

Magnesium: Mineral Link To Energy

Magnesium has many roles in energy metabolism. In order to understand how important magnesium is, one needs a contracted overview of the body's energy systems, with emphasis on the areas impacted by this essential mineral. Physical activity of any nature increases the body's demand for energy, with the greatest requirements coming from the skeletal, cardiac, and smooth muscles. All energy for muscle contraction is derived from the hydrolysis of ATP. Metabolic rates can be 20 times higher during aerobic activity and up to 50 times higher during intense anaerobic activity.^{1,2} Magnesium is intimately linked to the metabolic cycle of ATP production and hydrolysis.

There are three overlapping and mutually supportive energy systems that provide the ATP needed for physical activity or exercise: (1) immediate, (2) nonoxidative (glycolytic) and (3) oxidative. Exercise variables determine which energy system is most activated, as seen in Table 1.

Short term, high intensity exercises are anaerobic and they rely on the first energy system listed above, the *immediate energy system*, which includes:

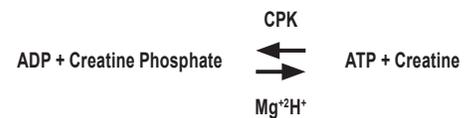
1. ATP existing in muscle sarcoplasm

2. ATP from ADP + inorganic phosphate (myokinase reaction)
3. ATP from creatine phosphate (CPK reaction)

The second and third components of the immediate energy system create most of the ATP needed for short term high intensity exercise, since ATP existing in the muscle can only sustain muscle contraction for less than a second.

The formation of ATP from ADP and inorganic phosphate in the immediate energy system requires the enzyme, myokinase. This enzyme requires magnesium for its activity. The third component of the immediate energy system involves creatine phosphate. Creatine phosphate is a high energy phosphate compound that donates

its phosphate to ADP to form ATP via the creatine phosphokinase (CPK) reaction (see below).



Creatine phosphokinase (CPK) is the key enzyme for formation of the dominant supply of ATP in the immediate energy system. CPK is regulated by magnesium and hydrogen ions. The full enzyme/substrate/magnesium complex is required for the reaction to proceed.

The second energy system listed above, the nonoxidative (glycolytic) energy system, is the main source of

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Table 1
ATP Physical Activity Table

Energy Systems	Exercise Type	Representative Activity
Immediate	Anaerobic	Sprinting Weight Lifting
	Most Sports	
Nonoxidative (Glycolytic)	Transitional Anaerobic	Tennis, Ballet Circuit Training
	Most Sports	
Oxidative	Aerobic	Jogging, Cycling, Hiking Stair Climbing

Most sports are of an interval nature, and they rely on the immediate and nonoxidative energy systems heavily. However, even in short duration exercise, some oxidative energy may be involved.

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ATP for transitional anaerobic forms of exercise (cross between aerobic and anaerobic). In this system, carbohydrates act as the fuel for the glycolytic reactions. These reactions convert glucose to pyruvate and result in the production of ATP.

To illustrate Table 2, magnesium is the only metal that allows enolase to convert 2-phosphoglycerate to phosphoenolpyruvate (which contains a high energy phosphate bond). This is the last step before the formation of pyruvate. In addition, magnesium is an important factor in the pyruvate kinase conversion of phosphoenolpyruvate to pyruvate, which produces ATP.

Aerobic exercises rely primarily on the oxidative energy system for their source of energy. ATP from this energy system comes from the mitochondrial electron chain and the citric acid cycle. Acetyl Coenzyme A (Acetyl CoA) is the major fuel for the citric acid cycle. During glycolysis, glucose is converted to pyruvate. If oxygen is present, pyruvate is further converted to acetyl CoA. The formation of acetyl CoA links anaerobic glycolysis in the cytosol to aerobic metabolism in the mitochondria. Magnesium is the key catalyst for the multienzyme regulatory switch between anaerobic and aerobic energy systems.

