medicine personnel. The purpose of the statement is to recommend lightning-safety policy guidelines and strategies for medical personnel and others involved with athletic or recreation activities about the hazards of lightning. The statement provides background and recommendations on lightning that are supported by 31 references from the scientific literature.

The background information includes lightning-flash development, lightning casualty demographics, and mechanisms and common effects of lightning. Also addressed are the components of a lightning-safety policy, safe and unsafe locations, criteria for postponement and resumption of activities, obligation to warn, and prehospital care of victims.

Heading the list of recommendations is the formulation and implementation of a comprehensive, proactive lightning-safety policy and emergency action plan. Included in this plan are an established chain of command, a designated weather watcher, a means of monitoring local weather forecasts, a listing of specific safe locations, use of specific criteria for suspension and resumption of activities, and use of recommended lightning-safety strategies. The primary choice for a safe location from lightning is a substantial building, or a fully enclosed vehicle with a metal roof and the windows closed the secondary choice. Participants should seek a safe structure at the first sign of lightning or thunder so that all individuals are safe by the time the flash-to-bang count approaches 30 seconds. Activities should be suspended and should not be resumed for at least 30 minutes after the last sound of thunder or lightning flash.

COMMENT BY DAVID H. PERRIN, PhD, ATC

Sports medicine personnel assume responsibility for all aspects of an athlete's safety. Included in this realm of responsibilities is protection from the lethal effects of lightning. Lightning kills approximately 100 people and injures hundreds more annually. Each year, we read of a tragic lightning event at some interscholastic or intercollegiate practice or game. These events are usually preventable, and failure to formulate and implement a lightning-safety plan represents negligence on the part of the sports medicine team.

Athletic events with a large number of spectators also present special challenges for the sponsoring organization. This statement discusses the importance of public address systems to warn about impending lightning danger. The warning should be commensurate with the age and understanding of the spectators and should include safety instructions.

For a complete reprint of the lightning safety for athletics and recreation statement, contact: National Athletic Trainers' Association, Communications Department, 2952 Stemmons Freeway, Dallas, TX 75247. ❖

ACL Surgery: Practical Considerations

ABSTRACT & COMMENTARY

Synopsis: *Careful placement of femoral and tibial tunnels, careful performance of a notchplasty, and the use of consistent arthroscopic and radiographic landmarks prevent surgical error.*

Source: Fineberg MS, et al. Practical considerations in anterior cruciate ligament replacement surgery. *J Arthroscopy* 2000;16(7):715-724.

In this technical review, fineberg and colleagues describe the ACL anatomy and explain the terminology associated with this ligament that has developed over the past 30 years. The ACL "footprint" is described as such because of the distinct anterior "toe" that lies in close approximation to the intercondylar roof of the femur when the knee is in full extension. Functionally, the ACL provides a restraint to anterior translation and internal rotation of the tibia, varus and valgus angulation, and hyperextension of the knee.

The technical requirements of an ACL reconstruction must be within the parameters of normal ACL isometry,

which is 2.5 mm from flexion to extension. Although the attention to the femoral origin was most focused early in ACL surgery, guidelines for proper tibial tunnel placement have been well described. Incorrect tunnel placement at both the femoral and tibial sides can result in improper graft dynamics and eventual failure. Anterior femoral tunnel placement creates a graft that either limits flexion or produces abnormal graft strain with eventual graft stretch and failure. Anterior tibial tunnel placement creates graft impingement in knee extension and potential for failure. Posterior tibial tunnel placement creates a graft that is too vertical, which doesn't function properly in slight knee flexion where stability for pivoting or jumping is required.

Proper femoral tunnel placement requires a position posterior enough to leave only a 1-2 mm cortical "back wall" of the endoscopic femoral tunnel. The medial lateral position is slightly lateral to the center of the knee with the pin placed at 11 o'clock for the right knee, and 1 o'clock for the left. Critical femoral tunnel placement is required to avoid an anterior position that in turn creates abnormal graft dynamics and frequent failure.

Tibial tunnel placement can be deceiving and again is slightly lateral to midline on plain radiographs. Arthroscopic anatomic landmarks are used to place the center of the tibial tunnel in the posterior aspect of the ACL tibial footprint. This site is ideally at the junction of the posterior and middle one-thirds of the footprint. Additionally, the surgeon can reference from a site 7 mm anterior to the PCL edge, the anterior horn of the lateral meniscus, and the anterolateral slope of the medial intercondylar eminence. Careful evaluation of pin placement prior to tunnel reaming should be carried out by viewing the pin with the knee in and near full extension. Intraoperative radiographs in extension can be used to document tunnel position so that the anterior edge of the tibial tunnel is posterior and parallel with Blumensaat's line to avoid impingement.

Graft-tunnel length mismatch can create difficulties in fixation, especially when the tibial tunnel is too short. A low angle of approach is frequently the culprit and can be avoided by using a 55° angled approach when creating the distal tunnel entrance site. With a short tibial tunnel, the ACL graft bone plug is prominent so that interference screw fixation is suboptimal and may require substitution with a staple or screw and post. In my experience, twisting the graft will allow for graft shortening and the ability to use an interference screw for fixation. Finally, screw divergence should be avoided to allow optimal fixation but is less important on the femoral side where bone density is the greatest. Also, graft position in the femur produces a wedge effect with inherent stability. Tibial interference fixation is the weaker link and convergent screw placement in this tunnel is of greater importance but technically easier than on the femoral side.

COMMENT BY ROBERT C. SCHENCK, Jr., MD

This current concepts review in the *Journal of Arthroscopy* details the technical points and potential pitfalls in endoscopic ACL reconstruction. It is useful for the practicing sports medicine specialist as it clearly identifies the key points in the technical exercise of an endoscopic ACL reconstruction. Careful attention to tunnel placement, adhering to identifiable landmarks, will help ensure isometry and avoid impingement and graft failure. ❖

CME Questions

15. Which of the following recommendations applies to the formulation and implementation of a lightning-safety program?

a. Seek safety when the flash-to-bang count is 30 seconds.
b. Resume activities 15 minutes after the last sound of thunder or lightning flash.
c. Seek safety at the first visual sighting of lightning.
d. Seek a safe structure or location at the first sign of lightning or thunder activity.

16. How can meniscal repair results be improved in older patients with tears that extend into the avascular zone of the meniscus?

a. They cannot be improved; these tears are irreparable.
b. With closely placed inside-out vertical mattress sutures and cautious rehabilitation
c. With multiple absorbable fixation devices stacked on both surfaces of the meniscus
d. With trephination and fibrin clot

17. The center point of the tibial tunnel is determined by which of the following?

a. Anterior horn of the lateral meniscus
b. A site 7 mm anterior to the PCL
c. The ACL stump
d. Posterior half of the ACL footprint
e. All of the above

18. Commotio cordis:

a. occurs primarily in professional athletes in their mid 40s.
b. is associated with coronary artery disease.
c. although frequent in occurrence rarely has a negative outcome.
d. can be prevented by using aluminum bats.
e. primarily affects white males.

