What about Magnesium?

Studies show that an imbalance in magnesium can significantly reduce your performance levels. Are you neglecting this important electrolyte?

Kimberly J. Brown, MS, RD, Sports Nutritionist

Do you constantly battle muscle cramps during intense or long training? Does muscular weakness prevent you from putting forth full effort? Do asthmatic symptoms prevent you from completing workouts? Does it feel as if your heart skips a beat, causing feelings of lightheadedness and dizziness? Are physical returns from an intensive strength training program less than anticipated? If you answered yes to any of these questions, you may be suffering from a magnesium imbalance and consequent hindered endurance performance. The good news is that an imbalance can be corrected relatively quickly (within 48 hours), helping redirect your performance back to your peak.

The initial response of physical exercise is an accelerated metabolism, which increases activity within our metabolic pathways. Magnesium is vital for converting glycogen to glucose for use as the body's fuel during exercise; without this conversion, muscular weakness occurs secondary to depletion of muscle glycogen stores. Magnesium also helps regulate the synthesis of protein, thereby having important implications when looking at recovery from endurance exercise and maintenance of lean mass. Furthermore, because magnesium is directly responsible, along with calcium, for the production of adenosine triphosphate (ATP) or energy during metabolism, proper levels of magnesium are needed for optimal muscle contraction and to sustain the high oxygen consumption necessary for peak endurance performance. And without adequate magnesium, the work of over 300 enzymes become sub-par, ultimately hosting a whole slew of problems, including heart abnormalities, airway constriction, nerve damage and insulin resistance.

Scientists believe that endurance athletes may be at heightened risk for magnesium deficiency and consequent health and performance problems as a result of the metabolic response of exercise as well as losses incurred via sweat and urine. This article explores the benefits of attaining magnesium balance through inclusion of magnesium-rich foods in our daily diet as well as replacement of magnesium losses during exercise.

What is Magnesium?

As the fourth most abundant element (behind sodium, potassium and calcium) found in the body, with a total of 50 to 60 percent being stored in the skeletal system and the remainder being stored in muscles and soft tissues, magnesium plays an instrumental role maintaining both structural (bone) and biochemical (muscle contraction, nerve transmission, enzyme production) homeostasis

within the human body. In fact, magnesium is responsible for 80 percent of all enzymatic reactions in the body, regulating virtually every body activity. Because of these established roles, attainment and maintenance of magnesium balance is crucial for optimal health and peak physical performance.

Causes of Imbalance

A magnesium imbalance is triggered by changes that occur in one or more of the stages of metabolism, such as reduced dietary intake, reduced absorption, redistribution and increased excretion.[1] Endurance athletes, whose sweat rate ranges from just under 1 liter per hour to over 1.5 liters per hour, seem to be at a greater risk for magnesium imbalance as compared to the general population due to high excretion rate.[2,3] An imbalance is even more likely in the athletic population when absorption rate or distribution is affected by interactions with several food substances, alcohol and various types of drugs.

Diet

Recommended Daily Allowance (RDA) for magnesium in adults ranges from 310 to 420 mg. There is not an established RDA for the athletic population, yet sports researchers have developed a performance daily intake (PDI) recommendation of 400 to 800 mg for magnesium as a result of research slowing depletion of magnesium stores during endurance training. Despite these recommendations, it is estimated that only 25% of Americans receive their RDA of magnesium in their diet and less than 40% consume ¾ their RDA for magnesium, perhaps due to all the refined and high-fat foods eaten in the Western diet. Statistics for females are even worse for magnesium, with estimations for intake averaging only 110 mg per 1,000 calories for a non-athletic population and 115 mg per 1,000 calories for an athletic population that included runners.[4] Another study of 30 female endurance athletes discovered an average intake of only 230 mg or 74 percent of the minimal requirement for the nutrient.[5] In contrast, many male endurance athletes have been shown to meet or exceed recommendations for magnesium, perhaps due to their high energy intake and better body image (less dieting). One study of six professional road cyclists reported a training diet that included a daily average of 634 mg of magnesium which, falls well within the PDI recommendation.[6] Deficiency symptoms, which are explained in a forthcoming paragraph, generally are exacerbated when less than 70 percent the RDA is consumed for a nutrient. Over time, a chronic low dietary magnesium intake may lead to a magnesium deficiency.

