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Magnesium supplementation in top athletes - effects and recommendations

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Abstract. Magnesium is a cofactor involved in many enzymatic systems, being necessary for protein synthesis, functioning of nervous and muscular systems, regulation of blood pressure and glycaemia, bone metabolism. A low dietary intake of magnesium is very common in general population. Additionally, there are categories of population that are even more predisposed to hypomagnesaemia. Top athletes represent a population category predisposed to magnesium deficiency due to increased urinary and sudorific losses, and in case of heavyweight disciplines, due to a decreased dietary intake. Many studies supported the role of magnesium in athletic performance and showed that magnesium increased the physical endurance and improved the force indices and muscle metabolism in athletes that had a rich diet in magnesium or received magnesium supplements. It is still uncertain whether the positive effects of magnesium supplementation in athletic performance are due to pharmacological actions of magnesium itself or to the reversal of a pre-existing magnesium deficiency. Therefore, the purpose of this article is briefly review of Magnesium importance in human health and athletics performance, various hypotheses that may explain magnesium's physiologic action mechanisms but also possible pathways for magnesium deficiency's correction.
Key words: *magnesium, athlete, deficiency, supplementation.*

Some basics of Magnesium

Magnesium is the second most abundant mineral in cells after potassium, but the two ounces or so found in the typical human body is present not as metal but as magnesium ions (positively-charged magnesium atoms found either in solution or complexed with other tissues, such as bone). Roughly one quarter of this magnesium is found in muscle tissue and three-fifths in bone; but less than 1% of it is found in blood serum, although that is used as the commonest indicator of magnesium status.

This blood serum magnesium can be further subdivided into free ionic, complex-bound and protein-bound portions, but it's the ionic portion that's considered most important in measuring magnesium status, because it is physiologically active.

The importance of magnesium as an essential nutrient has been emphasised as early as 1932 by Kruse et al., who induced an acute magnesium deficiency in rats by limiting the dietary intake of this element to 0.09mEq/kilogram. Hypo-magnesaemia produced hyperemia, neuromuscular progressive irritability that eventually precipitated fatal convulsions in these animals (1).

The role of Magnesium in the body

Mg is a cofactor involved in many enzymatic systems (more than 300 biochemical reactions), being necessary for protein synthesis, functioning of nervous and muscular systems, regulation of blood pressure and glycaemia, bone metabolism (2-4). Most studies regarding magnesium metabolism and homeostasis have shown that magnesium interferes with transmembrane sodium and potassium ion flow in smooth muscle, which explains its involvement in many physiological processes and why magnesium deficiency is linked to many pathological conditions of the cardiovascular, skeletal and nervous systems (5-7).

It also affects the active transmembrane transport of calcium and potassium ions, being a known calcium-channel blocker, and through these processes influences nerve conduction, muscular contraction and cardiac rhythm (4).
Its presence is necessary for both aerobic (oxidative phosphorylation) and anaerobic (glycolysis) energy production processes, both indirectly, as a component of ATP-Mg complex and directly, as an enzymatic activator (8).
It plays an important role in cell division, participating in DNA, RNA and glutathione synthesis (9).
It is essential in osteoblasts and osteoclasts functioning, vitamin D activation, calcitonin release and suppression of parathyroid hormone release (10). Magnesium depletion disturbs calcium homeostasis, hypocalcaemia being sometimes determined by a moderate or severe deficiency of Mg. The inadequate intake of magnesium stimulates extracellular depositions of calcium (calcifications). Although Mg deprivation increases intestinal absorption and renal reabsorption via a still unknown mechanism, if this process continues, Mg in bones will play a major role in maintaining a normal extracellular level of magnesium and up to 30% of intra osseous magnesium can be mobilized for this purpose. Research has shown that it is important to maintain an optimal ratio between calcium and magnesium intake, whose ideal value is 1:1. These mechanisms can explain the significant correlations between magnesium level and bone density, published by some authors (11, 12) and why they recommend Mg supplementation for menopausal women as a way to prevent osteoporosis (13).
A group of researchers from the Department of Cognitive Sciences of the Massachusetts Institute of Technology has shown that Magnesium regulates the activity of a key receptor involved in memory and learning processes and that a normal level of Magnesium in the cerebrospinal fluid is essential for maintaining the plasticity of the cerebral synapses. The authors claimed that an increase of magnesium level in the brain would ameliorate the cognitive processes and memory (14). In fact, the authors of an earlier study (1996) also reported positive effects after magnesium administration to children with ADHD. These effects were attributed to an improvement in cerebral activity and a sedating effect of magnesium on CNS (15).

Recommended dietary allowances for Magnesium and sources of magnesium

The UK recommended intake for magnesium (the daily amount deemed adequate to prevent deficiencies in 97.5% of the UK population) is set at 300 mgs for men and 270 mgs for women (16). The US has recently revised its figures upwards and now recommends an intake of 400 mgs per day for men aged 19-30 and 420 for those over 30; the figures for women under and over 30 are 300 and 310 mgs per day respectively (16, 17). However, some investigators believe these should be set even higher at 450-500mg/day (18).
Daily allowance of magnesium has been set by the Institute of Medicine in Washington in terms of age and sex (see table I) (19).

