Ergogenic Aids
What Athletes Are Using—and Why

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Athletes at all levels explore ergogenic aids. Testosterone and growth hormone are still abused and difficult to detect. Single doses of albuterol or salmeterol do not seem ergogenic, but questions remain about prolonged dosing and about other beta-agonists. Caffeine can be ergogenic for prolonged or brief exertion. Creatine supplementation is legal and in vogue among strength and power athletes. Not all studies agree, but creatine seems ergogenic for repeated brief bouts of intense exercise. Ergogenic aids pose vexing questions for athletes, physicians, and society.

The Olympic motto is Citius, Altius, Fortius—swifter, higher, stronger. Maybe, at least in the strength and power sports, we should add fraudator, the Latin word for deceiver. In spite of increasingly sophisticated drug testing at the Olympics, suspicions of the use of illegal ergogenic aids are stronger than ever. Proof of cheating is often lacking, but by all appearances, the suspicions are well-founded. In a never-ending game of cat and mouse, athletes who cheat seem always one step ahead of those who try to catch them.

Attempts to enhance athletic performance are not new. The Olympic Games date back 2,700 years. Continued

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years, so trickery in sport likely dates back at least that long. Ancient Greek Olympians ate mush-rooms to win. Aztec athletes ate the human heart. In the late 1800s, European cyclists took heroin, cocaine "speedballs," and ether-soaked sugar tablets. The winner of the 1904 Olympic marathon, Tom Hicks, took strychnine and brandy during the race. The winner of the 1920 Olympic 100-m dash, Charlie Paddock, drank sherry with raw egg before the race. In the 1960 Olympics, Danish cyclist Knut Jensen died in the road race from taking amphetamine. In the 1967 Tour de France, famed British cyclist Tommy Simpson died, also from amphetamine.1

Deaths like Simpson’s and other drug-related sports incidents led the International Olympic Committee to begin Olympic drug testing for stimulants in 1968.2 Since then, Olympic testing has expanded and struggled to stem a rising tide of drug use. We have witnessed waves of use that included stimulants, anabolic steroids, beta-agonists, hormones, and now the rumored testosterone patches. We have seen the diluting and “masking” of drugs. Among athletes caught for drug use, we have seen creative excuses and maneuvers, including claims of sabotage. And athletes continue to experiment with legal drugs and nutrients, such as asthma medications, caffeine, and creatine.

Drug use, though, is not limited to Olympic or elite athletes. Many adolescent athletes—boys more than girls—try anabolic steroids.3 A recent study4 explores the efficacy of a “testosterone boost” for normal young men who stay fit by lifting weights. Another5 probes the potential of growth hormone as a “rejuvenator” for older men who want to stay active. Athletes at all levels—some asthmatic and some not—want to know if asthma medications improve performance. Caffeine is widely used as an ergogenic by community runners, cyclists, and triathletes. Judging from sports-related magazines and newsletters, creatine is popular among colle-
giate and community strength and power athletes. Given these trends, a review of the history and state of the art in ergogenics is in order.

Anabolic Steroids
In the 1956 World Games in Moscow, US physi-}

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less fat, narrower hips, and higher hematocrits. Anabolic steroids turned East German female swimmers into "lumbering beauties" who won Olympic medals during the 1970s and 1980s (Sports Illustrated, October 16, 1985;84; Time, August 5, 1996:84). China followed suit. Between 1982 and 1994, Chinese women came out of obscurity to set world records in swimming and running. Then officials sprang urine tests on the athletes, and from 1993 to 1994, found that 11 Chinese stars, including seven female swimmers, were on dihydrotestosterone (Sports Illustrated, October 16, 1995;84; Time, August 5, 1996:84). In 1996, rumors suggested that some Chinese athletes used testosterone patches in training. Experts say that the amounts of testosterone (as from skin patches) are difficult to detect but can measurably boost strength and speed in women (Time, August 5, 1996:84).

Experts also think that some male Olympians are using testosterone^ but cannot accurately determine the extent because of imprecise testing. The new high-resolution mass spectrometer first used at the 1996 Olympics is highly sensitive to traces of most anabolic steroids, but cannot tell synthetic testosterone from the natural kind. Because natural testosterone levels vary widely in men, high readings alone prove little, so the ratio of testosterone to a key metabolite, epitestosterone (7E7 ratio), is used to determine a positive test. This ratio is about 1 in most men, rarely greater than 3 (recent alcohol use may raise it to 2 to 3), and very rarely greater than 6. (The blanket use of this number is complicated by the fact that 1 in 2,000 men is apparently deficient in an enzyme that produces epitestosterone, and this deficiency could abnormally raise the 7E7 ratio.) Olympic testers call a test positive only if the ratio is greater than 6. This offers room to dope with testosterone up to the cutoff of 6, or to "raise the denominator" by taking epitestosterone, as some male athletes may be doing. Olympic officials soon hope to have a test that detects synthetic testosterone, which changes carbon isotope ratios in urine. The test will measure the ratio of carbon 13 to carbon 12 in urinary testosterone.

