



Excerpt From  
**Sports Medicine Concepts, Inc.**

The Athletic Training Room Guide to Ergogenic Aids in Athletics:  
By Michael Cendoma, MS, ATC.

### **Introduction**

Ergogenic aids are dietary supplements or drug agents used by athletes to enhance performance. As athletes become bigger, stronger, and faster, the difference between winning and losing is often measured in milliseconds or inches. Such competition drives many athletes to look to ergogenic aids, ranging from anabolic steroids to plant roots to gain an edge on their rivals. Many of the performance enhancing agents used by athletes are regulated by certain sports organizations. However, regulation varies widely as agents banned by the International Olympic Committee (IOC) and the National Collegiate Athletic Association (NCAA) differ from those banned by major league baseball, football, or track and field, etc. A review of lists of such banned agents reveals that many are readily available on the shelves of pharmacies and health food stores while others are only available by prescription, finding their way into locker rooms illegally. Be it legal or illegal, banned or not banned, performance-enhancing agents tempt any athlete with the promise of a competitive edge. The result is a \$3 billion per year and growing industry.

Most ergogenic aids are legal for sale, but some are regulated regarding their sale and distribution. Accordingly, prescription drugs require a prescription to be sold. Nonprescription drugs have been determined to be safe and effective by the Food and Drug Administration (FDA); these drugs are available without a prescription, have been determined to be safe and effective by the FDA, and must be labeled in accordance with FDA regulations. A third category, referred to as “dietary supplements”, has spurred much debate as these agents are not subject to the same scientific scrutiny and are not required to demonstrate any scientific effectiveness pertaining to the claims made by manufacturers. Additionally, the safety of these products is regulated quite differently. Rather than manufacturers having to prove the safety and effectiveness to the satisfaction of the FDA before being permitted to sell the agent, the FDA must prove that the product is unsafe before requiring the manufacturer to remove it from store shelves. Finally, manufacturers of dietary supplements are not held accountable for the quality or quantity of the ingredients in their products. In all, consumers are not protected from unfounded claims or dangerous side effects possibly associated with dietary supplements and other ergogenic aids. It is therefore the role of the sports health care professional to help guide athletes in making informed and educated decisions regarding use of performance enhancing agents.

This program has been designed to provide information to sports health care professionals in a clear and concise manner, such that it can be readily passed on to athletes. This program outlines three popular performance-enhancing agents used in athletics today, including anabolic-androgenic steroids, creatine and caffeine. This review centers specifically on the effectiveness, physiological mechanisms, dosing, adverse effects, and possible drug interactions.

**GO TO TEST**

## **Anabolic-Androgenic Steroids Androgens, 17-beta hydroxylated steroids, 19-nortestosterone derivatives (“cutting steroids”)**

### *Brief History*

The use of male sex hormones, or androgens, have been widely used and abused by athletes due to their ability to increase physiological precursors associated with improved athletic performance; the most common steroid being testosterone in a natural or synthetic form. Performance benefits have been observed most in women, and in men with below normal testosterone secretions<sup>8</sup>. Dianabol was the first anabolic steroid introduced in the United States. Dr. John Ziegler developed the drug in response to testosterone use by Soviet athletes during the 1956 World Games in Moscow. Soon after the introduction of Dianabol other anabolic steroids were introduced and use of these agents soared as athletes grew bigger, stronger, and faster with their use. However, serious side effects, including unhealthy cholesterol profiles, heart attack, stroke, liver tumors, prostate problems, and mood changes were tied to use of these agents. Early in the battle over use of anabolic steroids scientists were quickly discredited when arguing that anabolic steroids were not effective in enhancing performance. Evidence soon began to mount that anabolic steroids did in fact improve strength in athletes who trained aggressively while using them<sup>5</sup>.