Table I. Recommended Dietary Allowances (RDAs) for Magnesium (1)

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	30 mg*	30 mg*		
7–12 months	75 mg*	75 mg*		
1–3 years	80 mg	80 mg		
4–8 years	130 mg	130 mg		
9–13 years	240 mg	240 mg		
14–18 years	410 mg	360 mg	400 mg	360 mg
19–30 years	400 mg	310 mg	350 mg	310 mg
31–50 years	420 mg	320 mg	360 mg	320 mg
51+ years	420 mg	320 mg		

Institute of Medicine (IOM). Food and Nutrition Board. Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D and Fluorideexternal link icon. Washington, DC: National Academy Press, 1997.
*Adequate Intake (AI)

Foods with increased content of fibres, such as vegetables, spinach, seeds, nuts and whole grains are reach sources of magnesium (4). Fruit, meat and fish supply poor levels, as do refined foods. Magnesium is a fairly soluble mineral, which is why boiling vegetables can result in significant losses; in cereals and grains, it tends to be concentrated in the germ and bran, which explains why white refined grains contain relatively little magnesium by comparison with their unrefined counterparts (20). Contrary to common belief, milk and dairy products are not particularly rich sources of magnesium. The magnesium content of plant foods tends to reflect soil magnesium concentrations and growing conditions, especially as magnesium is not routinely added to soils by farmers during intensive fertilization (21). Water also contains magnesium in different proportions from 1/mg/l to more than 120 mg/l (22).
From the total dietary intake of magnesium, only 30-40% is intestinally absorbed (3).

Magnesium deficiencies

Many people fall short of optimum magnesium intakes, and this has been confirmed in a number of studies. Dietary intakes of magnesium in the United States have been declining over the last 100 years from about 500 mg/day to 175-225mg/day (23) and amore recent national survey suggested that the average magnesium intake for women is as low as 228mgs per day (24). But since this figure is derived using a one-day diet recall method, it may actually be an overestimate of actual magnesium intakes (25). American researchers found that more than 60% of US adults were failing to meet even the previous (lower) RDA for magnesium (26). Recent data provided by the National Health and Nutrition Examination Survey (NHANES) have shown that the diet of most Americans included suboptimal levels of magnesium, except for those who took magnesium supplements (27, 28). Another study published in 2005, showed that 2/3 of Americans have a dietary intake of magnesium below the recommended minimal level, 19% of them even below half of this level (29). Meanwhile, the UK's Food Standards Agency estimates that the average daily intake of magnesium in Britain for both men and women is just 227 mgs - only two thirds of the US recommended daily amount (RDA).
Risk groups for magnesium deficiency. Although magnesium is considered an effective treatment for many severe diseases, (diabetes, asthma, high blood pressure, metabolic syndrome, preeclampsia and eclampsia, etc.), it is still uncertain whether the positive effects of magnesium supplementation in these medical conditions are due to pharmacological actions of magnesium itself or to the reversal of a pre-existing magnesium deficiency, responsible for their etiology or pathogenesis. This hypothesis is very probable, since a low dietary intake of magnesium is very common in general population.
Additionally, there are categories of population that are even more predisposed to hypomagnesaemia, because magnesium homeostasis involves the intestine, kidney and osseous system, and the physiological disturbances of these organs affect magnesium metabolism (30).
Magnesium absorption takes place mostly in jejunum and ileum via an active transcellular diffusion process and a passive mechanism mediated by a cationic electrochemical gradient. Intestinal malabsorption caused by Chron's disease, celiac disease, enteritis and surgical removal of small intestine, especially ileum (small bowel syndrome), can induce hypomagnesaemia (3). The proton pump inhibitors, used to treatment of hyperacidic gastritis**,** gastric and duodenal ulcer and gastro-esophageal reflux can produce hypomagnesaemia, too (31-34).
Renal function also influences significantly magnesium metabolism. Kidneys filtrate approximately 2.4 g/day of Mg, but most of it is reabsorbed and only 5% is normally excreted in urine. Diuretics can affect the level of magnesium; loop and thiazide diuretics decrease magnesium level, due to an increased urinary excretion, while K+ sparing diuretics (amiloride and spironolactone) augment it, due to an increased renal reabsorption (35).
Diabetes mellitus can secondarily produce a magnesium deficit by increasing the urinary losses of magnesium (36, 37).
Older people also represent a population category with an increased risk for inadequate levels of magnesium, due to a reduction of intestinal absorption and an increased renal excretion as compared to younger population (38). Furthermore, thelong-term use of medicationin many aged patients interferes with magnesium homeostasis (39).
Alcoholism reduces the plasma level of magnesium through mechanisms that involves both a decrease in intestinal absorption due to pancreatitis and hepatic steatorrhea increased

urinary excretion due to a renal dysfunction. Other possible mechanisms are secondary hyper-aldosteronism caused by a hepatic dysfunction, phosphorus and Vitamin D deficiency, ketoacidosis etc (40).

As we will show further on, top athletes also represent a population category predisposed to magnesium deficiency due to increased urinary and sudorific losses, and in case of heavyweight disciplines, due to a decreased dietary intake.

Medical conditions associated with magnesium deficiency. The symptoms of an early magnesium deficiency are nausea, vomiting, fatigue, headache, insomnia, confusion, irritability, muscle weakness, while an advanced hypomagnesaemia produces muscle cramps, paresthesia, cardiac arrhythmia and coronary spasm. A very low level of magnesium generates severe hypocalcaemia and hypokalaemia that can be corrected only through simultaneous administration of magnesium (3, 4).

A few scientific studies published in the early 1980s supported a possible involvement of magnesium deficiency in coronary spasm, due to an effect on vessel smooth muscles (41). Many subsequent studies have found significant correlations between inadequate levels of magnesium and various cardiovascular pathological conditions such as high blood pressure, ischemic heart disease and arrhythmia (42-46). An epidemiological study that followed the evolution of 12000 subjects over a period of 19 years showed an inverse relationship between magnesium plasma concentration and mortality rate produced by ischemic vascular diseases, data suggesting that the subjects with the highest level of plasmatic magnesium had a 30% lower risk of developing heart disease (47).

Hypomagnesaemia has also been linked to diabetes mellitus due to the role that magnesium plays in maintaining glycaemia and diminishing resistance to insulin (48-50). Although American Diabetes Association considers that there are no convincing proves to include magnesium in the treatment of diabetes mellitus (51), many studies have demonstrated that magnesium had a positive effect on decreasing glycaemia in diabetics (50-53).