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Do Hamstring Tendons Regenerate Like Lizard Tails?

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In an effort to provide our subscribers with a premiere periodical that keeps them current in sports medicine literature, we are pleased to provide this exclusive issue on the timely topics of nutraceuticals, nutritional supplements, banned, and nonbanned substances. This is a bonus to our subscribers. We welcome John MacKnight, MD, as the co-editor of this special issue. Dr. MacKnight is an internist with sports medicine training who brings needed expertise in these areas. His contribution deals with growth hormones. In addition, we welcome Drs. Robert Posey and Thomas Armsey from the University of Kentucky. They provide an in-depth study on nutritional supplements. Dr. Arthur Weltman from the University of Virginia provides information and analysis on prohibited substances and methods for performance enhancement. Dr. Robert Schenck is an associate editor of Sports Medicine Reports.

Nutraceuticals and Osteoarthritis

ABSTRACT & COMMENTARY

Source: McAlindon TE, et al. Glucosamine and chondroitin for treatment of osteoarthritis. A systematic quality assessment and meta-analysis. *JAMA* 2000;283:1469-1475.

This is a thorough analysis of trials using nutraceuticals in the management of osteoarthritis (OA) over the past 20 years. McAlindon and associates combed the literature through MEDLINE (1966-1999), and bibliographies from *Arthritis and Rheumatism*, the *British Journal of Rheumatology*, and *Osteoarthritis and Cartilage* (1978-1998) to identify such studies involving the evaluation of glucosamine and chondroitin sulfate. Follow-up with authors, manufacturers, and content experts was performed to help clarify findings and identify sources of bias. Only controlled trials (minimum 4 week duration) vs. placebo in patients with OA of the knee or hip and evaluating at least one realistic outcome measure (i.e., Lesquesne Index, WOMAC, global pain scores) were selected.

INSIDE

Fifteen of a potential 37 studies qualified and were submitted to meta-analysis. Study quality was investigated using a previously described (*JAMA*) point scale assessed by two reviewers of the McAlindon team. This scoring system allows for a range of 0 (worst) to 65 (best) points to evaluate the scientific quality and has been shown in previous studies to be reliable in several study analyses. Of the 17 studies, quality of science was moderate to poor, averaging 36% (range, 12-55%, standard deviation [SD], 12%). Only one of the 17 studies used an intent-to-treat analysis. None of the studies reviewed were funded by an independent or government source. Evaluation of funding source (self-described or through author contact) revealed some form of manufacturer or industry funding in 15 of 17 studies analyzed. Seven of the 17 studies included an investigator from the company as an author.

Those limitations accepted, all studies reviewed showed a positive effect on outcome of OA with glucosamine and/or chondroitin sulfate. Of those six studies involving glucosamine, a total of 911 patients participated, and improvement in outcome ranged from 12-52%. Combining the patients into one group, there was a moderate benefit with glucosamine on OA, an effect size of 0.44 with confidence intervals of 95%. Studies evaluating chondroitin sulfate involved 799 patients with benefit scores improving by 14-55%. Chondroitin sulfate appeared to have a larger benefit than glucosamine. McAlindon et al concluded that glucosamine and chondroitin sulfate improved outcomes in the treatment of OA, "but the studies reviewed contain methodologic problems that have been associated with exaggerated estimates of benefit." McAlindon et al further noted that, "it seems probable that these compounds do have some efficacy in treating OA symptoms, and that they are safe, and because of this, may have considerable use in OA treatment." As many authors have noted, future controlled trials are needed with independent funding sources to clearly identify the degree of benefit these substances produce.

COMMENT BY ROBERT C. SCHENCK, Jr., MD

Only recently has interest in glucosamine and chondroitin sulfate increased such that clinical and basic science studies are being performed. Three recent studies at the Orthopaedic Research Society have focused on the mechanism of glucosamine and chondroitin sulfate on a molecular level.[3-5] Currently, both European and American nutraceutical companies are carrying out clinical studies on the effectiveness (symptom modification vs disease modification) of nutritional supplementation in the management of OA. Finally, the National Institutes of Health has funded a multicenter trial to clinically evaluate the symptom modification of these nutritional supplements. These studies and trials will be outlined below as they provide a greater understanding of these somewhat "mysterious" nutritional agents.

The culture of nutritional supplementation requires definition of commonly used terms with which physicians may not readily be familiar. Most agents used initially in the management of OA are nonsteroidal anti-inflammatories (NSAIDs), and these medications function to limit or ameliorate the breakdown products from articular degeneration. "Chondroprotective" agents describe any medication or "compound" which can block progression of degenerative joint disease (DJD) and stimulate repair of damaged cartilage; these include glucosamine, chondroitin sulfate, hyaluronan, and diacerhein. The theoretical basis of chondroprotection is the provision of substrate or components of the hyaline matrix; for example, supplying substrate or providing a stimulus to increase the synthesis of complete aggrecan macromolecules.

Finally, the concept of disease modification vs. symptom modification is an important distinction when using nutritional supplements. Disease modifying aspects of glucosamine and chondroitin sulfate alone or in combi-

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nation have been claimed by industry and researchers alike. Symptom modification (as attested by the meta-analysis above) is generally accepted with the use of these compounds for mild to moderate OA, but independent non-industry supported studies are needed. Disease modification in non-inflammatory OA would be a significant clinical finding in the use of glucosamine and chondroitin sulfate but, as of yet, has not been shown conclusively.

Recent mechanistic studies have given further credence to the use of nutritional supplementation in the management of mild to moderate OA. Mimms et al recently showed increased production of proteoglycans when bovine cartilage explants were cultured with glucosamine and chondroitin sulfate alone and in combination.[3] Mimms et al noted that combination therapy demonstrated the greatest proteoglycan synthesis compared to glucosamine or chondroitin sulfate alone. Mimms et al went on to show the ability of nutritional supplements to prevent interleukin-1 (IL-1)-induced aggrecan depletion. Mimms et al concluded that dietary supplementation may play a role in promoting cartilage health, maintenance, and repair. In another study, Sandy and colleagues evaluated the mechanism by which one component of nutritional supplements may effect chondroprotection.[4] Glucosamine was shown to block the aggrecanase response of chondrocytes to IL-1 in an in vitro model using rat chondrosarcoma cells and bovine cartilage explants. These studies are the first independently funded investigations to show a mechanism by which glucosamine and chondroitin sulfate both influence the production of proteoglycans while also inhibiting the degradation of aggrecan, two important components of normal cartilage metabolism.

Clinically, glucosamine can be administered via intravenous, intramuscular, intra-articular, and oral routes. Oral intake of the sulfated or hydrochloride forms shows approximately 70% absorption with excretion through the renal system. Glucosamine is produced commercially from animal sources. It is sold as a nutritional supplement, is not regulated through the FDA, and does not require standard prescription dosing.