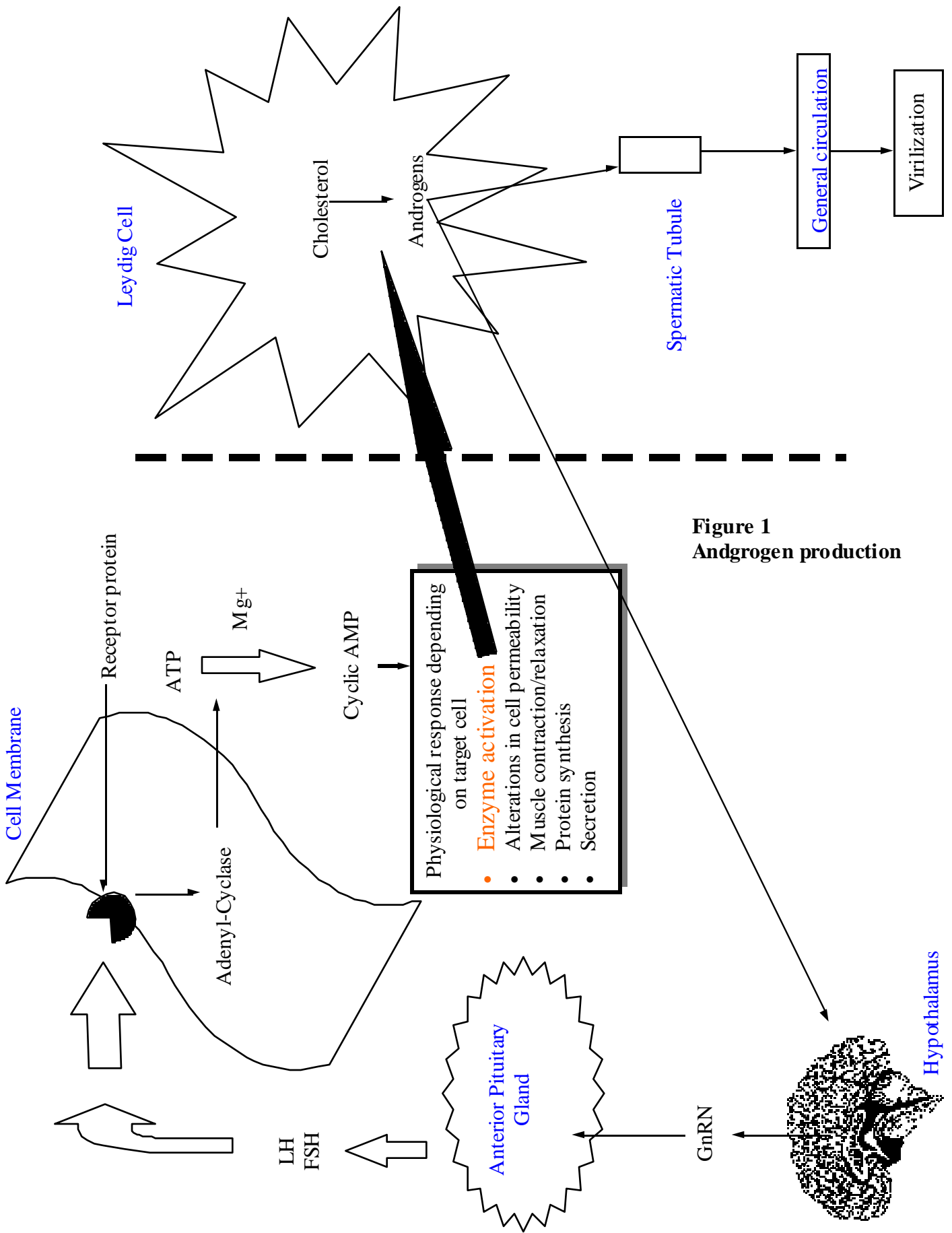
Anabolic-androgen steroids are a Drug Enforcement Agency (DEA) schedule CIII drug, requiring a prescription due to their potential for abuse<sup>4</sup>. Anabolic-androgen steroids are banned by the IOC and the NCAA<sup>3,7</sup>.

### *Effectiveness*

Today athletes continue to use anabolic-androgenic steroids to increase size and strength, decreasing recovery time, and for increasing aggressiveness. Clinical research suggests that anabolic steroids are an effective medium for increasing size, muscle mass, and strength, through stimulation of proteins in organs and tissues particularly responsible for the development of male sexual characteristics. These characteristics include effects on protein formation and muscle development, bone growth and calcium retention, and red blood cells that are thought to provide a boost to athletic performance. The extent to which steroids are effective in boosting athletic performance may be linked to amount of training, dosing, and diet<sup>1,6,8</sup>.

### *Physiological Mechanisms*

Naturally occurring testosterone results from an initial release of gonadotropin releasing hormone (GnRH) from the hypothalamus in the brain. This results in release of luteinizing hormone (LH) and follicle stimulating hormone (FSH) from the pituitary gland. When these hormones reach cell membranes they attach to a receptor and initiate the enzyme adenyl cyclase. Inside the cell adenyl cyclase results in production of cyclic AMP, which then results in a number of physiological responses, including enzyme activation, alterations in cell permeability, muscle contraction or relaxation, protein synthesis, and secretion. The physiological response initiated depends upon the target cell (Figure 1). In the Leydig cell the activation of enzymes results in the transformation of cholesterol to androgens. These then travel through the spermatid tubule where they increase spermatogenesis, then on to the circulation where they facilitate the development of male sex characteristic. The increased production of androgens also acts within a feedback loop to continually regulate the release of GnRH from the hypothalamus<sup>8,10</sup>.



**Figure 1**  
**Androgen production**

Testosterone released in the process outlined above enters the cell membranes of skeletal muscle cells within minutes of release and is transformed to dihydrotestosterone. This compound then combines with a cytoplasmic receptor protein. The new compound travels to the cell nucleus where it combines with a nuclear protein and increases levels of messenger RNA. In the cell's ribosome this messenger RNA initiates RNA polymerase to increase protein synthesis (See Figure 2). This increased protein synthesis is the basis behind increased muscle mass and strength associated with steroid use as injected or ingested artificial androgens and testosterone act similarly to naturally occurring hormones<sup>8</sup>.

### *Dosing*

Dosages used by athletes for performance enhance can be 10 to 100 or up to 1000 times the accepted therapeutic use of the drugs. These agents are often taken in oral and injectable forms simultaneously, referred to as "stacking". Athletes may also take a number of different agents in combination and in accordance with an overlapping schedule to avoid developing a tolerance to the drugs, referred to as "cycling". Generally, steroids are used over a 6-12 week period, often during the athlete's off-season to avoid drug test detection.