Bronchial asthma has also been correlated with inadequate levels of magnesium (54, 55) and a couple of recent studies supported the positive effect of Mg supplementation on bronchial asthma, due to a decrease of bronchial mucosa sensitivity in children (56, 57). Magnesium has been proposed for prophylaxis of migraine crisis, the positive effects being due to its involvement in the vasoconstriction/vasodilatation processes and release of neurotransmitters (58- 60).

The use of magnesium in treatment of depression is still uncertain, but a low level of magnesium has been associated with a low level of serotonin (61, 62).

The role of Magnesium in athletic performance

Magnesium effect on energy production.

Magnesium has been one of the most used supplements for enhancing athletic performance (63). Many studies supported the role of magnesium in athletic performance and showed that magnesium increased the physical endurance (64, 65) and improved the force indices and muscle metabolism in athletes that had a rich diet in magnesium or received magnesium supplements (66).

Magnesium's pivotal role in both anaerobic and aerobic energy production, particularly in the metabolism of adenosine triphosphate (ATP), the "energy currency" of the body. The US researchers concluded that low dietary magnesium impairs function during exercise. The mechanisms behind this effect are unclear, but it seems likely that a magnesium shortfall can cause a partial uncoupling of the respiratory chain, increasing the amount of oxygen required to maintain ATP production. There is also evidence that a magnesium shortfall boosts the energy cost, and hence oxygen use of exercise because it reduces the efficiency during exercise of muscle relaxation, which accounts for an important fraction of total energy needs during an activity like cycling (67). One study of male athletes supplemented with 390 mgs of magnesium per day for 25 days resulted in an increased peak oxygen uptake and total work output during work capacity tests (68); in another, on sub-maximal work, supplemental magnesium elicited reductions in heart rate, ventilation, oxygen uptake and carbon dioxide production (69); in a third, physically active students, supplemented with 8 mgs of magnesium per kilo of body weight per day, experienced significant increases in endurance performance and decreased oxygen consumption during standardized, sub-maximal exercise (70).

As a result of some studies performed on gerbils, the authors noticed that, when compared to

control a group, the group of animals that received parenterally a solution of magnesium sulphate had an increased length of physical performance and also experienced increased levels of glycaemia and decreased levels of lactate production during exercise, effects that were attributed to magnesium (71, 72).
A recent study on the use of magnesium in 1,453 adults demonstrated that higher serum (blood) magnesium levels were associated with better muscle integrity and function. This included grip strength, lower-leg muscle power, knee extension torque and ankle extension strength. These results highlight the importance of magnesium for improving muscle function and performance (73).
An earlier study showed that a magnesium supplementation of 8 mg/kg associated to a strength training at 3 times per week produced a significantly larger increase in strength compared to the control group that followed the same training protocol, but without magnesium supplementation. The authors concluded that the result was due to the role that magnesium plays in protein synthesis at the level of ribosomes (74).
An increase of strength indices can be due to the stimulation of testosterone secretion that was induced by physical training.
A 2011 study showed that a dose of magnesium of 10mg/kg produced a greater increase of testosterone level in a group of tae kwon do athletes, when compared to the control group that didn’t receive the supplement. At the end of the study, the authors concluded that magnesium administration produced an increased level of testosterone both in sedentary and trained subjects, but the maximal increase was noticed when magnesium supplementation was associated with training (75).
However, other studies carried out on physically active people with 'normal' serum magnesium and muscle magnesium concentrations have found no functional or performance improvements associated with supplementation (76, 77).
On the evidence available so far, the scientific consensus is that extra magnesium can enhance performance when (as is all too often the case) magnesium intakes fall below optimum levels. But in subjects already consuming magnesium at or above this optimum level, there is little hard evidence to suggest that taking more confers extra benefits.
The negative influence that magnesium depletion has it on athletic performance can also be explained by its effect on body composition. In this respect, we mention the fact that a group of Japanese researchers claimed that there is a corre-elation between magnesium level and body fat percent, reporting that increased body mass indices had a statistically significant association to low level of magnesium (78). In fact, a few authors stated that a deficit of magnesium is involved in pathogenic mechanisms of the Metabolic Syndrome, characterized by the triad of obesity, diabetes mellitus and hyper-cholesterolemia, through a pro-inflammatory effect, but this effect manifests itself only when magnesium daily intake is below 10% of normal. Although a moderate deficit of magnesium does not initiate an inflammatory process, it has an aggravating effect, especially when a simultaneous oxidative stress is present (79). Many studies have found correlations between the deficit of magnesium and the C reactive protein level, a marker of inflammation (80, 81).
Magnesium effect on postexercise recovery. An inadequate level of magnesium can affect the recovery after exercise and the process of a normal adaptation to effort.
A hyperactivity of the sympathetic system, induced by a magnesium deficit, produces an increased release of norepinephrine and cortisol, which represents a defective adaptation to physical exercise that normally needs a strong vagal tonus.
A study published in 2009 by Kazuto Omiya et al. concluded that the abnormal exercise tolerance associated with chronic insomnia is caused by a hypersensitivity of cardiac rhythm to sympathetic system stimulation, which appears as a result of a decreased intracellular magnesium (78).Other authors also claimed that an optimal level of magnesium in the body is correlated with a reduction in sympathetic system activity, low stress level, good relaxation and better sleep (82).
Although it does not support the idea of a positive effect of magnesium supplements on athletic performance, a 2013 study reported a decreased postexercise blood pressure, both in anaerobic and aerobic exercise (83).
Furthermore, the link between magnesium deficiency and a low sensitivity to insulin suggests a defective replenishment of glycogen stores in hypomagnesaemia and, through this mechanism, an inadequate postexercise recovery in athletes that present this disequilibrium.
Magnesium is necessary for normal muscular contraction and relaxation. Low magnesium levels are associated with an increased incidence of

muscle cramps, which can often be reversed with the addition of magnesium supplements. In one research trial, swimmers taking magnesium supplements during their training and competitions found an 86% reduction in muscle cramps. The reductions occurred after only three days of supplementation (73).