More than 30 clinical studies have been performed in humans and animals since the 1960s. Although many are small studies, there are several double-blinded placebo-controlled trials. Furthermore, the specialized outcome and objective measurements used in the 1990s have only recently been applied to clinical trials of glucosamine and chondroitin sulfate.[12] Most studies have shown symptomatic improvement in the management of arthritis with minimal side effects. However, as will be shown below, there is a significant placebo affect with any medication, and this must be remembered when evaluating any new treatment in patient care.

An example of such early studies is that by Vas et al (1982) evaluating the efficacy of glucosamine (1.5 g/d) vs. ibuprofen (1200 mg/d) in 32 patients with OA;[8] 18 patients were administered glucosamine sulfate and 20 patients were given ibuprofen. After two weeks of therapy, ibuprofen provided greater pain relief. However, at eight weeks follow-up, glucosamine gave greater pain relief. In this study, a pain scale from 0-3 was used as well as physician observations in determining pain relief.

In an open trial of 1208 patients (involving 252 physicians, 1982), 1.5 grams of glucosamine sulfate/d were administered with “good or sufficient” pain relief noted in 94% of patients at six and eight weeks follow-up.[7] Furthermore, there was an increase in arthritic symptoms after discontinuance of glucosamine. Symptoms were physician rated, and the supplement was well tolerated with few side effects. One study from Thailand in the early 1980s evaluated intra-articular glucosamine for knee arthritis administered once a week for five weeks, double-blinded, vs. saline injection.[6] An improvement in pain and knee flexion were seen. At eight weeks post-injection treatment, more than 50% of patients treated with glucosamine injections noted continued relief with less than 10% noting relief after using saline injections. In another recent study using combined glucosamine hydrochloride, low molecular weight chondroitin sulfate, and manganese ascorbate (Cosamin DSÒ, Nutramax Laboratories, Inc., Edgewood, MD), Das et al randomized 93 patients to either treatment with 1 g glucosamine hydrochloride, 0.8 g chondroitin sulfate twice daily, or placebo.[9] Twenty-eight percent of patients in the placebo group responded favorably compared to 52% of the supplemented group with both groups having similar rates of adverse reactions.

It is with the McAlindon meta-analysis and patient use of nutritional supplements that the National Institutes of Health current multicenter trial is so important. Three treatment arms and placebo will compare glucosamine alone, chondroitin sulfate alone, and combination therapy (glucosamine/chondroitin sulfate) against placebo. This trial is centered at the University of Utah and involves 13 medical centers around the country. The trial will evaluate symptom modification and not disease modification. The findings of this important study will provide great information for the treating clinician in the use of glucosamine and chondroitin sulfate in the treatment of mild to moderate OA.

Oral supplementation is not indicated for inflammatory arthropathies such as rheumatoid arthritis, crystalline arthropathies such as gout, nor in pregnancy or in children. If a patient is diabetic, the clinician should follow

serum glucose. Most dosing regimens are based on weight as recommended by Theodosakis et al.[10] (*See Table.*)

Table

Less than 120 lbs.	GS 1000 mg
	CS 800 mg
120-200 lbs.	GS 1500 mg
	CS 1200 mg
More than 200 lbs.	GS 2000 mg
	CS 1600 mg

Side effects of glucosamine and chondroitin sulfate appear to be minimal in humans. As noted above, inpatient double-blinded studies showed no significant changes in CBC, BUN/creatinine, glucose, PT, or PTT. In the study by Tapadinhas et al, there was a low incidence of side effects with the use of 1.5 g of glucosamine sulfate daily in 1208 patients. The use of glucosamine in patients with diabetes is unclear, but many researchers recommend closely following blood sugars when using the supplement in diabetics.

Finally, purity and the presence of active ingredients vary greatly between products. In one recent study, Eddington and colleagues evaluated the label claims of 32 chondroitin containing products.[11] Twenty-six of the 32 products were found to contain less than 90% of the chondroitin sulfate stated on the label with 17 products containing less than 40% of the label claim. Fourteen products containing glucosamine were also analyzed. Twelve of the 14 glucosamine products contained 90% or more of the glucosamine. In summary, deviations from label claims highlight the inconsistencies of many dietary supplements and actual content found in the product.

Conclusion

The use of glucosamine and chondroitin sulfate is not included in most treatment algorithms where acetaminophen, ambulatory aides, NSAIDs, including the new COX-2 inhibitors, injections, and joint replacement, have been the traditional treatment approach. Many patients currently use glucosamine/chondroitin sulfate with or in place of NSAIDs. The use of glucosamine and chondroitin sulfate in those patients failing acetaminophen and unable to tolerate NSAIDs may create an additional niche for oral supplementation. With further studies on efficacy and safety profiles, the clinical indications for glucosamine and chondroitin sulfate will become better defined. When recommending a product such as glucosamine or chondroitin sulfate to a patient, the clinician frequently has little experience in alternative therapies. In my opinion, one should recommend the product that has been used in recent clinical trials and that has documented purity. Using a supplement based on data obtained with a different product does not confer efficacy. Nutritional supplements vary in purity and content, and careful scrutiny of products and careful recommendation is in the best interest of patients.

One interesting question raised by McCarty in 1994 is, "Why has glucosamine taken so long to hit the USA?" As McCarty noted, glucosamine was first used in Germany in 1969, and as reviewed above, five double-blind trials were performed in the 1980s. All studies showed uniform results with improvement in symptoms. McCarty comments, "America's massive, richly funded medicopharmaceutical complex has evinced not one shred of interest, undoubtedly because glucosamine is an unpatentable natural agent." That is until the recent discovery of glucosamine and chondroitin sulfate by the American consumer. ❖

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Nutritional Supplements

By Robert G. Hosey, MD
and Thomas D. Armsey, MD

Synopsis: *Many nutritional agents claiming ergogenic performance-enhancing properties are presently available. Understanding their use allows the physician to provide appropriate guidance with regard to efficacy and safety.*

Source: Armsey TD, Green GA. Nutrition supplements: Science vs. hype. *Physician Sportsmed* 1997;25(6):77-92.

Nutritional supplements continue to generate significant public interest and enormous revenues throughout the world. According to the Food and Drug Administration, the 1997 retail sale of dietary supplements generated $12.7 billion in the United States alone. This huge financial incentive, partnered with minimal federal regulation, makes this industry ripe for skepticism and corruption. Because of this, the supplement industry has developed the Council for Responsible Nutrition which selfregulates the industry and promotes legitimate scientific research of nutritional supplements. Unfortunately, these regulatory measures usually only respond to problems in the industry and do not proactively assure supplement safety. In addition, sports superstars have acknowledged the use of supplements in their training regimens, further boosting the mystique surrounding certain supplements. Combine this with advertising aimed at high school, collegiate, and recreational athletes, all eager to improve performance, and it is easy to appreciate the drive behind the increasing popularity of supplement use.

Sports medicine physicians are in an excellent position to advise athletes, coaches, and administrators about the potential benefits and risks of supplements. Therefore, physicians caring for athletes need appropriate knowledge of these "nonbanned" ergogenic aids. The purpose of this article is to review the mechanisms of action, scientific evidence of performance enhancement, and potential adverse effects of the commonly used nutritional supplements.