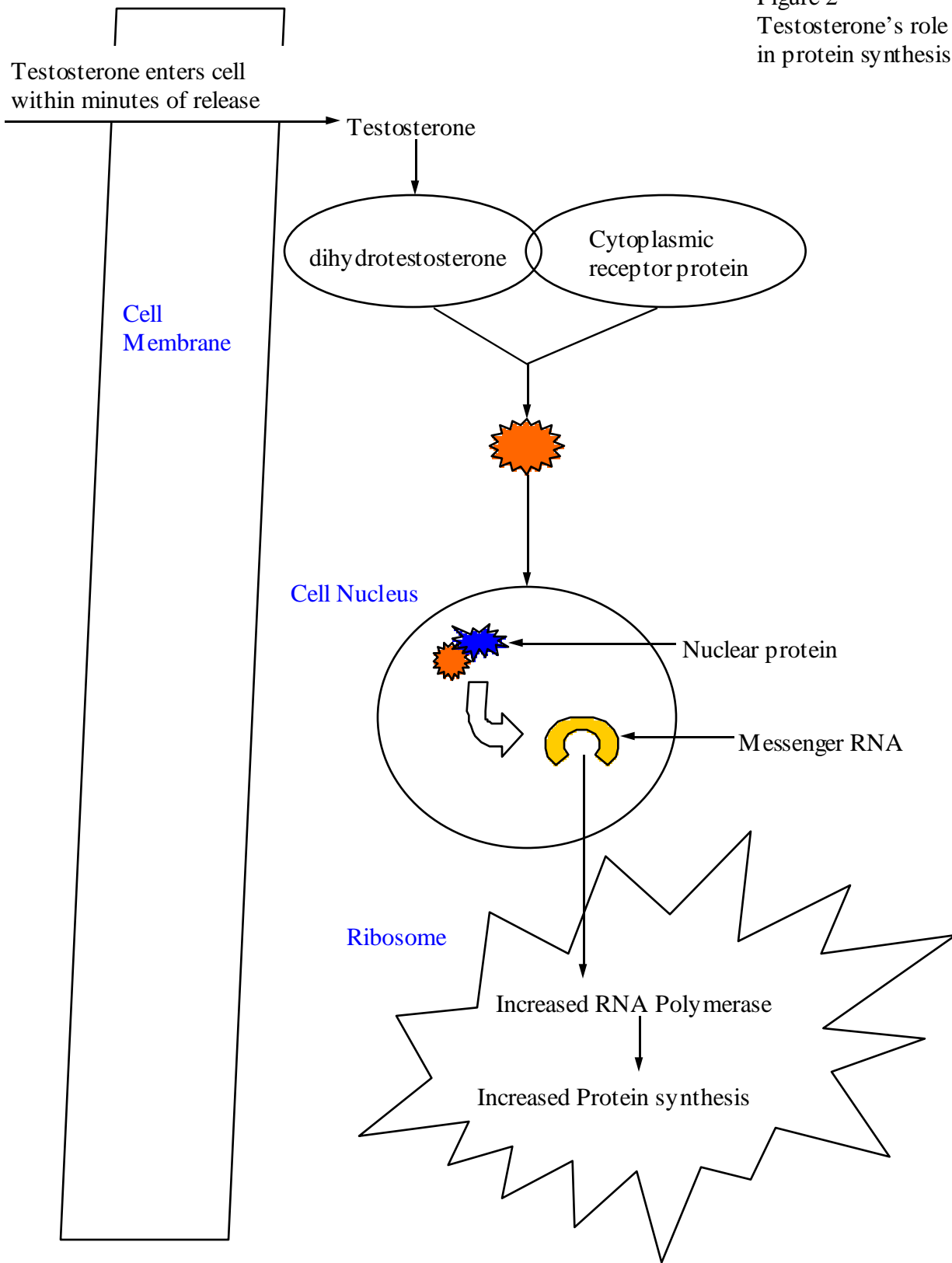
### *Adverse Effects*

Adverse side effects of steroid use are well documented including: 1) hypertension and unhealthy cholesterol profiles leading to increased risk of heart attack and stroke, 2) abnormal liver function, increased liver bleeding, and cancer, 3) testicular atrophy, impotence and enlarged breasts in males, 4) decreased breast size, irregular menstrual cycles, fluid retention, and virilization in females, 5) psychological effects including mania, depression, aggressiveness, and hostility<sup>2,8,9</sup>. Both performance enhancing and adverse effects appear to be more pronounced in women as they are not adapt to the male sex hormones<sup>8</sup>.

### *Possible Drug Interactions*

The use of anabolic-androgenic steroid agents is of particular concern for diabetics and individuals taking oral anticoagulants. These agents have been found to effect glucose metabolism such that diabetics may require additional insulin. A number of anabolic-androgenic steroids may also facilitate the action of oral anticoagulants, thus requiring a reduction in the anticoagulant dosage<sup>4</sup>.

Figure 2  
Testosterone's role  
in protein synthesis



## Creatine

### *Brief History*

Creatine is a natural substance found in raw meat and fish. The body also synthesizes some creatine in the liver, kidney, and pancreas. British sprinters and hurdlers first used creatine as a supplement during the 1992 Olympics. Since becoming commercially available as creatine monohydrate in 1993, creatine supplementation has become widespread, particularly among weight lifters, power athletes, sprinters, and football players<sup>1,10</sup>. The result of widespread use throughout the NCAA and Olympic athletes has had a filtering down effect of sorts as many high school and younger athletes also use creatine in an attempt to boost performance. Presently, creatine is a legal substance under both NCAA and IOC regulations<sup>14</sup>. Creatine supplements are widely available and heavily marketed through health food stores, health clubs, and pharmacies and are popular among elite, high school, and recreational athletes alike. Therefore, sports health care professionals must have a thorough knowledge of its effects in order to be able to educate athletes regarding its use, possible benefits, and potential adverse effects.

### *Effectiveness*

Creatine may be beneficial to athletes engaging in anaerobic activities, but has not been shown to be of benefit during aerobic activities such as running, cycling, and swimming; where it may actually facilitate dehydration. However, creatine may be of benefit in aerobic activities requiring intermittent bouts or short bursts of high-intensity anaerobic activity<sup>17,18,23</sup>. Creatine has also been shown to buffer lactic-acid build up, thus possibly delaying fatigue associated with increased lactic acid production during aerobic activities<sup>10</sup>. Some questions arise regarding creatine's effectiveness in highly-trained athletes where it is theorized that muscle creatine stores may already be at full capacity<sup>17,18</sup>.