Magnesium deficiencies in athletes. Even athletes, who might be expected to take greater care with their diets, are not immune from magnesium deficiency; for example, studies carried out in 1986/87 revealed that gymnasts, footballers and basketball players were consuming only around 70% of the RDA (84, 85), while female runners fared even worse, with reported intakes as low as 59% of the RDA (86).

Some authors claim that the positive results of magnesium supplementation on athletic performance a reduce till a correction of magnesium deficit that characterizes top athletes and less to a magnesium effect *per se* (65).

There are a couple of scientific studies that claim that the decrease of magnesium is a metabolic modification induced by a sustained physical training. An analysis performed in Israel on metabolic effects of an intense training carried out over a period of 6 months, showed that the study subjects presented modifications of more metabolic parameters, the decrease of magnesium serum concentration being considered a primary modification. It's worth noticing the that the level of magnesium didn't change immediately after the race, but only 72 hours later and remained reduced over a long period of time, which varied between 18 days and 3 months (87).

In their analysis regarding the relationship between magnesium and physical exercise, published in 2006, Nielsen and Lukaski warned that physical exercise induces a redistribution of magnesium in the body to accommodate increased metabolic needs. Urinary and sweat losses increase the requirements of magnesium in athletes who train strenuously by more than 10-20%.Dietary intake of magnesium in general population is considered insufficient for these athletes. In addition, the athletes that participate in heavyweight categories (e.g., weightlifting, boxing, etc.,) but also the female gymnasts, whose performance require a low body weight, are even more predisposed to magnesium deficiency, due to a low intake caused by a caloric restriction (65).

Magnesium supplementation may produce improvement of athletic performance by correcting the low status of magnesium in athletes, which is associated with an increased demand of oxygen for the same effort and a decreased exercise endurance. The same authors consider that in athletes the risk of hypovitaminoses, especially for fat soluble vitamins, is much smaller than the risk of mineral deficiency (88).

Bohl and Volpe, in their analysis concerning magnesium involvement in physical exercise, published in 2002, also showed that the dietary reference intakes for magnesium, in amount of 310-420 mg/day, are insufficient for those who participate in physical training and enumerated a couple of studies that claimed that magnesium improves athletic performance (89).

On the other hand, regarding the direct effect of magnesium on athletic performance, a recent study (2014) has showed that magnesium supplementation produced an increase of performance indices in volleyball players, even in those athletes who hadn't had low levels of magnesium (90).

Magnesium deficiency and sudden death risk in athletes. Of paramount importance regarding the predisposition of top athletes to inadequate levels of magnesium is the association of hypomagnesaemia with an increased risk of sudden death by favouring arrhythmias (91). It is well known that this risk is higher in top athletes than in general population (92). Stendig and Lindberg stated thatsudden death in athletes during physical exercise is linked to a persistent deficit of magnesium (93). Endurance running, due to excessive sweat losses, can induce a severe deficiency of magnesium towards the end of the race, increasing significantly the risk of a serious arrhythmia (94).

Testing For Magnesium Status

Our body contains approximately 25 g of Mg out of which 50-60% lies in bones, 27% in musculature, 19% in other soft tissues and less than 1% in plasma (95). Intracellular Mg is mostly bound by chelators, such as ca ATP, ADP, proteins, DNA, RNA and citrate. Physiological concentrations range between 0.75 and 0.95mmol/l (96), a blood value below 0.75 mmol/l being considered hypomagnesaemia (97).

Since only 0.3% of the total Mg is present in serum, magnesium serum concentration is considered a poor indicator of Mg status. There have been proposed many methods to investigate the level of Mg in the body, such as measuring its

concentration in saliva and urine, Mg load tolerance tests, etc., but none was considered satisfactory (98). Most experts agreed that a correlation between clinical manifestations and lab values could be the best way to diagnose hypomagnesaemia (99, 100).
Total blood magnesium (TMg) is the most widely used assay, but this has the disadvantage of including complex and protein-bound magnesium, whereas it's the ionic portion that's physiologically active. This test is also insensitive to the movements of magnesium that occur within the body as a result of exercise. However, the recent introduction of ion-selective electrode (ISE) technology now enables scientists to measure ionic magnesium directly, and this is considered one of the best methods. But even then it's not all plain-sailing, since ionic magnesium levels tend to fluctuate significantly according to the time of day, with higher values recorded in the morning and lower values in the evening. This circadian magnesium rhythm is believed to be linked to changes in physical activity levels through the day, but the whole subject of 'intra-body' magnesium fluctuations remains poorly understood.
Nevertheless, the best results seem to be obtained when ionic magnesium is sampled from fasting, non-exercised subjects first thing in the morning (101).

Magnesium Supplementation

Oral supplementation. IOM (Institute of Medicine) recommendations regarding the amount of Magnesium that can supplement the dietary intake for healthy persons are presented in table II (19). These recommendations were made in 1996 and they should be updated since current dietary intake, due to an intensive agricultural production and an increased processing of food, contains increasingly smaller amounts of this element, which is essential for the normal functioning of the human body.
Although oral supplementation of Mg is possible, the processes of remineralisation and replenishment of intracellular and extracellular Mg take time and are influenced by many factors. An inversely proportional relationship has been described between magnesium intake and its rate of absorption, which varied between 65% (in case of a low intake of magnesium) and 11% (high ingestion). When a high dose of magnesium is administered, there is another factor that interferes with Mg absorption, namely an accelerated intestinal transit, due to an increased osmolarity and stimulation of peristalsis (102). In addition, concomitant administration of other mineral supplements, such as zinc or calcium, can negatively intestinal absorption rate of Mg.
The inexpensive oral supplements of magnesium generally contains magnesium oxide, which is poorly absorbed (4%). Magnesium citrate is much better absorbed (50%), but is not so cheap. Out of a daily intake of 300-400 mg elemental Mg, only an amount of 12-16 mg can be used (the ionized form).
A few studies showed that soluble preparations are generally better absorbed and magnesium aspartate, citrate, lactate and chloride have a superior bioavailability compared to magnesium oxide and sulphate (103-106).