Creatine Monohydrate

Creatine (methylguanidine-acetic acid) is an amino acid that is found naturally in skeletal muscle and other tissues of the body. Creatine is endogenously synthesized from arginine and glycine in the liver, pancreas, and kidneys. Additional creatine is also obtained from dietary sources such as meats and fish. The majority of creatine exists as phosphocreatine (PCr) in skeletal muscle, while only approximately 25% exists as free creatine. Both creatine and PCr are involved in the production of adenosine triphosphate (ATP), the major intracellular energy compound. As a result of creatine's involvement in "energy production" via ATP formation, its use as a potential ergogenic aid has evolved.

In 1992, investigators found that creatine supplementation increases skeletal muscle stores of PCr and free creatine. Shortly thereafter it was introduced as a potential ergogenic aid. While use among scholastic, collegiate, and professional athletes has been assumed to be "high," few studies have documented prevalence of use among these groups. However, a recent study by the NCAA revealed that 13% of intercollegiate athletes have used creatine monohydrate in the past 12 months. Additionally, in two separate single division I university settings, 41% of 219 and 28% of 750 athletes surveyed reported using creatine. Among these athletes, use was higher in males and was most prominent with football, track and field, diving, baseball, and basketball athletes.

Dosage and Mechanism of Action

Creatine is generally ingested at a loading dose of 20-25 g for 5-7 days, followed by a maintenance dose of 2 g/d. This regimen increases muscle creatine stores an average of 20%, although individual variations will occur. With cessation of supplementation, creatine stores in skeletal muscle generally return to baseline within four weeks time.

Creatine supplementation increases the bioavailability of PCr inside the skeletal muscle cell. This is thought to enhance muscle performance in two ways. First, during brief, high-intensity (anaerobic) exercise, PCr transfers its phosphate group to ADP, replenishing the available ATP to be used for energy. Second, PCr buffers the intracellular hydrogen ions that are associated with fatigue during exercise. Therefore, creatine supplementation may provide an ergogenic effect by increasing the

force of muscular contraction and prolonging exercise capability.

Body Composition and Exercise Performance

Weight gain from creatine supplementation has been noted for both the loading phase and with long-term use. Weight gain has been on the order of 0.5-2.0 kg and likely results from increased body water retention. To date, creatine supplementation has not been consistently proven to result in muscle accretion. It is more likely that long-term body composition changes are the result of the athlete's ability to perform higher intensities of weight training.

Creatine supplementation has been demonstrated to be ergogenic in repeated bouts of certain activities including weight lifting, cycling, running, rowing, and repetitive sets of muscle contractions. How this data applies to athletic performance on the field, however, has yet to be elucidated. Furthermore, creatine supplementation has no proven ergogenic ability in activities that are primarily aerobic in origin. Weight gain associated with creatine use in these endurance type athletes may offset any potential gains from creatine supplementation.

The mean Cr concentration in human skeletal muscle is approximately 125 mmol/kg-dm with a "normal range" of 90-160 mmol/kg-dm. Approximately half of athletic subjects will exhibit concentrations lower than 125 mmole/kg-dm, with women and strict vegetarians substantially lower. Those individuals with skeletal muscle concentrations of ([Cr] < 125) are likely to exhibit the most significant increases in muscle Cr concentration, PCr resynthesis, and performance enhancement with the use of creatine supplementation. Athletes with levels of Cr at the higher end of the normal range are more apt to show little or no ergogenic effect from creatine supplementation. This wide spectrum of Cr concentrations in athletes may explain many of the conflicting results in the literature.

Side Effects

No deleterious side effects have been consistently documented in subjects using short-term creatine supplementation. However, there have been anecdotal reports of creatine causing nausea/vomiting, hypertension, renal dysfunction, muscle cramping, and dehydration. While there is a lack of scientific evidence to implicate creatine supplementation as a health risk, this does not necessarily equate with safety of the supplement. As creatine is a relatively new supplement, the long-term effects and, perhaps, even some of the short-term effects of creatine supplementation remain unknown.

Chromium Picolinate

Chromium is an essential trace mineral present in various foods, such as mushrooms, prunes, nuts, whole grain breads, and cereals. It has been found that the intake of chromium in the general population is less than the recommended daily amounts. Chromium by itself has a low gastrointestinal absorption rate. As a result, three molecules of picolinic acid are often added to increase the absorption and bioavailability and produce the supplement chromium picolinate (CrPic).

Mechanism of Action

Chromium supplementation became popular after it was found that exercise increases chromium loss, raising the concern that chromium deficiency may be prevalent among active individuals. Chromium seems to function as a co-factor that potentiates the action of insulin in carbohydrate, fat, and protein metabolism. Promoters of CrPic claim it increases glycogen synthesis, improves glucose tolerance and lipid lipoprotein profiles, and increases lean body mass.

Body Composition and Exercise Performance

Early on, CrPic supplementation seemed to hold some promise as an ergogenic aid. Decreased percent body fat and increased lean mass were found in collegiate athletes and students performing resistance training and taking 200 mcg per day of CrPic. Critical analysis of these studies, however, reveals that imprecise measurement techniques may have accounted for these "ergogenic" results. More recent studies using precise measurement techniques have failed to demonstrate any significant improvement in percent body fat, lean body mass, or strength. Therefore, the current consensus of the scientific community is that CrPic is ineffective as an ergogenic aid.

Side Effects

Most of the studies involving CrPic have been short-term studies and have revealed no major side effects. However, when supplemented at doses of 50-400 mcg per day, CrPic has been implicated in precipitating adverse events including anemia and cognitive impairment. Therefore, with a limited scientific rationale as an ergogenic aid and the noted potential adverse effects, CrPic supplementation should be discouraged.

Beta-Hydroxy-beta-Methylbutyrate

One of the most recent additions to the nutritional supplement armamentarium is beta-hydroxy-beta-

methylbutyrate (HMB). HMB is a metabolite of the essential branched-chain amino acid, leucine, and is produced in small amounts endogenously. HMB is also found in various food sources, such as catfish, citrus fruits, and breast milk. In the early 1980s, HMB was studied as a repartitioning agent in livestock because of its ability to promote lean muscle mass without the use of anabolic hormones.

Mechanism of Action

HMB seems to be unique in regards to its mechanism of action. It has been hypothesized that HMB is an anti-catabolic agent that results in a decrease in protein breakdown. Although the exact mechanism of action is currently unknown, promoters suggest that HMB regulates the enzymes responsible for protein or muscle breakdown, decreasing protein (muscle) catabolism, thereby creating a net anabolic effect. By minimizing protein breakdown, HMB, when combined with a resistance-training program, may cause an increase in muscle mass and strength.