There is evidence that creatine may enhance muscle size giving rise to its popularity among body builders. However, this was shown in research involving subjects with neuromuscular disease and may not carry over to benefit athletes<sup>22</sup>.

### *Physiological Mechanisms*

Energy for exercise is provided via three primary metabolic systems; 1) phosphagen, 2) glycolysis, and 3) aerobic. The physiological bases of the benefits of creatine supplementation lie in the phosphagen system.

During this process energy is provided to working musculature by breaking phosphate bonds associated with adenosine tri-phosphate (ATP) molecules stored within muscle cells. Approximately 12,000 calories are stored in each phosphate bond. When a phosphate bond is broken, this energy becomes available for muscle contraction and ATP is transformed to adenosine di-phosphate (ADP). In some cases the remaining phosphate bond associated with ADP is broken to release its energy, thus forming adenosine mono-phosphate (AMP).

Creatine is normally obtained from dietary sources, including fish and red meat. Dietary sources provide approximately 1-2 g of creatine per day. In addition, another 1-2 g per day is synthesized from amino acids, arginine, glycine, and methionine in the liver, kidney, and pancreas. Dietary and synthesized creatine is primarily stored in skeletal muscle as free creatine,

but a vast percentage of creatine is converted to and stored as creatine-phosphate (CP). As CP creatine can then serve as a phosphate donor to either AMP or ADP, reconstituting ADP and ATP respectively. CP and free creatine exist in a reversible equilibrium in skeletal muscle. During bouts of intense exercise the tendency is to transform stored creatine to CP for use in rapidly replenishing ATP stores for anaerobic energy. Once CP has aided in the reformulation of ATP it is transformed to creatinine in the kidney and excreted at a rate of 1-2 g per day<sup>1,10,14,21</sup> (Figure 3).

Stored creatine levels vary greatly among individuals. Studies suggest an average creatine concentration of 90-160mmol/kg-dm. Those with lower stored creatine concentrations, such as vegetarians, may benefit most from supplementation as supplementation has been shown to increase CP stores from 6-16%<sup>1,10</sup>.

Creatine's primary ergogenic effect has been identified as contributing to energy metabolism via the phosphagen system. However, athletes may also benefit from other possible actions associated with creatine. Creatine is not generally associated with enhancing aerobic performance, but, creatine has been shown to buffer and reduce lactic acid produced during glycolysis<sup>10,14,21</sup>. Thus, there could be an indirect effect on aerobic activity by decreasing the detrimental effects of lactic acid on performance.

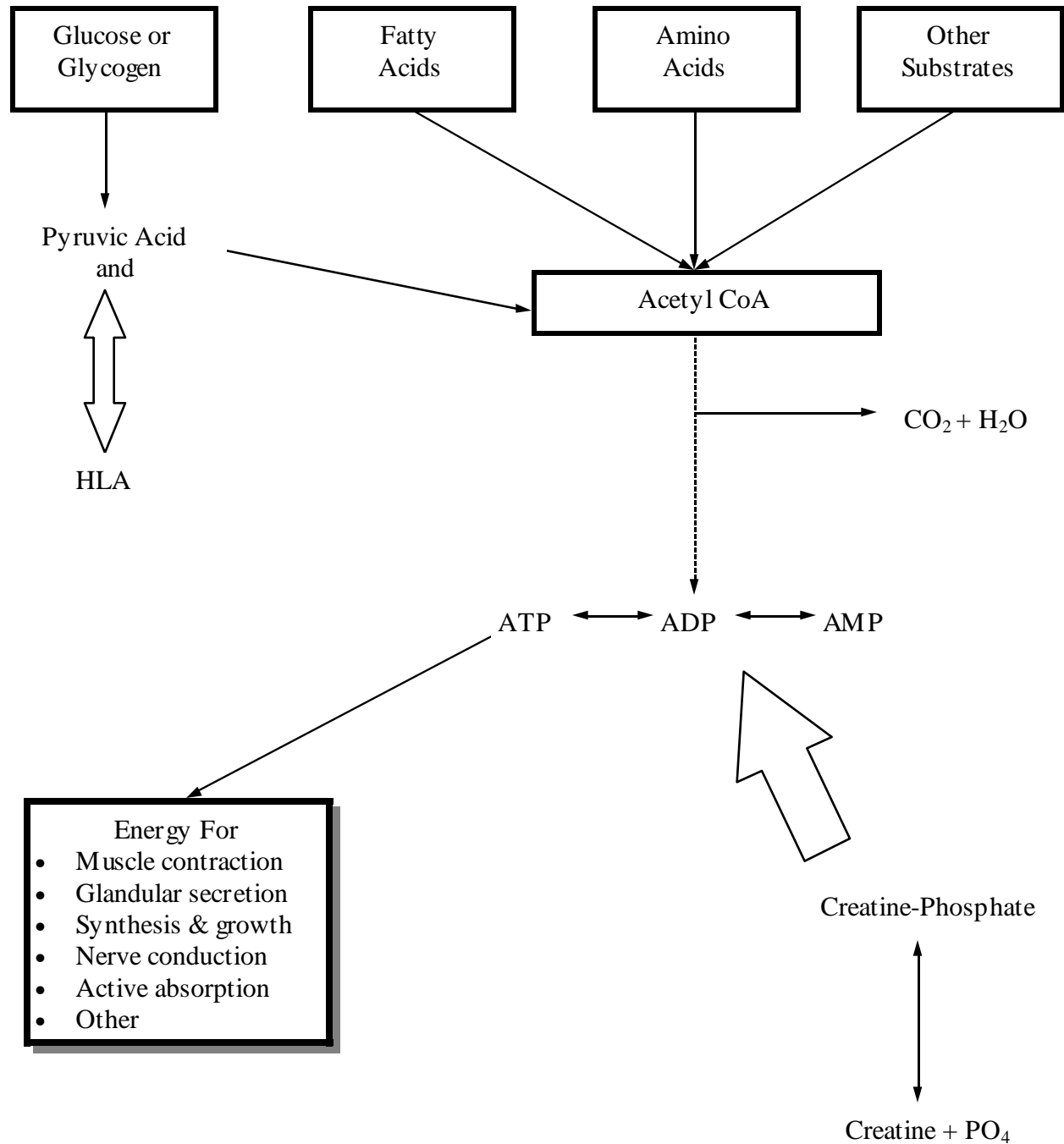
Creatine has become popular among bodybuilders due to evidence linking supplemental use to weight gain and muscle growth<sup>2,7,8,9,11,18,27</sup>. Weight gain associated with creatine supplementation may be on the order of 0.5 to 1.6 kg during the initial 5-day loading phase. This initial weight gain is due primarily to water retention. Some evidence suggests that with prolonged creatine supplementation weight gain may result from actual muscle growth due to increased protein synthesis. However, initial perception of muscle growth with creatine supplementation is most likely due to increased muscle volume associated with water uptake by skeletal muscle cells to maintain equilibrium.