Table II. Tolerable upper intake levels (ULs) for supplemental Magnesium (19)

Age	Male	Female	Pregnant	Lactating
Birth to 12 months	None established	None established		
1–3 years	65 mg	65 mg		
4–8 years	110 mg	110 mg		
9–18 years	350 mg	350 mg	350 mg	350 mg
19+ years	350 mg	350 mg	350 mg	350 mg

Institute of Medicine (IOM). Food and Nutrition Board. Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D and Fluorideexternal link icon. Washington, DC: National Academy Press, 1997.

Topical Supplementation

Topical or transdermal administration of magnesium is an interesting alternative to oral route, considering the many interferences in the absorption of magnesium oral supplements. Transdermal magnesium is applied topically, using either magnesium lotions or magnesium bath salts.

The local effect on mucosae and skin is well documented. There have been some studies that showed the positive effects of nebulized magnesium sulphate on bronchial asthma (107) and on skin cells proliferation and differentiation (108).

In fact, some of the benefits of Dead Sea bath salts are attributed not to the high content of salt, but to magnesium itself, the prevalent cation of Dead Sea water (109).

Comparative studies regarding the effects of a solution whose salinity was similar to that of Dead Sea water, showed cleared benefits over a normal saline solution, both in the treatment of ENT conditions (such as chronic sinusitis) (110) and rheumatoid arthritis (111).

The hypothesis of topical supplementation of magnesium, although appealing, faces a challenge: transdermal diffusion of magnesium or its salts. Unfortunately, there are few studies in scientific literature concerning transdermal absorption of magnesium. We are of the opinion that the benefits obtained in the treatment of rheumatoid arthritis, using solutions with a high content of magnesium, represents a strong argument that magnesium effectively crosses the skin barrier.

In an earlier study (1977), a couple of authors verified the transdermal absorption of a Magnesium Sulphate solution, of various concentrations, applied on skin for 8 hours. The results showed that the transdermal absorption of magnesium increased linearly with solution concentration and skin surface area (112).

More recently, Dr R.H. Waring et al., from the University of Birmingham, School of Biosciences, have published an online study regarding transdermal absorption of magnesium after daily baths with Epsom Salt (1% solution of Magnesium sulphate).

Each daily bath lasted for 12 minutes, over a period of 7 days. Plasmatic concentrations of magnesium were determined before and at 2 hours after hydrotherapy, while urinary concentration of magnesium was measured at 24 hours post immersion.

The results showed an increase of magnesium plasma concentrations from 104.68 ± 20.76 ppm/ml before experiment to 114.08 ± 25.83 ppm/ml after the first bath. Plasmatic concentration of magnesium increased progressively over the course of treatment, reaching 140.98 ± 17.00ppm/ml after 7 days.

The author concluded that body immersion in a solution of magnesium sulphate caused an increase in plasmatic concentration of magnesium. The renal excretion of magnesium increased significantly after the first day, from an initial value of 81 ± 44.26 ppm/ml to 198.93 ± 97.52 ppm/m at 24 hours after the first bath. The greatest increases of urinary excretion of magnesium were recorded in those subjects who presented the smallest increases of plasmatic magnesium, and the author hypothesized that in these subjects magnesium ions that crossed the skin barrier were excreted, because the plasmatic level of magnesium had already been optimal. However, urinary excretion of magnesium decreased over the course of 7 days, so that at the end of the 7th day it reached values similar to those recorded at the beginning of the treatment (118.43 ± 51.95), although the plasma level increased, implying that after an extended application of transdermal magnesium, this mineral accumulates in the body.

The authors recommended a protocol of 2-3 baths a week, in a solution of 1% $MgSO_4$ (that is 600mg in 60 l water), for a maximal benefit of general population.

The study concluded that magnesium sulphate (Epsom salt) baths are an easy and certain method to increase magnesium level in the body (113).

A pilot study published by Watkins K and Josling PD, initially in European Journal for Nutraceutical Research, in April 2010, and then in “The nutrition Practitioner”, called “A pilot study to determine the impact of transdermal magnesium treatment on serum levels and whole body Ca-Mg ratio” also asserts that magnesium effectively crosses the skin barrier.

The authors showed that transdermal application of a 31% magnesium chloride formulation could alter serum magnesium levels and whole body calcium/magnesium ratios.

After 12 weeks’ treatment 89% of subjects increased their cellular magnesium levels by 59.7% on the average. Similar results using oral supplementation were noticed only after 9-24 months (114).

An aqueous solution of magnesium chloride, also known as “magnesium oil” is used as a massage lotion for treating headache and muscle cramps, and certain authors claim that the absorption of this solution is good enough to be used as a treatment for magnesium deficiency