Dietary intake of protein, carbohydrate and fat can also affect magnesium balance. The prevalence of such fad diets as Atkins and Zone has fueled an increase in dietary protein and fat in a population that already consumes more than adequate amounts of these nutrients. Besides the negative effect high-protein diets have on hydration status, cardiovascular health and bone health, excessive protein intake also contributes to increased urinary loss of magnesium. Furthermore, the fat content in high-protein foods is enough to reduce the absorption of magnesium and may impair endurance performance.[7] Similarly, diets favoring refined foods, processed foods or sugars can be equally detrimental to magnesium balance due to the diminished content of magnesium in these foods. Therefore, athletes whose meal plate favors protein, fat or refined products are encouraged to transform their plates in favor of fruits, vegetables and whole grains with moderate amounts of lean protein. This will help promote a correct balance of magnesium, calcium and phosphorus within the body.

To compound the problem of low reported dietary intakes of magnesium and consequent risk for a magnesium deficiency, there are a several food nutrients that hinder the absorption rate of magnesium, which averages about 25 to 60 percent, and/or increase the body's need for magnesium.

Dietary fiber, despite its pronounced health benefits, slightly lowers the absorption rate of magnesium. In addition, beverages containing phosphoric acid (soda, diet soda), aspartame (diet soda, Crystal Light), or caffeine and foods/beverages high in oxalic acid (beet greens, chard, rhubarb, spinach, cocoa, tea, almonds) prevent absorption of magnesium within the GI tract. Furthermore, the consumption of large amounts of fats, cod liver oil, calcium, vitamin D, and protein decreases magnesium absorption. Finally, high levels of zinc and vitamin D increases the body's need for magnesium. Therefore, athletes favoring the intake of any of these food nutrients are encouraged to slightly bump up their magnesium intake to compensate for reduced absorption and increased urinary loss.

Drug & Alcohol Use

Many drugs bind with magnesium, leading to excretion via urine rather than distribution in bones or soft tissue. Such drugs include asthma medications, thiazide, loop diuretics, birth control pills, some anticonvulsants, some antibiotics and steroids. Furthermore, many drugs cause biochemical surges that occur from high glucose (sugar) and catecholamines (adrenaline), which are released as a side-effect of many drugs, including some pain medications, anti-cancer drugs and anti-convulsants. Over time, continued use of these drugs may contribute to a magnesium imbalance. Individuals who regularly consume alcoholic beverages should also be forewarned that a mere two ounces of alcohol can significantly increase the excretion of magnesium, thereby enhancing risk for an imbalance.[8]

Sweat Loss

In addition to magnesium loss in urine, significant losses via sweat have been reported in athletes engaged in prolonged exercise bouts. In more moderate conditions (70 degrees F) for a 10k race spanning over 40 minutes, magnesium losses via sweat average 7.25 mg.[9] Measured concentrations of magnesium in sweat generally average about 6 mg/liter, but may be higher in certain individuals and in hot climates.[8,10-12] One study reported a daily loss of 15.2 to 17.8 mg of magnesium in sweat in cyclists training in heat (100 degrees F). This excretion represented 10 to 15 percent of total daily magnesium losses (feces, urine and sweat) and 4.4 to 5.2 percent of daily magnesium intake. Similar losses of 2.3 mg per hour of exercise in heat have been reported.[13-14] Ironman athletes, who often train long on weekends, could lose as much as 25 percent of the daily magnesium excretion in six to eight hours, compounding their risk for a magnesium imbalance and consequent cramping during exercise again if dietary intake and mineral replacement is not adequate.