Creatine and CP exist within skeletal muscle cells in concentrations of 9 and 45mOsmol/l of water, respectively. There is a great tendency to maintain cell equilibrium, therefore, as skeletal muscle cell creatine and CP concentrations rise, a cell will rapidly draw in extracellular water via osmosis in order to maintain equilibrium. The increased water uptake increases muscle volume and may give the appearance of increased muscle mass. This process could facilitate dehydration, particularly among endurance athletes, as water is drawn in from extracellular fluids, including plasma and interstitial fluid. Water exchange to maintain equilibrium within skeletal muscle cells may take a few seconds to a few minutes while water consumed during exercise may not be available to help maintain overall equilibrium for up to 30 minutes, as it first needs to clear the gut before moving to the blood and tissues<sup>21</sup>. Thus, athletes should be advised to increase water intake when creatine supplements are used.

### *Dosing*

Evidence suggests that the potential ergogenic effects associated with creatine supplementation are obtained with an initial loading dose of 20-30g/day or 0.3g/kg of body weight (bw) for 5 days followed by regular maintenance doses of 2g/day or 0.03g/kg bw<sup>3,11,12,13</sup>. Some research has found an initial loading dose outline above for 2 days is equally effective in increasing mus-

Figure 3  
The Creatine-Phosphate Energy System



cle creatine and CP stores<sup>25</sup>. Ingestion of creatine supplements with a carbohydrate beverage may increase creatine uptake and muscle creatine concentrations<sup>14</sup>.

Skeletal muscle has a creatine capacity of 150-160mmol/kg-dm, a concentration obtainable with the loading and maintenance doses outline above. Exceeding recommended doses to gain further or quicker benefit is futile as excess creatine is simply excreted by the kidneys. With cessation of supplemental creatine intake baseline concentrations will return after 28 days<sup>5,12</sup>.

### *Adverse Effects*

The FDA has logged 32 complaints, ranging from seizure, cardiac arrhythmia, cardiomyopathy, deep vein thrombosis, rhabdomyolysis, and death, to use of dietary creatine supplementation<sup>24</sup>. However, the Centers for Disease Control (CDC) have yet to be able to find a scientific link between reported complaints and creatine supplement use. Thus, adverse effects resulting from creatine supplementation remain anecdotal; though there does appear to be consistencies that may be significant.

Common complaints from creatine supplement use include increased muscle cramping, gastrointestinal pain, and diarrhea. Dehydration may also be reported, particularly among endurance athletes; and for some, associated weight gain may adversely effect performance<sup>14,19,25</sup>.

There are also a number of unstudied concerns regarding possible side effects that have yet to come to light, including possible renal dysfunction resulting from a 90-fold increase in excretion rates; this does not appear to be harmful with short-term supplement use. Other areas of concern include: potential adverse effects of creatine supplementation on the heart, brain, and testes, where creatine is naturally found; possible irreversible suppression of natural synthesis of creatine; and possible adverse effects on sperm metabolism<sup>13,14,25</sup>.

### *Possible Drug Interactions*

Though there are no known drug interactions, there are a number of conditions that should lead an individual to seek the advice of a sports medicine professional before initiating use of creatine supplementation. These include hypertension, kidney disease, and gastrointestinal disorders.

### *Comments*

There is mounting evidence suggesting creatine supplementation has little, if any, ergogenic effects; and, anecdotal reports continue to suggest that many, as of yet, scientifically unproved adverse short- and long-term effects will come to light. Like many dietary supplements and ergogenic aids creatine demonstrated positive effects in a number of specific laboratory settings under specific control, such as one-time events. These results were often observed using a special population of subjects, including muscular dystrophy patients and vegetarians<sup>14, 22</sup>. Thus, questions remain as to how these over-generalized results actually reflect outcomes in athletics.

Juan (1999) attributes conflicting results and misconceptions concerning creatine to a number of scientific design flaws, including lack of crossover design, subject variability (both outline above), and author bias. Simply put, author bias results when the author of a scientific investigation puts a certain spin on outcomes. This spin may indicate a more favorable outcome than is actually reflected in the data.