Body Composition and Exercise Performance

Scientific research in livestock and humans seems to suggest that supplementation with HMB may, in fact, increase lean muscle mass and strength. Nissen has conducted randomized, double-blinded, placebo-controlled studies to evaluate the ergogenic potential of HMB in exercising males. In the first study, 41 untrained subjects participated in a four-week-structured resistance-training program. This study demonstrated statistically significant improvements in lean muscle mass and strength as well as significant decreases in muscle breakdown products (3-methylhistidine and creatine phosphokinase) while supplementing a controlled diet with 1.5 or 3.0 g HMB/d vs. controls. The second study evaluated both trained and untrained male subjects in a similarly designed weight training program. Both groups demonstrated statistically significant increases in lean muscle mass and one-repetition maximum bench press with a coincident decrease in percent body fat vs. controls with the use of 3.0 g HMB/d.

Therefore, HMB supplementation (dosages of 1.5-3.0 g/d) has been shown to augment resistance-training programs in novice and experienced male subjects with regard to muscle mass, strength, and percent body fat, presumably by decreasing muscle catabolism. Further studies regarding this supplement may continue to support these anabolic, "steroid-like" effects, as well as elucidate the role of HMB in protein metabolism.

Side Effects

Currently, there are no reported sideeffects of HMB supplementation, but the safety profile of this agent is still unknown. Also, there are no corroborating studies to prove that HMB is an effective ergogenic aid. Therefore, it is premature to recommend HMB supplementation as a safe and effective ergogenic aid.

Dehydroepiandrosterone

In 1996, the FDA banned the sale and distribution of dehydroepiandrosterone (DHEA) for therapeutic purposes until the safety and efficacy profiles could be reviewed. Although this action was instituted to decrease the availability of this agent, the ensuing media attention served to popularize this supplement. Currently, by avoiding therapeutic claims, manufacturers are still able to sell DHEA as a nutritional supplement. DHEA was discovered in 1934 to be an androgenic hormone produced in the adrenal glands. It is a precursor to the production of both androgens and estrogens in primates. It is also available exogenously in wild yams which are sold in many health food stores as a source of DHEA.

The current theoretical action of DHEA stems from the fact that as a precursor to androgenic steroids, it may increase the production of testosterone and provide an "anabolic steroid effect." Promoters also claim that DHEA slows the aging process and advertise it as the "fountain of youth."

Body Composition and Exercise Performance

Only a few randomized, double-blinded, placebo-controlled studies have been published on the effects of DHEA supplementation. Two have demonstrated significant increases in androgenic steroid plasma levels, along with subjective improvements in physical and psychological well-being, while supplementing with 50 mg/d for six months or 100 mg/d for 12 months. Whether DHEA has any effect on body composition or fat distribution is still unclear. The effect of DHEA on healthy individuals younger than 40 years of age is also unknown and virtually unstudied.

Side Effects

Few consumer complaints have been reported as to the adverse effects of DHEA. The most concerning are the irreversible virilizing effects seen in women, including hair loss, hirsutism, and voice deepening. Males have also reported irreversible gynecomastia with DHEA use which may occur from an elevation in estrogen levels. Because the current scientific knowledge is inadequate, long-term adverse effects are unknown.

Therefore, the safety of this "hormone replacement" therapy must be queried prior to its medical endorsement. Unlike most other nutritional supplements, DHEA may substantially increase the risk of uterine and prostate cancer that accompanies prolonged elevated levels of unopposed estrogen and testosterone.

Also of interest to competitive athletes, DHEA supplementation may alter the testosterone/epitestosterone ratio to levels that exceed the 6:1 ratio used by the International Olympic Committee (IOC) and National Collegiate Athletic Association (NCAA) to screen for exogenous testosterone use and, thus, may create a risk for disqualification from international competition. Due to the lack of clinical evidence that DHEA enhances performance in athletes, as well as the potentially devastating adverse effects associated with its use, DHEA supplementation should not be endorsed by the medical community.

Conclusion

This article presents information regarding several popular nutritional supplements and their use as ergogenic aids. Although some of these supplements may have potential benefits, it is important to mention the NCAA guidelines which state, "there are no shortcuts to sound nutrition, and the use of suspected or advertised ergogenic aids may be detrimental and will in most instances, provide no competitive advantage."

The skepticism over nutritional supplements is due to a number of factors. As mentioned in this article, there is a paucity of properly performed scientific research to support a positive effect for many of these substances. In addition, the lack of rigorous FDA regulation may lead to impurities in the preparation of supplements as has already been documented in a number of investigative reports. Finally, the cost of nutritional supplements must be addressed. The Table demonstrates the considerable financial burden that is created by these often unproven ergogenic aids. In an era of shrinking athletic department budgets, it makes little sense to invest in nutritional supplements which offer little or no benefit to the athlete. Therefore, decisions regarding the use of nutritional supplements should only be made on the basis of proper scientific study and proven benefit to the patient. ❖

Table

Cost Comparison

Creatine	
	20-25 g/d (loading dose): $7.20/d for one week
	2 g/d (maintenance dose): $3.60/d
Chromium	
	200 mcg/d: $0.43/d
HMB	
	3.0 g/d: $3.48/d
	1.5 g/d: $1.74/d
DHEA	
	50 mg/d: $0.67/d
	100 mg/d: $1.34/d

Source: *National Supplement Association and General Nutrition Centers*

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Prohibited Classes of Substances and Prohibited Methods for Performance Enhancement

By Arthur Weltman, PhD

Synopsis: *This overview discusses the various classes of banned substances, the reasons they are banned, and the desired effects for which athletes take them.*

Source: Mottram DR. Banned drugs in sport. Does the International Olympic Committee (IOC) list need updating? *Sports Medicine* 1999;27(1):1-10.

During the recent olympic games in sydney, Australia, there was considerable attention paid to the practice of "doping" to enhance athletic performance. The pressure to win and the riches and fame associated with success have contributed to a culture where many athletes will do almost anything to win. For example, in a 1995 poll of 198 elite U.S. athletes, the following question was asked: You are offered a banned substance with two guarantees: 1) you will not get caught; 2) you will win. Would you take the substance? Only three answered no. More frightening was the result of the question that followed. You are offered a performance enhancing substance with two guarantees: 1) you will not get caught; 2) you will win every competition you enter for the next five years and then you will die

from the side effects of the substance. Would you take it? More than 50% said yes.

The International Olympic Committee (IOC) initiated drug testing in 1968 after a Tour de France cyclist from England died from an amphetamine overdose. Testing has consistently expanded and more sophisticated detection techniques have evolved. However, athletes still cheat. During the 1998 Tour de France, the coach and all nine riders of the top-ranked Festiva team of France were suspended after a team car was found to contain large quantities of amphetamines, steroids, "masking agents" (substances used to elude drug testing), and erythropoietin. A week later, four Chinese swimmers were banned for two years for using a banned diuretic at the world championships. During the recent Olympics in Sydney, seven competitors tested positive for various banned substances and a number of competitors (including 27 Chinese athletes) chose not to compete in the games presumably because of new anti-doping policies.