Human Growth Hormone

The situation of recombinant human growth hormone (hGH) seems similar to that of anabolic steroids in the early years of their use. Scientists report that hGH may not increase effective strength or performance, but some athletes, convinced it works, use it. For example, two recent studies suggest no performance benefit from hGH. When 16 untrained men underwent a 12-week muscle-building program, receiving either hGH or placebo, the hGH increased fat-free mass and total body water, but not muscle protein synthesis, muscle size, or strength. With hGH use, insulin action was slightly impaired, and two of the men contracted carpal tunnel syndrome. When seven trained weight lifters were given hGH for 2 weeks as they continued training, the hGH did not increase the rate of muscle protein synthesis or reduce the rate of whole-body protein breakdown.

The early interest in hGH as a "rejuvenator" is fading. Now a 6-month, controlled, randomized, double-blind study of hGH in healthy older men (mean age 75 years) reports slight improvements in body composition (decrease in fat mass, increase in lean mass), but no increase in strength, endurance, or cognitive function.

No test can now detect abuse of hGH, but Olympic scientists vow to perfect one by the Sydney Olympics in 2000. This test will focus on blood markers (hGH itself and insulin-like growth-factor-binding proteins), and so calls for a change in Olympic policy which now permits testing only of urine.

Clenbuterol and Other Beta2 Agonists

Beta2 agonists (clenbuterol, turbutelene, albuterol, salmeterol) are not anabolic steroids but are potentially anabolic, and so their systemic use is banned. Yet in the 1982 Olympics, two athletes tested positive for clenbuterol.

Studies show that clenbuterol affects animals in different ways. It increases muscle mass and cuts fat in livestock and in laboratory ani-
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mals, mainly from a selective hypertrophy of skeletal muscles. It can retard muscle wasting in denervated rodents. Research also suggests that, although clenbuterol increases muscle mass in rodents, it decreases the oxidative potential of those same muscles, perhaps by decreasing the expression of the beta2 adrenergic receptors or by preferentially increasing nonmitochondrial proteins. As a result, clenbuterol decreases endurance running in rodents. This decrease in performance, however, can be offset, in mice at least, by an exercise regimen.11

No human studies are available on whether clenbuterol can increase strength or power, yet some athletes are using clenbuterol without proof of its effectiveness or safety. Strength athletes use it along with steroids, or after they stop steroids, to retard loss of muscle and "strip" fat to "define" muscles. Some athletes note troubling tachycardia while on clenbuterol; others have stopped taking it because of tremor. Two European bodybuilders on clenbuterol died suddenly, but it's unclear whether the drug contributed to their deaths.12

A similar quandary exists for albuterol (salbutamol), legal only in inhaled form for exercise-induced asthma. In a 3-week study13 of a slow-release oral form of albuterol, it seemed to increase, though inconsistently, the voluntary strength of young men. A study14 in which healthy young men took oral albuterol (4 mg four times daily for 6 weeks) suggests that resistance exercise may augment any strength gain from albuterol.14 In two other studies,15 however, long-acting inhaled salmeterol had no ergogenic effect on maximal or endurance cycling in asthmatic men, or on anaerobic cycling or peak leg torque in nonasthmatic men. For now, all long-acting beta2 agonists are banned, but some authors are calling for legalizing salmeterol for asthmatic athletes.16

Whether the legal inhaled form of albuterol is ergogenic remains controversial. As reviewed in four recent studies,17 the weight of evidence suggests that single doses of albuterol are not ergogenic for asthmatic or nonasthmatic athletes. Two early studies in cyclists suggested that albuterol was ergogenic, but their design has been faulted, and six other studies (three in cyclists, two in runners, one in power athletes) found no immediate ergogenic effect for albuterol on either power or endurance. Researchers do caution, however, that albuterol is conceivably ergogenic at higher or prolonged dosage.18

In spite of the confusing research picture regarding albuterol, the peculiar epidemic of "asthma" among elite athletes suggests that they think
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albuterol is ergogenic. The declared prevalence of exercise-induced asthma (EIA) among American Olympians shot up from just over 10% at the 1984 Summer Games to nearly 60% at the 1994 Winter Games (P.Z. Pearce, MD, personal communication, 1994). Though some of this increase could be ascribed to the contribution of cold weather to EIA, the size of the increase suggests that more and more Olympians want to be "approved" to use albuterol in order to level the playing field.

Caffeine

Caffeine is a legal drug (to a urine level of 12 µg/mL) that can be ergogenic for both elite and recreational athletes. Recent controlled studies find that moderate doses of caffeine (3 to 6 mg/kg) ingested 1 hour before exercise enhance endurance performance at legal urine levels. In one study of trained runners, a high caffeine dose (9 mg/kg) before "race-pace" exercise increased endurance running time and continued
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cycling time an astonishing 44% and 51%, respectively. How caffeine does this is unclear, but a metabolic action is most likely involved, in that caffeine increases plasma free fatty acid levels and muscle triglyceride use, while sparing muscle glycogen use early in exercise. In addition, increases in plasma epinephrine usually occur, but are not essential to the endurance enhancing effect of caffeine.