In addition to possible investigative design flaws, there appears to be a very strong placebo effect associated with creatine supplementation<sup>14</sup>. For example, as outline previously, an athlete may experience weight gain 0.5 to 1.6 kg in the initial 5-day loading dose phase. This may be perceived as muscle mass when it is most likely due to associated water retention, as it is physiologically impossible to add muscle mass within this time frame. The increased weight gain may be perceived as increased muscle mass and accompanying strength. Under these conditions of looking and feeling stronger the athlete may be motivated to work harder, lift more, or run faster without any physiological adaptations having taken place.

The placebo effect is likely responsible for much of creatine's popularity, particularly among impressionable adolescents. Behind much of the placebo effect may also be the marketing and advertising efforts of manufacturers whose claims may be suspect and are not scientifically scrutinized by the FDA. Regardless, creatine supplements are popular and will likely remain so. Therefore, sports health care professionals must be prepared to offer legitimate information pertaining to the positive and negative aspects of its use as an ergogenic aid.

Advice:

1. Creatine supplementation may or may not enhance performance
2. Athlete's should begin with a 2-5 day loading dose of 20-30g/day or 0.3g/kg bw followed by a 2g/day or 0.03g/kg bw maintenance phase. Intake above and beyond these dosages will only be excreted.
3. Weight gain is to be expected and may be due to water retention. This may adversely affect performance.
4. The FDA does not require manufacturers to substantiate their claims regarding creatine. Therefore, the claims made may not be scientifically proven and the ingredients are not held to any standards.
5. Creatine supplements should be taken at the athlete's own risk as there are a number of potentially serious adverse effects and the long- and short-term effects are not fully understood.
6. Water consumption should be increased while taking creatine supplements.

## Caffeine

### *Brief History*

Caffeine is an alkaloid substance in the methylxanthine drug class. This drug class is known to have a number of pharmacological properties, including relaxation of smooth and bronchial muscle, stimulation of the central nervous system and cardiac muscle, and diuretic properties. Caffeine is used by some athletes to improve performance and mental concentration during both anaerobic and aerobic activities

### *Effectiveness*

Studies indicate caffeine may be responsible for increased physical performance and reduced perceived exertion during a wide array of activities. Caffeine appears to be most effective in enhancing prolonged endurance exercise and during short-term high-intensity exercise lasting approximately 5 minutes<sup>4,5,7</sup>. The benefit of caffeine relating to anaerobic events is questionable and less convincing.

The effects of caffeine vary greatly in individuals due to differing tolerances for the drug. Ergogenic benefits appear most predictable in trained athletes who are habitual users of caffeine<sup>1,2</sup>. Some question the benefits of caffeine as an ergogenic aid as results have been demonstrated during strict lab settings and thus do not take into consideration the possible diminished role caffeine may have during actual competition, when epinephrine levels rise in response to increased stress. Many feel the performance benefits of the epinephrine during actual competition would significantly outweigh any effects of caffeine<sup>7</sup>.

### *Physiological Mechanisms*

Caffeine is in the drug class methylxanthine, which are generally known to result in relaxation of smooth and bronchial muscles, stimulate the central nervous system and cardiac muscle, and act as a diuretic<sup>6</sup>. Caffeine is also believed to increase plasma fatty acid (FA) and triglyceride concentrations, decrease perceived exertion, and increase motor unit recruitment<sup>2</sup>.

During prolonged endurance exercise caffeine may benefit athletes via a glycogen sparing effect. Caffeine's actions involving increasing plasma FA and triglycerides results in mobilization of fat which can be used for use as energy, diminishing the demand on valuable muscle glycogen stores<sup>2,5,6</sup>. During exercise lasting 20 minutes or less glycogen is not a limiting factor, thus glycogen sparing cannot be an ergogenic benefit. These athletes may benefit from decreased perceived exertion, resulting in increased mental strength and concentration, and increased stimulation of the CNS. Stimulation of the CNS results in increased neuronal excitability and motor unit recruitment that may result in quicker reaction times and improved muscular performance<sup>5</sup>.

The benefits of caffeine use for power or anaerobic events are inconclusive. However, caffeine may aid performance during these events by reducing perceived exertion and increasing motor unit recruitment<sup>5</sup>. Caffeine may also be of benefit to these athletes due to a direct influence of skeletal muscle that has been shown to result in an increased capacity to do work<sup>6</sup>.

### *Dosing*

Normal therapeutic doses of caffeine range from 100-300mg, or the equivalent of 1-3 5oz cups of brewed coffee. For ergogenic benefits, 3-6 mg/kg bw is generally recommended within 1 hour of exercise<sup>2,4,5</sup>. This dosage is sufficient to provide any ergogenic benefits of caffeine while maintaining legal limits set by the IOC and NCAA. Higher dosages may result in caffeine levels that exceed IOC and/or NCAA limits and have not been shown to provide any additional benefits to performance.

Pills may be a more effective source of caffeine relative to coffee. Caffeine can be found in any number of pill form sources, including guarana, kola nut, and mate. These sources can often be found in combination with other herbal supplements, sports drinks, and other beverages. Caffeine can also be obtained in pill form via brand name over-the-counter sources such as Vivarin. Abstaining from caffeine intake for several days prior to competition may also enhance the ergogenic effects of caffeine<sup>4</sup>.

### *Adverse Effects*

Ingestion of normal doses of caffeine, 85-250 mg or 1-3 cups of coffee, is sufficient to decrease drowsiness and fatigue in addition to more rapid and clearer thought without adverse consequences. Increased doses, 10-15 mg/kg bw, is associated with progressive CNS stimulation, increased anxiety, restlessness, insomnia, tremors, hyperesthesia, irritability, tachycardia, and GI disorders. Even greater doses can lead to focal and general convulsions. Susceptibility to potential adverse effects is very individual. Athletes with lower tolerance or increased susceptibility may find that caffeine intake actually impairs performance<sup>4,6</sup>. Though caffeine is a diuretic, it is not likely to cause dehydration.