The citric acid cycle (Krebs Cycle) occurs in the mitochondrial matrix and is the final common pathway for the oxidation of fuel molecules (glucose, fatty acids, and amino acids). In the course of the citric acid cycle, Acetyl CoA is completely oxidized to form carbon dioxide. The first four reactions of the citric acid cycle are catalyzed by isocitrate

dehydrogenase, which requires magnesium for its activity, and is the enzymatic key to the overall rate of this cycle. In the mitochondrial membrane creates a proton gradient. The energy generated by this proton gradient is sufficient to drive ATP synthesis. The enzyme complex ATPase, which uses the energy from the electron transport chain to synthesize ATP, requires magnesium in order to function.^{2,3}

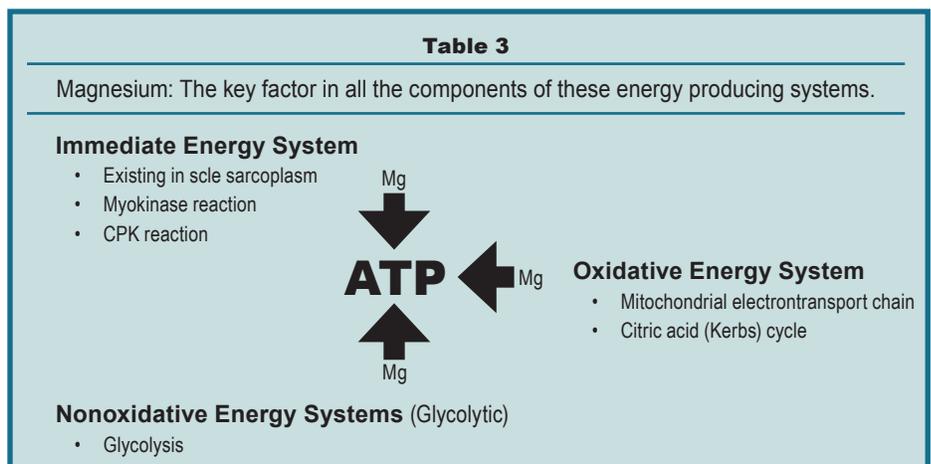
All energy for muscle contraction comes from the hydrolysis of ATP. The enzyme ATPase drives the hydrolysis of ATP. All known ATPase reactions require magnesium to cleave the high energy phosphate bond of ATP. In skeletal muscle, magnesium must attach to ATP before myosin ATPase can hydrolyze the ATP. Thus, adequate magnesium

must be present for skeletal muscle contraction.

Table 3 shows energy systems that are used to fuel physical activity. Magnesium has been mentioned as a key factor in many components of each system. **Magnesium should be a major component of any nutritional regimen aimed at sports, energy, or fitness.**

1. Champe P, and Harvey R, *Lippincott's Illustrated Reviews, Biochemistry 2nd Edition*, 1994:61-126.
2. Brilla L, Lombardi VP, "Magnesium and Sport Performance," *Sports Nutrition Minerals and Electrolytes* (Kies and Driskell Editors), CRC Press Boca Raton, 1995:139-177.
3. Garfinkel L, Garfinkel D, "Magnesium Regulation of the Glycolytic Pathway and the Enzymes Involved," *Magnesium 4* (2-3): 1985:60-72.

Table 2 Production of ATP	
Magnesium and magnesium chelates are key components of the following enzymes in the glycolytic production of ATP ³	
Glucokinase (hexokinase)	Glucose-6-phosphate
Phosphoglucose isomerase	Phosphofructokinase
Aldolase	Phosphotriose isomerase
Phosphoglycerate kinase	Phosphoglyceromutase
Enolase	



Energy Considerations

The aforementioned studies demonstrate that the importance of magnesium to the body's key energy form, ATP, is unquestionable. The biochemical paths and energy systems impacted by magnesium are both numerous and startling. Many hundreds of studies have demonstrated the various ways that magnesium imparts a positive influence on the body's energy. There are many other factors involved in the energy systems of the body. Fuels such as carbohydrates, certain amino acids, and lipids are necessary. So are some other minerals, vitamins, and other accessory nutrients. However, it seems that magnesium is one factor in energy formation that tends to be in short supply in many diets, and therefore acts as a possible limiting factor in energy production. Studies have indicated that Albion's patented magnesium amino acid chelate is an effective way to increase energy production. There may be some question as to which form of Albion magnesium chelate, aspartate or Glycinate, is more effective in this. A direct comparison has not been done. Many feel that the most important thing is to increase the body magnesium content, and that the amino acid ligand is irrelevant. It should be noted that the oral administration of aspartates alone (Maughan & Sadler, Int J. Sports Med, 4, 119, 1983) was shown to have no benefit to energy production. Since both magnesium glycine and aspartate chelates from Albion have significantly increased body magnesium content, theoretically the one that most increases body content will probably have the greatest impact on energy production.