Case Study

A 37-year old triathlete reported to the medical tent midway through Ironman competition with aching in his muscles and thighs, and generalized tenderness in all his skeletal muscles. He had a noticeable limp, as his calf muscle contracted spasmodically. During previous training, he did notice weakness of the legs, which began to "wobble" toward the latter stages of a workout. Severe muscle cramps and spasms often prevented completion of several of his workouts. Doctors determined that all his blood work was normal except for a serum magnesium content of 0.54 mmol/L (reference range 0.7 to 1.5 mmol/L). A Registered Dietitian administered a 24-hour recall, which indicated that his "typical diet" was very low in magnesium. The athlete admitted to "not eating any vegetables at all" and discussed his passion for chips, lasagna, and bread with butter and jam. His active lifestyle, which in itself decreases serum magnesium through sweat, combined with poor eating habits, undoubtedly resulted in a negative magnesium balance and consequent symptoms of muscle cramping and fatigue.

Treatment included infusion with a saline solution that included magnesium. Within 48 hours, the athlete reported that his muscle spasms had subsided and that he had very little muscle soreness.

Deficiency Symptoms

When magnesium excretion exceeds its assimilation within the GI tract, a state of negative magnesium balance occurs causing magnesium pools to become depleted and serum levels of magnesium to fall (hypomagnesaemia). Exercise under certain conditions appears to lead to magnesium depletion. In fact, several studies have indicated a transient fall in serum magnesium concentration during prolong exercise, with the most significant drops occurring in hot and humid environments.[10-11,15-17] Unfortunately, because 99 percent of the total body magnesium is located within our cells or in bone, serum magnesium levels (sMg) and red blood cell magnesium are not always an accurate reflection of the amount of mineral stored in the body which makes a magnesium imbalance tough to pinpoint. However, athletes displaying any of the symptoms listed in Table 1 are encouraged to evaluate their magnesium intake from food as well as other factors that may place them at elevated risk for a magnesium imbalance. Fortunately, because the kidneys are extremely efficient in maintaining magnesium homeostasis, symptomatic magnesium deficiencies are rarely reported.

Table 1. Symptoms associated with a magnesium deficiency

Muscular weakness	*Muscle cramps*	*Tremors*
Elevated blood pressure	*Loss of appetite*	*Nausea*
Tetany (sustained contraction)	*Anxiety*	*ECG changes*
Bronchial constriction (asthma)	*Irritability*	*Insomnia*
Elevated resting heart rate	*Numbness*	*Depression*
Lethargy (fatigue)		

Obtaining Magnesium Balance

Food Intake

Magnesium is found extensively in the foods we eat, especially dairy products, fish, meat and seafood. One-half cup of shrimp contains about 20 percent of the RDA. Additional sources of magnesium include apples, apricots, avocados, bananas, blackstrap molasses, brewer's yeast, brown rice, cantaloupe, figs, garlic, grapefruit, green leafy vegetables, kelp, lemons, lima beans, millet, nuts, peaches, black-eyed peas, salmon, tofu, watercress, wheat and whole grains. Magnesium can also be found in hard water (~20 mg/liter) and some bottled waters (up to 100 mg/liter). Note that magnesium works best with potassium and calcium; foods containing all three of these nutrients include wheat germ, sunflower seeds, soybeans, almonds, brazil nuts, pistachios and pecans. Add these foods to salads, cereal and snack foods to help meet your daily magnesium needs. Cooking with or consumption of the following herbs will also help boost magnesium intake: alfalfa, cayenne, chamomile, fennel seed, lemongrass, licorice, paprika, parsley, peppermint, raspberry leaf, red clover and sage.