Doping is prohibited because it is fundamentally against the ethos of sport. In addition, many of the substances and methods used are harmful to the athletes' health and can cause serious short and long-term damage. Nevertheless, the practice has become so commonplace in elite class athletics that it has necessitated the creation of the Olympic Movement Anti-Doping Code that addresses the use of banned substances and doping techniques. One of the problems with any anti-doping code is that many common medications, such as painkillers, cold medicines, and asthma medications, can contain prohibited substances. Athletes must be very cautious with any medication that they are taking because it is the athletes' responsibility to know whether there are banned substances in medications that they are taking. If a competitor wants to use a prohibited substance for therapeutic use, he/she must have written approval of the Medical Advisory Committee of the IOC Medical Commission prior to the Olympic Games.

At each Olympic games, all medal winners and a random competitor are drug tested. In Atlanta, Ga, 2000 tests were conducted for 11,000 athletes. The minimum required sanction for a first offense with a major doping substance is a suspension from all competition for two years. Any records or medals achieved at the time of, or after, the sample was taken are stripped. In addition, other organizations (e.g., the International Federation) may choose to impose additional sanctions on the competitor.

What substances are banned? The Olympic Movement Anti-Doping Code Appendix A (www.nodoping.org) provides a list of prohibited classes of substances and prohibited methods (April 1, 2000). The list below identifies these prohibited substances and gives examples of the ergogenic benefits and risks associated with representative substances from each class.

Prohibited Classes of Substances

Stimulants

Stimulants include amineptine, amiphenazole, amphetamines, bromantan, caffeine, carphedon, cocaine, ephedrines, fencamfamin, mesocarb, pentetrazol, pipradrol, salbutamol, salmeterol, terbutaline (asthma treating drugs are allowed by inhaler only, provided written documentation of asthma and/or exercise-induced asthma is provided by the team physician to the relevant medical authority), and related substances.

Athletes use stimulants (e.g., amphetamines) to try to gain an ergogenic edge. Although early research suggested that amphetamine use did not result in improved athletic performance, more recent research suggests that they may enhance skills that are important to performance. People who take amphetamines experience a decreased sense of fatigue, increased systolic and diastolic blood pressure, increased heart rate, redistribution of blood flow to skeletal muscles, elevation of blood glucose and free fatty acids, and increased muscle tension. Recent studies suggest that amphetamines can enhance speed, power, endurance, concentration, and fine motor coordination. However, the use of amphetamines is inherently dangerous. Dangers of amphetamine use include physiological or emotional drug dependency resulting in a cyclical compensatory dependency on amphetamines and barbiturates. General side effects include headache, agitation, insomnia, nausea, dizziness, and confusion which may all negatively effect performance. Prolonged intake of high doses of amphetamines can produce weight loss, paranoia, psychosis, repetitive compulsive behavior, and nerve damage.

Caffeine may be a possible exception to the general rule against taking stimulants. Some studies suggest that ingesting the amount of caffeine commonly found in 2.5 cups of coffee (330 mg, legal under current IOC guidelines of a urine concentration of < 12 mg/mL) one hour before exercising may extend endurance in the face of moderately strenuous exercise. This is thought to be due to increased mobilization of fat and, hence, glycogen sparing. However, most endurance athletes now take carbohydrate feedings during exercise as this is a more effective ergogenic aid that inhibits the mobilization of fat.

Narcotics

Narcotics include buprenorphine, dextromoramide, diamorphine (heroin), methadone, morphine, penta-

zocine, pethidine, and related substances. (Note: codeine, dextromethorphan, dextropropoxyphene, dihydrocodeine, diphenoxylate, ethylmorphine, pholcodine, and tramadol are permitted.)

Anabolic Agents

Anabolic androgenic steroids

a. clostebol, fluoxymesterone, metandienone, metenolone, nandrolone, 19-norandrostenediol, 19-norandrostenedione, oxandrolone, stanozolol, and related substances

b. androstenediol, androstenedione, dehydroepiandrosterone (DHEA), dihydrotestosterone, testosterone, and related substances

Beta-2 agonists

Beta-2 agonists include bambuterol, clenbuterol, fenoterol, formoterol, reproterol; also includes salbutamol, salmeterol, and terbutaline which can be authorized for therapeutic inhalation for asthma, and related substances.

It is clear that certain anabolic agents in combination with an adequate diet and training program can enhance the development of muscular strength. The American College of Sports Medicine (ACSM) recently published a Position Statement on Anabolic Steroids. The ACSM concluded that: 1) anabolic-androgenic steroids in the presence of an adequate diet and training program can contribute to increases in body weight, often in the lean compartment; 2) gains in muscle strength achieved through high intensity exercise and proper diet can be increased by the use of anabolic-androgenic steroids; 3) anabolic-androgenic steroids do not increase aerobic power or muscular endurance, although some endurance athletes do use them for their anti-catabolic properties which presumably speeds up the recovery process. Anabolic-androgenic steroids have been associated with adverse effects on the liver, cardiovascular system, reproductive system, and psychological status; the use of anabolic-androgenic steroids is contrary to the rules and ethical principles of athletic competition.

Although the ACSM position stand reviewed the literature regarding controlled substances, several so-called food substances (androstenedione, DHEA) are also considered as anabolic agents and are on the list of banned substances.

Clenbuterol, one of the beta-adrenergic agonists, has become popular among athletes because of its purported tissue-building, fat-reducing benefits. Although few human studies are available, animal studies suggest that clenbuterol increases skeletal and cardiac muscle protein deposition and slows fat gain by enhancing lipolysis. Because of these supposed properties, some athletes switch to clenbuterol after discontinuing steroids (during the "washout" period prior to competition). There have been short-term side effects reported in humans accidentally "overdosing" from eating animals that were treated with clenbuterol. These include muscle tremor, agitation, palpitations, muscle cramps, rapid heart rate, and headache. Although this drug may have some clinically legitimate promise in treating muscle wasting disease and the muscle loss associated with forced immobilization or aging, its use as an ergogenic aid cannot be justified or recommended.

Diuretics

Diuretics include acetazolamide, bumetanide, chlortalidone, etacrynic acid, furosemide, hydrochlorothiazide, mannitol (by intravenous injection), mersalyl, spironolactone, triamterene, and related substances.

Diuretics are generally used for weight control. They are typically used by jockeys, wrestlers, and gymnasts to keep their weight down. Other athletes who are taking banned drugs will use diuretics to increase fluid loss. These athletes hope that the extra fluid in the urine will result in a decreased concentration of banned substances in the urine, a practice known as "masking."

There are no known direct ergogenic effects of diuretic use. As a matter of fact, much of the fluid loss results from the loss of extracellular fluid, including plasma. This reduction in plasma volume can result in a reduction in maximal cardiac output, which in turn results in decreased maximal oxygen consumption and impaired endurance performance. In addition, the diuretic-induced reduction in plasma volume can impair temperature regulation during exercise as well as result in electrolyte imbalance with resultant muscle fatigue and muscle cramping.