Enhanced Exercise Performance Linked To Magnesium Amino Acid Chelates From Albion

The importance of magnesium in the production of energy is without question. Magnesium has been linked to all aspects of the body's production of energy. Carbohydrates, lipids, and proteins cannot produce the source of muscle contraction energy - ATP - without the presence of magnesium. Albion's patented magnesium amino acid chelate has been evaluated for its various physiological benefits in many scientific studies over the years. This magnesium amino acid chelate has been shown to be absorbed from 189% to 543% better than magnesium salts.⁸ In spite of this greater absorption, Albion's magnesium chelate has been shown to be better tolerated than some other magnesium forms,⁴ and to have beneficial effects on platelet function⁵ and primary dysmenorrhea.⁶ Most importantly as far as energy is concerned, Albion's patented magnesium amino acid chelate increases tissue magnesium levels⁷. Albion's magnesium amino acid chelate has been demonstrated to have positive effects on energy and physical performance as described in the five studies below.

(1) "Numerous studies indicate that the availability of oxygen and the capacity for substrate metabolism in muscle may become rate limiting factors during aerobic

endurance exercise in man and animals. In addition, the chemical form in which these factors are presented to working muscle may also be important for optimal tissue uptake and in determining endurance capacity. To determine the effects of mineral chelates on endurance time in rats, groups of adult (6 month old) virgin female congenic LA/N rats were administered chelated forms (manufactured by Albion) of magnesium aspartate (Mg-ASPch) or potassium aspartate (K-ASPch*), or the corresponding salt forms of the two compounds (Mg-ASPs; K-ASPs) via gavage in increasing dosages of 0, 6.25, 12.5, or 100 mg/kg BW for 3 days, followed by a swim (30°C; 12 inches deep) to exhaustion exactly 2 hours after the last gavage treatment. Prior to mineral administration, stability of all compounds under conditions prevalent in the GI tract was validated via exposure to pHs 2-8 for < 30 minutes, followed by silica gel chromatography of the products. Stability of the Albion minerals was found to be >95% under these conditions. (The salt forms were almost completely dissociated according to Ellis). Rats were limited to 1 swim/week to minimize potential training effects on outcome. Mg-ASPch and Mg-ASPs resulted in significant dose related increments (>2 fold increase) in swim duration, which K-ASPch and K-ASPs were associated with only mild increases (swim duration Mg-ASPch > Mg-

**If your mineral is not
an Albion chelate,
it's just salt!**

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ASPs > K-ASPch > K-ASPs). These results indicate that the antecedent administration of chelated minerals may enhance endurance exercise, and may therefore be a useful ergonomic adjunct for endurance exercise."⁹ (*Note: Authors referred to the Albion produced potassium aspartate as chelate. Potassium cannot be chelated. Albion's potassium's are complexes only.)

(2) In a subsequent study conducted at Drexel University and submitted for publication, it was shown that when magnesium was chelated to aspartic acid according to Albion's patented process, this patented chelate increased physical endurance 151% over that obtained with the magnesium aspartate salts usually sold in the market place.¹⁰

(3) In an earlier, unpublished study performed by Dr. Harvey Ashmead, the effectiveness of Albion's magnesium chelates in increasing energy (ability to perform work or exercise) was demonstrated in a study similar to that of Ellis, et al. In Ashmead's study, there were three groups of rats. One group received a placebo; the second received a supplement based on Albion's amino acid chelated magnesium. The magnesium supplementation lasted one week. On the last day, the animals swam to exhaustion. The placebo group lasted 10.1 minutes, the inorganic magnesium group lasted 13.8 minutes, while the Albion chelated magnesium group swam for 48.3 minutes. These data suggest that Albion's chelated magnesium

was 3.4 to 4.3 times more effective at increasing the animals' energy.