References

1. Kruse HD, Orent ER, McCollum EV (1932*).* Studies on magnesium deficiency in animals. Symptomatology resulting from magnesium deprivation. *J Biol Chem;* 96: 519-539.
2. Food and Nutrition Board (1997). Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride *Washington, DC: National Academy Press.*
3. Rude RK (2010). Magnesium. In: *Encyclopedia of Dietary Supplements*. 2nd ed. Coates PM, Betz JM, Blackman MR, Cragg GM, Levine M, Moss J, White JD, eds. New York, NY; pp 527-37.
4. Rude RK. Magnesium. In: Ross AC, Caballero B, Cousins RJ, Tucker KL, Ziegler TR (2012*). Modern Nutrition in Health and Disease*. 11th ed. Baltimore, Mass: Lippincott Williams & Wilkins; pp159-75.
5. Dacey M. J (2001.) Hypomagnesemic disorders. *Crit. Care Clin;*17:155-173;
6. Iannello S. & Belfiore (2001) Hypomagnesemia. A review of pathophysiological, clinical and therapeutical aspects. *Panminerva Med*.;43:177-209.
7. Innerarity, S. (2000). Hypomagnesemia in acute and chronic illness. *Crit. Care Nurs.* Q. 23:1-19.
8. Altura, B. M. Basic biochemistry and physiology of magnesium: A brief review. *Magnesium and Trace Elements* 10:167–171
9. Hartwig A. (2001). Role of magnesium in genomic stability Mutation *Research/Fundamental and Molecular Mechanisms of Mutagenesis;* Volume 475, Issues 1–2, Pages 113–121
10. Rude RK, Singer FR, Gruber HE. (2009) Skeletal and hormonal effects of magnesium deficiency. *J Am Coll Nutr*; 28:131–41.
11. Tucker KL (2009). Osteoporosis prevention and nutrition. *Curr Osteoporos Rep*; 7: 111-7.
12. Mutlu M, Argun M, Kilic E, Saraymen R, Yazar S. (2007*)* Magnesium, zinc and copper status in osteoporotic, osteopenic and normal post-menopausal women. *J Int Med Res*; 35: 692-5.
13. Aydin H, Deyneli O, Yavuz D, Gözü H, Mutlu N, Kaygusuz I, Akalin S (2010). Short-term oral magnesium supplementation suppresses bone turnover in postmenopausal osteoporotic women. *Biol Trace Elem Res;* 133: 136-43.
14. Abumaria N, Wu LJ, Huang C, Zhang L, et al. (2010*).* Enhancement of learning and memory by elevating brain magnesium. *Neuron;* 65: 165–177.
15. Starobrat-Hermelin B, Kozielec T (1997). The effects of magnesium physiological supplementation on hyperactivity in children with attention deficit hyperactivity disorder (ADHD). Positive response to magnesium oral loading test. *Magnes Res.;* 10(2): 149-56.
16. UK Food Standards Agency/COMA.
17. US Institute of Medicine and National Academy of Sciences.
18. Altura BM, Altura BT (1996). Role of magnesium in patho-physiological processes and the clinical utility of magnesium ion selective electrodes *Scandinavian Journal of Clinical and Laboratory Investigation*;56 (Supplement 224): 211-234.
19. Institute of Medicine (IOM) (1997). Food and Nutrition Board. Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride *Washington, DC: National Academy Press.*
20. Hamilton A (2006). Just how important is magnesium to athletes? *www.bodybuilding. com/fm/peak32.htm.*
21. National Research Council of Canada: Ottawa (1979) ON: NRCC Publications.
22. Azoulay A, Garzon P, Eisenberg MJ. (2001). Comparison of the mineral content of tap water and bottled waters. *J Gen Intern Med;*16:168-75.
23. Altura BM (1994). Introduction: importance of Mg in physiology and medicine and the need for ion selective electrodes**,** S*candinavian Journal of Clinical and Laboratory Investigation*; 54 (Supplement 217):5-9.
24. Peninngton JA (2000). Current detery intakes of trace elements and minerals in *Clinical Nutrition of the Essential Trace Elements and Minerals*. *The Guide For Professionals*, Eds. J.D.Bogden and L.M.Klevay, Spriger; pp 49-67, ISBN : 978-61737-090-8.
25. Anderson, R.A.Bryden, N.A.Polansky, M.M. (1993). Dietary intake of calcium, chromium, copper, iron, magnesium, manganese, and zinc (duplicate plate values corrected using derived nutrient intake) , *J Am Diet Assoc;* 93:462-464.
26. Institute of Medicine (1997). Food and Nutrition Board, Washington, DC: National Academy Press.
27. Moshfegh A, Goldman J, Ahuja J, Rhodes D, LaComb R. (2009). What We Eat in America, NHANES 2005-2006: Usual Nutrient Intakes from Food and Water Compared to 1997 Dietary Reference Intakes for Vitamin D, Calcium, Phosphorus, and Magnesiumexternal link icon. *U.S. Department of Agriculture, Agricultural Research Service*
28. Bailey RL, Fulgoni III VL, Keast DR, Dwyer JD (2011). Dietary supplement use is associated with high intakes of minerals from food sources. *Am J Clin Nutr*; 94: 1376-81.