Peptide Hormones, Mimetics, and Analogues, Including:

1. Chorionic Gonadotrophin (hCG) prohibited in males only;
2. Pituitary and synthetic gonadotrophins (LH) prohibited in males only;
3. Corticotrophins (ACTH, tetracosacride);
4. Recombinant Growth Hormone (rhGH);
5. Insulin-like Growth Factor (IGF-I) and all of the respective releasing factors and their analogues;
6. Erythropoietin (EPO);
7. Insulin (permitted only to treat athletes with documented insulin-requiring diabetes mellitus).

The use of human growth hormone (GH) in competitive athletes has been on the rise since it was "discovered" by the powerlifting community in the early 1980s.

GH is thought to provide similar benefits as anabolic steroids. The effects of GH that interest athletes include: stimulation of protein and nucleic acid synthesis in skeletal muscle; stimulation of bone growth (in bones where the growth plates have not fused); increased lipolysis and an overall decrease in body fat; increased blood glucose levels; and enhanced healing after musculoskeletal injuries. The risks of using GH include carpal tunnel syndrome, acromegaly, cardiomyopathy, insulin resistance leading to type 2 diabetes, and edema leading to hypertension.

Erythropoietin is a hormone that stimulates the production of red blood cells from the bone marrow. Recombinant erythropoietin (EPO) is used by endurance athletes to increase red blood cell concentration which results in an increase in oxygen carrying capacity of the blood. This leads to an increase in VO_2 max and enhanced endurance performance. Uncontrolled and unmonitored use of erythropoietin can lead to dangerous increases in blood viscosity, augmented exercise induced systolic blood pressure, increased risk of stroke, blood clotting, heart attack, heart failure and death.

Prohibited Methods

1. Blood Doping;
2. Administering artificial oxygen carriers or plasma expanders;
3. Pharmacological, chemical, and physical manipulation; (see related "Doping" article in this issue, pg. 12).

Classes of Prohibited Substances in Certain Circumstances

a. Alcohol
b. Cannabinoids
c. Local anesthetics
d. Glucocorticosteroids
e. Beta-Blockers

Out-of-Competition Testing

Unless specifically requested by the responsible authority, out-of-competition testing is directed solely at prohibited substances in anabolic agents, diuretics, (peptide hormones, mimetics, and analogues, and prohibited methods.

Summary

As can be seen from the extensive list of agents that are banned, the fight against doping is a continuous battle. The real problem is not related to major competitions. Athletes can use a number of classes of drugs out of competition, discontinue those drugs prior to competition, and technically be "drug free" during competition. Until random out-of-competition drug testing is initiated, it is doubtful that a major reduction in doping will occur. The recently formed World Anti-Doping Agency may have the capabilities to initiate these tests, but it will require the cooperation of the International Sports Federations as well as governments who must agree to be zealous about drug testing. ❖

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The Use and Abuse of Growth Hormone

By John M. MacKnight, MD

Synopsis: *Markers of bone metabolism may be useful in the detection of growth hormone abuse in sport.*

Source: Longobardi S, et al. Growth hormone (GH) effects on bone and collagen turnover in healthy adults and its potential as a marker of GH abuse in sports: A double blind, placebo-controlled study. *J Clin Endocrinol Metab* 2000;85(4): 1505-1512.

As a greater premium is placed on athletic achievement, sports medicine physicians are increasingly faced with the prospect of athletes using performance-enhancing substances. In recent years, the practice of "doping" has risen dramatically. As the means for detecting previous doping techniques, most notably the use of anabolic steroids, have improved, athletes have embraced a number of alternatives such as recombinant human growth hormone (rhGH). This study seeks to elucidate the effect of rhGH on several serum markers of bone and collagen metabolism and, in so

doing, lays the foundation for their potential use in detecting growth hormone abuse in competitive sports.

This double-blind, placebo-controlled study was carried out in 99 subjects between 18-35 years of age who had been training twice weekly for at least a year. Males and females were equally represented. The subjects were randomized to receive 28 days of low-dose (0.1 IU/kg/d) subcutaneous rhGH, high-dose (0.2 IU/kg/d) subcutaneous rhGH, or placebo followed by a wash-out period of 56 days. These doses were felt to simulate those of GH doping in sport. Serial assessments were made of bone and collagen markers including serum osteocalcin, C-terminal propeptide of type I procollagen (PICP), C-terminal cross-linked telopeptide of collagen type I (ICTP), and procollagen type III N terminal extension peptide (PIIIP).

During this study, serum levels of all of the studied markers increased significantly with both low and high-dose rhGH administration. This is in keeping with previous data on the influence of GH on bone remodeling and formation. No change in these parameters was seen in the placebo group, nor was any menstrual or diurnal variation found. The most remarkable increases were seen with ICTP and PIIIP, and osteocalcin, and PIIIP remained elevated throughout the 84 days of the study. These findings support a general acceleration of bone turnover and bone formation.

From a standpoint of doping control, this study has promising implications. There is presently no approved method to detect GH doping, largely because of its short half-life, unpredictable serum levels, and minimal excretion in urine. This study shows that the studied markers are significantly elevated in both rhGH treatment groups, creating the possibility that one or more of them could be used as a surrogate marker for GH doping in sport. Moreover, these changes persisted many weeks into the wash-out period, establishing their usefulness even at times far removed from the doping incident itself, a major advance over many present screening measures.

This is also an important study in the field of GH use. Longobardi and colleagues were able to demonstrate the strong influence that exogenous GH has on the bone and collagen metabolism of exercising individuals as compared to placebo-treated controls. This may give some insight into future uses for GH administration in a therapeutic role, most notably in osteoporosis where the risk for fracture may be reduced.

The study is somewhat limited by evaluating a predominantly caucasian population exercising at levels likely well below those of athletes who are likely to be involved in doping activities. Both flaws will need to be addressed in future studies before bone metabolism markers can be confidently used for GH doping detection in the athletic population.

Use of recombinant growth hormone (somatotropin, rhGH) as a doping agent in sport is on the rise. And although rhGH has been shown to increase muscle mass, muscle strength, and exercise capacity in GH-deficient patients, the data to date do not support the notion that rhGH administration to healthy athletes increases muscle strength or aerobic power. Typically administered daily as a subcutaneous injection, rhGH stimulates production of insulin-like growth factor I (IGF-I) through which GH exerts its anabolic effects in the body. Recombinant IGF-I is now commercially available (as somatomedin-1), as well as several low molecular weight, orally active growth hormone secretagogues.

Measurements of bone and collagen metabolism in the face of rhGH administration seem to be the most promising markers for rhGH doping in athletes. Furthermore, IGF-I levels and a number of IGF-I binding proteins may remain persistently elevated after rhGH administration. Changes in the relative concentrations of a number of these markers may also eventually serve as a useful means of indirect detection of rhGH use.