(4) Motocross racing is one of the most physically demanding of all competitive sports. The necessity for tight gripping of the handlebar controls over variable terrain, with constant concussion of the hand, often leads to a condition known as arm pump. Arm pump is characterized by pain, paresthesias, and sensory loss. The purpose of this study was to evaluate the effect of Endura on arm pump. The primary ingredient in Endura is a magnesium glycine chelate from Albion. The motocross athletes were divided into two groups, Endura and placebo. On race day one, all athletes raced in two motos, and the incidence of arm pump was recorded. During the next week, the athletes took a regimen of either Endura or placebo. On race day two, a week later, the athletes again raced in two motos, taking additional Endura or placebo between races. Again the incidence and time of arm pump was recorded. The Endura (magnesium glycine chelate) group had a 63% reduction in arm pump, with 50 % of the Endura group being completely free of symptoms. The researchers stated several proposed mechanisms by which the magnesium glycine chelate (Albion's) would work to eliminate arm pump, however, they felt that further studies would be needed to elucidate the exact mechanism.¹¹

(5) It has been suggested that part of the success of Olympic Gold Medal Winner Brooke Bennett who placed

first in the 1996 800 meters Freestyle was due to Albion magnesium amino acid chelate.¹²

4. Schutte SA, Lasher BA, and Janghorbani M. "Bioavailability of Magnesium Diglycinate vs. Magnesium Oxide in Patients with Ileal Resection." *J of Parental and Enteral Nutr.* 18, 1994:430-435.

5. Weaver K and Speigel KM, "Platelet Functional Responses to Oral Doses of magnesium and Fish Oil in Human Volunteers." *JACN* 7, 1988:407.

6. Abraham GE, "Primary Dysmenorrhea." *Clinical Obstetrics and Gynecology*, Harper and Row, Vol. 21 No.1, March 1978.

7. Sacks F, et al. "Effect of Magnesium Supplementation on Mononuclear Blood Cell and Urinary Magnesium Retention of Intravenous Magnesium and Blood Pressure in Normal Person," *Harvard Medical School, Grant HL34586 and PRO2635-01 NIH and Albion Labs.*

8. Ashmead HD, et al. *Intestinal Absorption of Metal Ions and Chelates* (Springfield: Charles C. Thomas) 163, 1985.

9. Ellis, G., V. Sallee, J. Glass, and O.L. Tulp. "Effects of Mineral Chelates on Swimming Time of LA/N Rats", Somatech Inc., Glen Mills, PA and Nutrition and Food Sciences, Drexel University, Philadelphia, PA. *FASEB Atlanta, BA, April 9-13, 1995.*

10. Ellis G., Personal Communication. Also Friedman H., et al., "Effects of Mineral Chelate Mixtures on Swimming Time in Rates". Submitted for publication, 1997.

11. Spencer, J., et al., "A Double-blind Evaluation of the Nutritional Supplement Endura Versus and Equivalent Number of Calories in the Form of Carbohydrates as a Treatment for Arm Pump in the Motocross Athlete" *Nutritional Perspectives*, pp. 19-21.

12. Schuler R., Personal Communication, 1996.

Closing Thought

In today's endeavors to allow man to achieve more, many ingredients are being promoted as natural ways to enhance physical performance. Herbal products are often touted in this area. Although herbs are naturally occurring products, their benefits are often of a pharmacological nature. This is fine, under certain circumstances. However, isn't it better to use ingredients that work within the normal biochemistry of the body to maximize physical performance? Albion's magnesium

amino acid chelates have been shown to increase body magnesium levels and thus enhance the benefits of magnesium to many areas that are concerned with energy and muscular performance. Benefits of Albion's magnesium chelates have been scientifically documented. The next time you are considering a supplement to boost performance, shouldn't the proven Albion magnesium amino acid chelate be an important part of that consideration?



Albion Human Nutrition

100 Maple Park Blvd., Suite 110
St. Clair Shores, Michigan 48081 USA
[P] 586•774•9055 | [TF] 800•222•0733
[F] 586•774•8838
[e] info@AlbionMinerals.com

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