29. King, D. et al. (2005). Dietary Magnesium and C-reactive Protein Levels, *J. Am. Coll. Nutr.*; 24(3):166-71.
30. McLean RM (1994). Magnesium and its therapeutic uses: a review. *Am J Med.;* 96(1): 63-76.
31. Broeren MA, Geerdink EA, Vader HL, van den Wall Bake AW. (2009). Hypomagnesium induced by several proton-pump inhibitors. *Ann Intern Med.* 151(10); 755-756.;
32. Hoorn EJ, MD, van der Hoek J, de Man RA, Kuipers EJ, et al (2010). A case series of proton pump inhibitor–induced hypomagnesemia. *Am J Kidney Dis.* February 25 (epub)
33. Kuipers MT, Thang HD, Arntzenius AB. (2009). Hypomagnesaemia due to use of proton pump inhibitors—a review. *Neth J Med*. 67(5);169-172
34. Mackay JD and Bladon PT. (2010) Hypomagnesaemia due to proton-pump inhibitor therapy: a clinical case series. *QJ Med* ; 103:387-395.
35. Sarafidis PA, Georgianos PI, Lasaridis AN. (2010). Diuretics in clinical practice. Part II: electrolyte and acid-base disorders complicating diuretic therapy. *Expert Opin Drug Saf* ; 9: 259-73.
36. Chaudhary DP, Sharma R, Bansal DD. (2010). Implications of magnesium deficiency in type 2 diabetes: a review. *Biol Trace Elem Res*; 134: 119–29.
37. Tosiello L. (1996). Hypomagnesemia and diabetes mellitus. A review of clinical implications. *Arch Intern Med;* 156: 1143-8.
38. Musso CG (2009). Magnesium metabolism in health and disease. *Int Urol Nephrol*; 41: 357-62.
39. Barbagallo M, Belvedere M, Dominguez LJ. (2009.) Magnesium homeostasis and aging. Magnes Res; 22: 235-46.
40. Rivlin RS (1994). Magnesium deficiency and alcohol intake: mechanisms, clinical significance and possible relation to cancer development (a review). *J Am Coll Nutr*; 13: 416–23.
41. Prasad DM, Turlapaty V, Altura BM (1980). Magnesium deficiency produces spasms of coronary arteries: relationship to etiology of sudden death ischemic heart disease. *Scienc*e; 208: 198-200.
42. Cappuccio, F. P. (2000). Sodium, potassium, calcium and magnesium and cardiovascular risk. *J. Cardiovasc. Ris*k; 7:1-3
43. Mizushima, S., Cappuccio, F. P., Nichols, R. & Elliott, P. (1998). Dietary magnesium intake and blood pressure: a qualitative overview of the observational studies. *J. Hum. Hypertens.* 12:447-453;
44. Jee, S. H., Miller, E. R., 3rd, Guallar, E., Singh, V. K., Appel, L. J. & Klag, M. J. (2002). The effect of magnesium supplementation on blood pressure: a meta-analysis of randomized clinical trials. *Am. J. Hypertens*. 15: 691-696.
45. Ceremuzynski, L., Gebalska, J., Wolk, R. & Makowska, E. (2000). Hypomagnesemia in heart failure with ventricular arrhythmias. Beneficial effects of magnesium supplementation. *J. Intern. Med*. 247: 78-86.
46. Shechter, M., Sharir, M., Labrador, M. J., Forrester, J., Silver, B. & Bairey Merz, C. N. (2000). Oral magnesium therapy improves endothelial function in patients with coronary artery disease. *Circulation*; 102: 2353-2358.
47. Ford E S (1999). Serum magnesium and ischaemic heart disease: findings from a national sample of US adults *Int. J.Epidemiol;* 28: 645-651.
48. Larsson SC, Wolk A. (2007). Magnesium intake and risk of type 2 diabetes: a meta-analysis. *J Intern Med*; 262: 208-14.
49. Rodriguez-Moran M, Simental Mendia LE, Zambrano Galvan G, Guerrero-Romero F. (2011). The role of magnesium in type 2 diabetes: a brief based-clinical review. *Magnes Res*; 24:156-62.
50. Simmons D, Joshi S, Shaw J. (2010). Hypomagnesaemia is associated with diabetes: not pre-diabetes, obesity or the metabolic syndrome. *Diabetes Res Clin Pract*; 87: 261-6.
51. Evert AB, Boucher JL, Cypress M, Dunbar SA, Franz MJ, Mayer-Davis EJ, Neumiller JJ, Nwankwo R, Verdi CL, Urbanski P, Yancy WS Jr. (2013). Nutrition therapy recommendations for the management of adults with diabetes. *Diabetes Care*; 36: 3821-42.
52. Schulze MB, Schulz M, Heidemann C, Schienkiewitz A, Hoffmann K, Boeing H. (2007) Fiber and magnesium intake and incidence of type 2 diabetes: a prospective study and meta-analysis. *Arch Intern Med*; 167: 956–65.
53. Dong J-Y, Xun P, He K, Qin L-Q. (2011). Magnesium intake and risk of type 2 diabetes: meta-analysis of prospective cohort studies. *Diabetes Care*; 34: 2116-22.
54. Hill, J., Micklewright, A., Lewis, S. & Britton, J. (1997) Investigation of the effect of short-term change in dietary magnesium intake in asthma. *Eur. Respir. J*. 10: 2225-2229.
55. Hijazi N, Abalkhail B, Seaton A. (2000) Diet and childhood asthma in a society in transition: a study in urban and rural Saudi Arabia. *Thorax*; 55: 775-779.
56. Gilliland FD, Berhane KT, Li YF, Kim DH, Margolis HG. (2002). Dietary magnesium, potassium, sodium, and children's lung function. *Am J Epidemiol.;* 155(2): 125-131.