Recent research suggests caffeine is also ergogenic for exercise lasting 20 minutes or less. Caffeine can enhance performance in a 20-minute swim, a 100-m swim trial, a 1500-m treadmill run, and brief bursts of all-out cycling. Any ergogenic effect in these efforts is surely not from muscle glycogen sparing, because the exercise is too brief. Rather, it probably stems from an effect on the brain (decreasing perceived exertion or increasing motor-unit recruitment) or from a direct effect on skeletal muscle.

The ergogenic effects of caffeine vary greatly, but are most predictable in trained athletes who habitually use caffeine. Few studies, however, have been done in the field, so the extent of caffeine’s ergogenic effects during competition remains unclear. In a recent controlled field study, caffeine did not improve performance in a 21-km road race in hot, humid conditions.

Creatine

Creatine, a natural substance found in raw meat and fish, locates in muscles and is critical for high-intensity muscle contractions. Creatine supplementation, a legal practice, was first used by British sprinters and hurdlers in the 1992 Olympics. Current reports in sports-related newsletters affirm that the use of creatine is widespread among elite and collegiate athletes, including weight lifters, power athletes, sprinters, and football players. One report states, “It is not unusual for trainers at almost every level to keep creatine in stock and dispense it to athletes.”

Creatine binds phosphate to form creatine phosphate. During brief, intense, anaerobic actions, like sprinting, jumping, or weight lifting, creatine phosphate regenerates adenosine triphosphate (ATP) to provide the energy necessary for muscle contractions. The aim of supplemental creatine is to increase resting levels of creatine phosphate so as to regenerate more ATP and sustain a high power output, thus delaying fatigue and improving performance. Creatine also helps buffer the lactic acid that accumulates in muscles during intense exercise.

The estimated daily need for creatine in humans is about 2 g, whereas the daily intake from meat or fish is about 1 g in the average American diet. The body makes up the deficit by producing creatine in the liver, kidney, and pancreas, using as precursors glycine and arginine. When dietary supply is low, the body steps up its production of creatine, but may not completely compensate, especially among vegetarians, who have a reduced body creatine pool.

Creatine stores vary greatly among individuals, and apart from diet, the reasons are unclear. Athletes with low stores might be most apt to benefit from supplementation. Muscle creatine levels increase an average of 20% after 6 days of supplementing at 20 g/day (“rapid creatine loading”). These higher levels can be maintained by ingesting 2 g/day thereafter. A similar, but slower, 20% rise in muscle creatine levels occurs by ingesting 3 g/day for 1 month, the “no-load” method.

Creatine is available commercially, but is classified as a nutritional supplement, not a drug, so its purity is not guaranteed. Twenty grams per day is a high dosage, since 20 g is the amount in 10 lb of raw steak. Yet other than a small weight gain (perhaps from a gain in muscle water that accompanies the creatine), there seem to be few short-term side effects, although some observers say high doses promote dehydration and possibly muscle cramping. Creatine is degraded to creatinine and eliminated in the urine. Questions remain about the potential long-term effects on muscles, specifically the heart, and on the kidneys.

Growing evidence suggests that creatine can improve performance in repeated bouts of all-out strength work or sprinting—whether pedaling or running. If further studies confirm this research, it has practical implications for some team sports and for many track and field events.
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events. Not all studies, however, are positive. A study of untrained men, for example, shows no ergogenic effect in single 15-second bouts of cycle sprinting. This "negative" study, however, does not refute the "positive" studies, because the trend of findings in this area is that total work improves not in the first bout of sprinting, but in the later bouts of a series of consecutive efforts.

Other negative studies are appearing. In one using videotaping, creatine had no effect on the runner's speed at any point during a 60-m sprint. In another study, creatine did not improve sprint performance in competitive swimmers. Finally, creatine supplementation does not—nor would it be expected to—benefit aero-

The Larger Issue

It is a sad commentary on human nature and society that so much effort is spent trying to de-

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test and deter drug abuse among athletes. But a big-money, winning-is-everything mentality grips much of our social life. Since sport mirrors society, the field of competition is a stage where athletes enact social values. And if winning is every-

The problem is not just how to keep young, sometimes impulsive athletes alive and well while preserving their liberty to do what they please with their bodies. The larger problem for the athlete and society is this: When one athlete decides to use drugs to win, that action presents a choice—make decisions as they try to do what is best for them or take the rules as society makes them. The athlete and society is this: When one athlete decides to use drugs to win, that action presents a choice—make decisions as they try to do what is best for them or take the rules as society makes them.
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