Recent reports have raised the possibility of distinguishing between recombinant and endogenous GH by simultaneous radioimmunoassay of the two GH isoforms (20 and 22 kDa). Endogenous GH is composed of 22 kDa and 20 kDa isoforms while rhGH contains only the 22 kDa isoform. Thus, alterations in the normal 22:20 kDa isoform ratio could be used as a means of detecting exogenous rhGH administration. This may be a powerful direct means of testing for GH doping, but again, due to the short half-lives of the involved peptides, testing would need to be carried out within days of GH use. For now, the study by Longobardi et al raises the most promising possibility for GH doping detection.

Additional Doping Agents and Future Trends in Doping Control in Athletes

Dating back nearly four decades, the Council of Europe in 1963, in response to rising concerns about the use of doping substances for unfair athletic advantage, established a definition for athletic doping practices: "The administering or use of substances in any form alien to the body or of physiological substances in abnormal amounts and with abnormal methods by healthy persons with the exclusive aim of attaining an artificial and unfair increase in performance in competition."

Such doping substances are generally grouped into two major categories: those used acutely for benefit during a competition and those used to enhance the effectiveness of

a training regimen leading up to competition. The use of "traditional" doping agents, such as anabolic steroids and stimulants, has been tempered by their ease of detection in urine via gas chromatography and mass spectrometry. Newer performance-enhancing substances, however, create unique challenges because of the difficulty in detecting them. Newer methods of doping detection often take advantage of unique physiologic or biochemical properties of the involved agents. The following is a brief review of the most common of these newer doping measures and the current trends toward increased detection.

Blood Doping

This is the practice of intravenously infusing autologous (reinfusion of athlete's own blood) or nonautologous blood in order to create supraphysiologic erythrocytosis. The practice dates back to the 1960s, with its most notable incident involving cyclists on the 1984 U.S. Olympic team. Blood doping results in an increase in total aerobic power by increasing the transport of oxygen to working muscles. Evidence would also suggest that not only is the volume of oxygen delivered to the muscle increased by blood doping, but the volume of oxygen used during intense exercise is increased significantly as well. The common practice is to infuse 2-3 units of blood 1-7 days prior to competition. High intensity aerobic sports such as cycling, cross country skiing, and long-distance running are the target sport groups.

Detecting nonautologous (allogeneic) blood depends upon the demonstration of blood group differences between the athlete's own cells and those of the transfused red cells. Autologous doping can be detected by simultaneously measuring the levels of erythropoietin, hemoglobin, bilirubin, and iron. As doping results in elevated hemoglobin levels, the secretion of endogenous erythropoietin displays a compensatory decrease. The retransfused red cells also are fragile and susceptible to hemolysis, resulting in elevations in both bilirubin and iron levels. Although there remain potential errors with this method, it has been found to detect 50% of positive cases and is at present among the best approaches.

Erythropoietin

Erythropoietin is a glycoprotein hormone secreted by renal cells to stimulate erythroid progenitor cells in the bone marrow. Repeated injections of recombinant erythropoietin (EPO) will increase hemoglobin concentration and hematocrit in a dose- and time-dependent fashion. Studies have revealed a significant increase in hemoglobin concentration and up to an 8% increase in maximal aerobic power with as few as six weeks of subcutaneous EPO administration.

Indirect methods of EPO detection center around the body's response to its administration. Reticulocyte counts, hemoglobin, hematocrit, and red blood cell numbers all rise. Then there is a rise in large erythrocytes with low hemoglobin content (hypochromic macrocytes) and an increase in the level of soluble transferrin receptors in plasma. ELISA testing for these transferrin receptors at present is the most reliable, indirect means of screening for doping with EPO.

Direct detection of EPO is at present too costly and laborious to be of practical use. Future methods will likely take advantage of the ability to detect differences between the isoforms of exogenously administered EPO and natural endogenous erythropoietin.

Anabolic/Androgenic Steroids (AAS)

Anabolic steroids and testosterone have been used for athlete doping since the 1950s. They increase muscle mass, strength, speed, and mental aggressiveness. They also decrease catabolism which allows for improved recovery from vigorous training. Because of these properties, their use is greatest among strength athletes in such sports as football, wrestling, powerlifting, sprinting, and field events. All anabolic steroids are structurally derived from testosterone, and those used in doping are generally found as an ester derivative administered in an injectable form. The most common preparations contain testosterone enanthate, cypionate, and propionate. The International Olympic Committee (IOC) formally banned anabolic steroids in 1975 with urine testing programs initiated in 1976. The first widespread testing for anabolic steroids came at the 1983 Pan American games.

Indirect screening for testosterone abuse has relied upon the urinary detection of an increase in the testosterone glucuronide: epitestosterone glucuronide ratio. Exogenously administered testosterone increases the urinary excretion of testosterone but also decreases epitestosterone excretion secondary to negative feedback on the pituitary with resultant decreased epitestosterone production. The normal mean ratio is one. A ratio value of six or greater is considered positive evidence for testosterone doping.

Additional indirect measures that take advantage of the negative feedback effect on endogenous testosterone synthesis are an increased urinary ratio of testosterone: luteinizing hormone (LH) or elevated serum ratio of testosterone: 17a-hydroxyprogesterone. The administration of one or two doses of ketoconazole, which decreases endogenous testosterone production, may also prove useful in evaluating an elevated urinary testosterone/epitestosterone ratio.

Direct measurement of testosterone esters uses serum mass spectrometry and gas chromatography to deter-

mine the 12C:13C isotope ratio of testosterone in urine. Synthetic testosterone has a much higher level of 13C than does endogenous testosterone. Presently considered a confirmatory test for those with elevated urinary testosterone ratios, it could also be used to detect doping with testosterone precursors such as dehydroepiandrosterone (DHEA), androstenedione (Andro), and dihydrotesterone (DHT). Screening for the remainder of the anabolic steroid agents at present is accomplished through the use of high-resolution mass spectrometry, first mandated at the 1996 Atlanta Olympic games.

Future Trends

Future trends in athletic doping will likely include the direct use of IGF-1, insulin, oral growth hormone secretagogues, and red cell substitute oxygen carriers such as stroma-free hemoglobin solutions or perfluorocarbon-based substitutes. Some are being used already to augment sport, with little if any ability to detect their use at present.

The future trends in doping control are in blood sample analysis. This creates a number of logistical and ethical concerns that will need to be resolved before blood testing becomes a standard part of the screening for performance-aiding agents in athletes. An additional technique still in its infancy for doping detection is the use of hair samples. The analysis of chemically-digested hair using gas chromatography and tandem mass spectrometry has promising implications for use in the detection of anabolic steroids and their esters, amphetamines, and corticosteroids. Though far from mainstream utilization at present, these techniques may provide the ability to take a "snapshot" of banned substance use that covers a period of time far exceeding that of today's methods. Much additional study is required, but novel approaches must constantly be sought if the medical community is to keep pace with the ever-advancing scourge of athletic doping activity.

Summary

Physicians who care for athletes must be aware of the increased doping behaviors and must have a working knowledge of the involved agents and their means of detection. Only through the vigilance of sports medicine practitioners and the governing bodies of sport can we hope to preserve the purity of athletic competition. ❖

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