Individuals with hypertension, ulcers, heart disease, anemia, and other medical conditions should consult a physician before using caffeine.

### *Possible Drug Interactions*

Coffee may block absorption of important minerals such as iron, zinc, thiamin, and calcium<sup>6</sup>. Additionally, according to the FDA, caffeine in combination with ephedrine alkaloids (ma huang, ephedra) has a synergistic affect on the heart and CNS. The FDA has proposed prohibiting products that contain both these ingredients from any source<sup>3</sup>. Caffeine and ephedra combination products are frequently marketed as supplements to boost energy and aid in weight loss. The FDA has received hundreds of reports of adverse reactions attributed to these combination products.

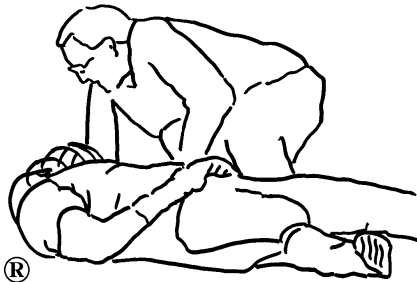
### *Comments*

Both the IOC and NCAA consider caffeine a restricted drug. The IOC permits up to 12mcg/ml of urine. The NCAA permits up to 15 mcg/ml of urine. An intake of more than 9mg/kg bw is required to exceed these levels, though the exact amount is impossible to determine as an individual's weight, gender, and body water levels can significantly influence caffeine levels. To exceed the IOC and NCAA limits an average 132 lb (60 kg) individual would need to ingest more than 6-6oz cups of coffee, 11-12oz sodas, or 3 Vivarin within 4 hours of testing. Caffeine has a half-life of 4-6 hours.

*Advice to Athletes*

1. Caffeine may or may not be beneficial to performance
2. Athletes should stay within the recommended doses to avoid adverse effects
3. Dosages above those recommended are not associated with additional benefits
4. Individual tolerances may impact the effects of caffeine
5. Caffeine should not be combined with ephedrine
6. Athletes should watch for signs of caffeine sensitivity or excessive intake
7. Caffeine is restricted by the IOC and NCAA
9. Seek the advice of a physician before beginning caffeine use if health problems exist

## **GO TO TEST**



**Professional Continuing Education From  
Sports Medicine Concepts, Inc.**

## **Management of Potentially Catastrophic Injuries in Athletics**

### **2001 Program Dates & Locations**

**Rochester, NY: January 13-14**

**Detroit, MI: March 5-6**

**\*\*Cincinnati, OH: March 24-25**

**Cleveland, OH: May 14-15**

**Baltimore, MD: June 15-16**

**Click on Sites for More Information**

**Or visit Our Web Site at**

**SportsMedicineConcepts.com**

**For an On-line Brochure**

## References:

### *Anabolic-Androgenic Steroids*

1. Bhasin S, Storer TW, Berman N, et al: The effects of supraphysiologic doses of testosterone on muscle size and strength in normal men. *M Engl J Med* 1996;335(1):1-7
2. Catlin DH, Wright J, Pope H Jr, et al: Assessing the threat of anabolic steroids. *Phys Sports-med* 1993;21(8):37-44
3. Catlin DH, Murry TH: Performance-enhancing drugs, fair competition, and Olympic sport. *JAMA* 1996;276(3): 231-237
4. *Drug Facts and Comparisons*. St. Louis: Wolters Kluwer Company; 2000
5. Eichner, R.E. Ergogenic aids: what athletes are using and why. *Phys Sports Med.* 1997; 25(4): [Available] <http://www.physsportsmed.com/issues/1997/04apr/eichner.htm>.
6. Elashoff JD, Jacknow AD, Shain SG, et al: Effects of anabolic-androgen steroids on muscular strength. *Ann Intern Med* 1991;115(5):387-393
7. NCAA banned substances list. [Available] [https://www.ncaa.org/sports-sciences/drugtesting/banned\\_list.html#street](https://www.ncaa.org/sports-sciences/drugtesting/banned_list.html#street)
8. *Sports Physiology*. In Guyton, A.C. *Human physiology and mechanism of disease*. 1987 (4<sup>th</sup> Ed.): p 656. Saunders. Philadelphia.
9. Su TP, Pagliaro M, Schmidt PJ, et al: Neuropsychiatric effects of anabolic steroids in male volunteers. *JAMA* 1993;269(21):2760-2764
10. Wilson JD: Androgens. In Goodman and Gilman (ed): *The pharmacological basis of therapeutics*, ed 9. McGraw-Hill, New York, 1996:1441-1457

### *Creatine*

1. Armsey, T.D., Jr. Nutrition supplements: science vs. hype. *Phys Sports Med.* 1997; 25(6): [Available] <http://www.physsportsmed.com/issues/1997/06jun/armsey.htm>.
2. Barnett C, Hinds M, Jenkins DG: Effects of oral creatine supplementation on multiple sprint cycle performance. *Aust J Sci Med Sport* 1996;28(1):35-39
3. Birch R, Noble D, Greenhaff GL: The influence of dietary creatine supplementation on performance during repeated bouts of maximal isokinetic cycling in man. *Eur J Appl Phys* 1994;69(3):268-276
4. Bosco C, Tihanyi J, Pucspk J, et al: Effect of oral creatine supplementation on jumping and running performance. *Int J Sports Med* 1997;18(5):369-372
5. Casey A, Constantin-Teodosiu D, Howell S, et al: Creatine ingestion favorably affects performance and muscle metabolism during maximal exercise in humans. *Am J Physiol* 1996;271(1 pt 1):E31-E37
6. Centers for disease control and prevention: Hyperthermia and dehydration-related deaths associated with intentional rapid weight loss in three collegiate wrestlers: North Carolina, Wisconsin, and Michigan, November-December 1997. *MMWR* 1998;47(6):105-108
7. Cooke WH, Barnes WS: The influence of recovery duration on high-intensity exercise performance after oral creatine supplementation. *Can J Appl Physiol* 1997;22(5):454-467
8. Dawson B, Cutler M, Moody A, et al: Effects of oral creatine loading on a single and repeated maximal short sprints. *Aust J Sci Med Sport* 1995;27(3):56-61