Supplement

Supplemental forms of magnesium may benefit endurance athletes, especially those with a

predisposition to muscle cramping and fatigue and/or those with poor dietary intake, since PDI recommendations exceed the RDA due to losses incurred via sweat and urine during intensive training. One clinical trial discovered that supplementation with 360 mg of magnesium each day for four weeks helped decreased serum lactate concentration and oxygen consumption in male competitive rowers. Cellular metabolism has also been shown to improve after supplementing with magnesium.[18] Note that dosing patterns during exercise will vary dependent on the athlete's weight, physical condition, weather conditions and sweat rate. Some scientists recommend a daily oral intake of 5 mg of magnesium per kg of body weight.[19] General recommendations for magnesium supplementation in preparation for an endurance event are approximately 300 mg (~of elemental magnesium) one hour before bedtime the night prior to the event and another 300 mg upon starting to sweat the day of the event. Doses on the day of the event can be split up so that the athlete is consuming ~100 mg of magnesium each hour of exercise until they obtain the recommended 300 mg. Remember to avoid mixing the magnesium with soda and/or sports drinks containing phosphates, as this will inhibit absorption of the magnesium.

Not all forms of magnesium are created equal with respect to absorption and acceptability; some are better absorbed with little side-effect whereas others are not absorbed very well at all and cause GI distress (nausea, diarrhea) when consumed. The best forms of supplemental magnesium are the ones chelated to an amino acid (magnesium gluconate, magnesium taurate) or a Krebs cycle intermediate (magnesium malate, magnesium citrate, magnesium fumarate) because their resorption rate is five to10 times more efficient than such inorganic forms of magnesium as magnesium chloride and magnesium carbonate. Perhaps the most accepted and best absorbed form of magnesium is magnesium gluconate.

Many people question the safety of supplementing with any nutrient, with fear of developing toxicity symptoms that tend to be just as bad, if not worse, as the deficiency symptom itself. With magnesium, toxicity symptoms (the most common being diarrhea) are highly unlikely because healthy kidneys are able to remove excess magnesium very quickly. Furthermore, magnesium within the blood vessels of the intestines rigidly controls the amount of magnesium being absorbed, which also helps with rapid removal of any excess magnesium from the body. Even so, it is always important to follow dosage recommendations with any supplemental form of a nutrient. With magnesium, it is not recommended to exceed a dose of 3,000 to 5,000 mg a day. Individuals with renal dysfunction are likely to develop toxicity symptoms at a lower dose and should not supplement with magnesium unless under the direct supervision of a physician.

Conclusion

Because magnesium plays an instrumental role in cellular energy metabolism, endurance athletes are encouraged to check their cellular mineral status every three months to prevent any deficiency symptoms and consequent declines in endurance performance. Magnesium balance can be maintained with a well-balanced diet that includes such magnesium-rich foods as wheat germ, sunflower seeds, soybeans, almonds, Brazil nuts, pistachios and pecans.

Remember to avoid excessive intake of protein and fats, as well as simple sugars and refined flours, to ensure adequate absorption of magnesium from food. Also, watch your intake of foods and beverages containing oxalic acid, phosphoric acid and aspartame. Athletes who consistently experience muscle cramping and/or fatigue may benefit from supplementation with magnesium. General recommendations for athletes experiencing symptoms consistent with a magnesium deficiency are approximately 5 mg of magnesium, preferably in the gluconate form, per kg of body weight each day until symptoms subside.

Kimberly J. Brown, MS, RD, is a sports dietitian and competitive endurance athlete who provides nutritional counseling and meal planning to athletes worldwide. For more information on her services, visit her website at www.kbnutrition.com. You can contact her at kim@kbnutrition.com.

References

1. Elin, R.J. (1988). Magnesium metabolism in health and disease. *Dis Month.* 34: 161-219.

2. Fallon, K.E., Broad, E., Thompson, M.W., Reull, P.A. (1998). Nutritional and fluid intake in a 100-km ultramarathon. *Int J Sports Nutr.* 8: 24-35.