9. Earnest CP, Snell PG, Rodriguez R, et al: The effect of creatine monohydrate ingestion on anaerobic power indices, muscular strength and body composition. *Acta Physiol Scand* 1995;153(2):207-209
10. Eichner, R.E. Ergogenic aids: what athletes are using and why. *Phys Sports Med.* 1997; 25(4): [Available] <http://www.physsportsmed.com/issues/1997/04apr/eichner.htm>.
11. Greenhaff PL, Bodin K, Soderlund K, et al: The effect of oral creatine supplementation on skeletal muscle phosphocreatine resynthesis. *Am J Physiol* 1994;226(5 pt 1):E725-E730
12. Harris RC, Soderlund K, Hultman E: Elevation of creatine in resting and exercised muscle of normal subjects by creatine supplementation. *Clin Sci* 1992;83(3):367-374
13. Hultman, E, Soderlund, K, Timmons JA, et al: Muscle creatine loading in men. *J Appl Physiol* 1996;81(1):232-237.
14. Juhn MS: Oral creatine supplementation: separating fact from fiction. *Phys Sports Med.* 1999; 27(5): [Available] [http://www.physsportsmed.com/issues/1999/05\\_99/juhn.htm](http://www.physsportsmed.com/issues/1999/05_99/juhn.htm).
15. Koshy KM, Griswold E, Schneeberger EE. Interstitial nephritis in a patient taking creatine. *NEJM* 1999;340:814-815
16. Kreider RB, Ferreira M, Wilson M, et al: Effects of creatine supplementation on body composition, strength, and sprint performance. *Med Sci Sports Exerc* 1998;30(1):73-82
17. Mujika, I., & Padilla, S. Creatine supplementation as an ergogenic aid for sports performance in highly trained athletes: a critical review. *Int J Sports Med.* 1997; 18: 491-496.
18. Mujika, I., Chatard JC, Lacoste L, et al. Creatine supplementation does not improve sprint performance in competitive swimmers. *Med Sci Sports Exerc.* 1996; 28: 1435-1441.
19. Poortmans JR, Auquier H, Renaut V, et al: Effect of short-term creatine supplementation on renal responses in men. *Eur J Appl Physiol* 1997;76(6):566-567
20. Pritchard NR, Kaira PA. Renal dysfunction accompanying oral creatine supplements. *Lancet* 1998;351:1252-3
21. *Sports Physiology*. In Guyton, A.C. *Human physiology and mechanism of disease.* 1987 (4<sup>th</sup> Ed.): p 656. Saunders. Philadelphia.
22. Tarnopolsky, M., & Martin J. Creatine monohydrate increases strength in patients with neuromuscular disease. *Neurology.* 1999; 52(4): 854-857.
23. Thompson, C.H., Kemp, G.J., & Sanderson, A.L., et al. Effect of creatine on aerobic and anaerobic metabolism in skeletal muscle in swimmers. *Br J Sports Med.* 1996; 30: 222-225.
24. United States Food and Drug Administration, Rockville, MD: The special nutritionals adverse event monitoring system. [Available] [http://vm.cfsan.fda.gov/cgi\\_bin/aems.cgi?QUERY=creatine&STYPE=EXACT](http://vm.cfsan.fda.gov/cgi_bin/aems.cgi?QUERY=creatine&STYPE=EXACT).
25. Vabdenberhe K, Goris M, Van Hecke P, et al: Long-term creatine intake is beneficial to muscle performance during resistance training. *J Appl Physiol* 1997;83(6):2055-2063
26. Vandenberghe K, Van Hecke P, Van Leemputte M, et al: Phosphocreatine resynthesis is not affected by creatine loading. *Med Sci Sports Exerc* 1999;31(2):236-242
27. Volek JS, Kraemer WJ, Bush JA, et al: Creatine supplementation enhances muscular performance during high-intensity resistance exercise. *J Am Diet Assoc* 1997;97(7):765-770

## *Caffeine*

1. Chesley, AE, et al: Variable effects of caffeine on muscle glycogenolysis in recreationally active subjects during aerobic exercise [abstract]. *Can J Appl Physiol* 1994;19(Suppl):10P
2. Eichner, R.E. Ergogenic aids: what athletes are using and why. *Phys Sports Med.* 1997; 25(4): [Available] <http://www.physsportsmed.com/issues/1997/04apr/eichner.htm>.
3. Food and Drug Administration press release P97-15. FDA proposes safety measures for ephedrine dietary supplements. June 2, 1997
4. Graham TE, et al: Coffee and exercise:metabolism and performance. *Can J Appl Physiol.* 1994;19:111-138
5. Graham TE, Spriet LL: Caffeine and exercise performance. *Sports Science Exchange (Gatorade Sports Science Exchange)* 1996;9:1-6
6. Serafin WE: Drugs used in treatment of asthma. In Goodman and Gilman (ed): *The pharmacological basis of therapeutics*, ed 9. McGraw-Hill, New York, 1996:672-679
8. Spriet L: Caffeine and performance. *Int J Sport Nutr* 1995;5:S84-S99.