3. Costill, D.L. (1984). Water and electrolyte requirements during exercise. *Clin Sports Med.* 3: 639-648.

4. Nuviala, R.J., Lapieza, M.G., Bernal, E. (1999). Magnesium, zinc, and copper status in women involved in different sports. *Int J Sport Nutr.* 9: 295-309.

5. Mueller, K.M. (1999). The female athlete triad: The prevalence of disordered eating, menstrual irregularities, low bone mass in female distance runners. *Unpublished manuscript, Illinois State University*.

6. Garcia-Roves, P.M., Terrados, N., Fernandez, S., Patterson, A.M. (2000). Comparison of dietary intake and eating behavior of professional road cyclists during training and competition. *Int J Sport Nutr Exerc Metab.* 10: 82-98.

7. Lukaski, H.C., Bolonchuk, W.W., Klevay, L.M., Milne, D.B., Sandstead, H.H. (2001). Interactions among dietary fat, mineral status, and performance of endurance athletes: a case study. *Int J Sport Nutr Exerc Metab.* 11(2): 186-198.

8. Consolazio, C.F., Matoush, L.O., Nelson, R.A., Harding, R.S., & Canham, J.E. (1963). Excretion of sodium, potassium, magnesium, and iron in human sweat and the relation of each to balance and requirements. *J Nutr.* 79: 407.

9. Wenk, C., Kunz, P., Steiner, G. (1993). Methodological studies on estimating the loss of sodium, potassium, calcium, and magnesium exemplified by a 10-km run. *Schweiz Z Sportmed.* 41(4): 159-163.

10. Rose, L.I., Carroll, S.L., Lowe, E.W., Peterson, E.W., Cooper, K.H. (1970). Serum electrolyte changes after marathon running. *J Appl Physiol.* 29: 449-451.

11. Beller, G.A., Maher, J.T., Hartley, L.B., Bass, D.E., & Wacker, W.E.C. (1975). Changes in serum and sweat magnesium levels during work in the heat. *Aviation Space Environ Med.* 46: 709-712.

12. Costill, D.L., Cote, R., & Fink, W. (1976). Muscle water and electrolytes following varied levels of dehydration in man. *J Appl. Physiol.* 40: 6-11.

13. Freedman, T., Anderson, J., Sterling, T., Schields, C., Mansmann, H.C. (1993). Oral magnesium gluconate for muscle cramps in professional football players—A preliminary report and empirical observations. *Unpublished manuscript presented at National Trainer's Association Annual Meeting, Kansas City, June 10-12, 1993*.

14. Bellar, G.A., Maher, J.T., Hartley, L.H., Bas, D.E., Wacher, W.E.C. (1972). Serum Mg and K concentrations during exercise in thermoneutral and hot conditions. *Physiologist.* 15: 84.

15. Cohen, I., Zimmerman, A.L. (1978). Changes in serum electrolyte levels during marathon running. *S AfrMed J.* 53: 449-453.

16. Refsum, H.E., Meen, H.D., Stromme, S.B. (1973). Whole blood, serum and erythrocyte magnesium concentration after repeated heavy exercise of long duration. *Scan J Clin Lab Invest.* 32: 123-127.

17. Stendig-Lindberg, G., Shapiro, Y., Epstein, Y., Gaiun, E., Schonberger, E., Graff, E., Wacker, W.E.C. (1985). Changes in serum magnesium concentration after strenuous exercise. *Unpublished manuscript presented at 4th International Symposium on Magnesium in Blacksburg, VA*.

18. Golf, S., et al. (1993). Is magnesium a limiting factor in competitive exercise? A summary of relevant scientific data. In *Magnesium.* (London: John Libbey & Company), pp 209-220.

19. Rayssiguier, Y., Guezennec, C.Y., Durlach, J. (1990). New experimental and clinical data on the relationship between magnesium and sport. *Magnes Res.* 3(2): 93-102.