57. Gontijo-Amaral C, Ribeiro MA, Gontijo LS, Condino-Neto A, Ribeiro JD. (2007). Oral magnesium supplementation in asthmatic children: a double-blind randomized placebo-controlled trial. *Eur J Clin Nutr.;* 61(1): 54-60.
58. Sun-Edelstein C, Mauskop A. (2009) Role of magnesium in the pathogenesis and treatment of migraine. *Expert Rev Neurother*; 9:369–79.
59. Schürks M, Diener H-C, Goadsby P. (2008) Update on the prophylaxis of migraine. *Cur Treat Options Neurol;* 10: 20–9.
60. Holland S, Silberstein SD, Freitag F, Dodick DW, Argoff C, Ashman E. (2012). Evidence-based guideline update: NSAIDs and other complementary treatments for episodic migraine prevention in adults. *Neurology*; 78: 1346-53.
61. Nechifor M. (2009) Magnesium in major depression. *Magnes Res.;* 22(3): 163S-166S.
62. Eby GA, Eby KL. (2006). Rapid recovery from major depression using magnesium treatment .*Med Hypotheses*.; 67(2): 362-70.
63. Sousa M1, Fernandes MJ, Moreira P, Teixeira VH (2013). Nutritional supplements usage by Portuguese athletes.*Int J Vitam Nutr Res.;* 83(1): 48-58.
64. Wang ML, Chen YJ, Cheng F. (2014). Nigari (deep seawater concentrate) enhances the treadmill exercise performance of gerbils. *Biol Sport*.; 31(1): 69-72.
65. Nielsen FH, Lukaski HC. (2006). Update on the relationship between magnesium and exercise *Magnes Res.;* 19(3): 180-9.
66. Lukaski HC1.(2000) Magnesium, zinc, and chromium nutriture and physical activity.*Am J Clin Nutr.;* 72(2 Suppl): 585S-93S.
67. Bergstrom M, Hultman E (1988). Energy cost and fatigue during intermittent electrical stimulation of human skeletal muscle, *J Appl Physiol*,; 65: 1500-1505.
68. Rude RK (1993). Magnesium metabolism and deficiency, *Endocrinol Metab Clin N Am*; 22:377-395.
69. Vecchiet L, Pieralisi G, D'Ovidio ML, (1995). Effects of magnesium supplementation on maximal and submaximal effort, in *Magnesium and Physical Activity*, Ed. L. Vecchiet. Parthenon Publishing Group London, UK; pp 227-237.
70. Brilla LR, Gunter KB (1995). Effect of magnesium supplementation on exercise time to exhaustion, *Med Exerc Nutr Health;* 4: 230-233.
71. Cheng SM1, Yang LL, Chen SH, Hsu MH, Chen IJ, Cheng FC (2010). Magnesium sulfate enhances exercise performance and manipulates dynamic changes in peripheral glucose utilization.*Eur J Appl Physiol.;* 108(2): 363-9 . Epub 2009 Oct 9.
72. Chen YJ1, Chen HY, Wang MF, Hsu MH, Liang WM, Cheng FC.(2009). Effects of magnesium on exercise performance and plasma glucose and lactate concentrations in rats using a novel blood-sampling technique *Appl Physiol Nutr Metab.*; 34(6): 1040-7.
73. McDonald R1, Keen CL (1988). Iron, zinc and magnesium nutrition and athletic performance, *Sports Med.*; 5(3): 171-84**.**
74. Brilla LR1, Haley TF.(1992). Effect of magnesium supplementation on strength training in humans. *J Am Coll Nutr*.; 11(3): 326-9.
75. Cinar V1, Polat Y, Baltaci AK, Mogulkoc R. (2011). Effects of magnesium supplementation on testosterone levels of athletes and sedentary subjects at rest and after exhaustion *Biol Trace Elem Res*.;140(1): 18-23.
76. Manore M, Merkel J, Helleksen JM, Skinner JS, Caroll SS (1995). Longitudinal changes in magnesium status in untrained males: effect of two different 12-weeks exercise training programs and magnesium supplementation. In: *Sports Nutrition: Minerals and Electrolytes*, CV Kies and JA Driskel Eds, CRC Press Boca Raton, FL, USA; pp 179-187.
77. Terblanche S, Noakes TD, Dennis DC, Marais DW, Eckert M (1992). Failure of magnesium supplementation to influence marathon running performance or recovery in magnesium-replete subjects, *Int J Sports Nutr;* 2: 154-164.
78. Kazuto Omiya, Yoshihiro J Akashi, Kihei Yoneyama, Naohiko Osada, Kazuhiko Tanabe, Fumihiko Miyake (2009). Heart-Rate Response to Sympathetic Nervous Stimulation, Exercise, and Magnesium Concentration in Various Sleep Conditions *International Journal of Sport Nutrition and Exercise Metabolism*; 19: 127-135.
79. Nielsen F. (2010). Magnesium, inflammation, and obesity in chronic disease. *Nutrition Reviews*; 68(6): 333–340
80. King DE, Mainous AG , Geesey ME, Woolson RF. (2005). Dietary magnesium and C-reactive protein levels. *J Am Coll Nutr*.; 24: 166–171.
81. King DE, Mainous AG , Geesey ME, Egan BM, Rehman S. (2006). Magnesium supplement intake and C-reactive protein levels in adults. *Nutr Res.*; 26:193–196.
82. Nielsen, Forrest H., LuAnn K. Johnson, and Huawei Zeng (2010). Magnesium supplementation improves indicators of low magnesium status and inflammatory stress in adults older than 51 years with poor quality sleep *Magnesium Research* 23(4): 158-168.
83. Kass LS1, Skinner P, Poeira F.(2013). A pilot study on the effects of magnesium supplementation with high and low habitual dietary magnesium intake on resting and recovery from aerobic and resistance exercise and systolic blood pressure.*J Sports Sci Med*.;12(1):144-50.

84. Hickson JF Jr, Schrader J, Trischler LC (1986). Dietary intakes of female basketball and gymnastics athletes, *J Am Diet Assoc*; 86 (2): 251-253.
85. Hickson JF, Wolinsky I, Pivarnik JM, Neuman EA, Itak JE, Stockton JE.(1987). Nutritional profile of football athletes eating from a training table *Nutr Res*; 7: 27-34.
86. Zierath J, Kaiserauer S, Snyder AC (1986). Dietary patterns of amenorrheic and regularly menstruating runners. *Med Sci Sports Exerc*; 18 (suppl): S55-6.
87. Stendig-Linndberg G, Wacker WE. Shapiro Y. (1991). Long term effects of peak strenuous effort on serum magnesium, lipids, blood sugar in apparently healthy young men. *Magnesium Res* 4(1): 59-65.
88. Lukaski HC (2004). Vitamin and mineral status: effects on physical performance.*Nutrition*; 20(7-8): 632-44.
89. Bohl CH, Volpe SL. (2002). Magnesium and exercise.Crit Rev *Food Sci Nutr*; 42(6): 533-63.
90. Setaro L1, Santos-Silva PR, Nakano EY, Sales CH, Nunes N, Greve JM, Colli C (2014). Magnesium status and the physical performance of volleyball players: effects of magnesium supplementation. *J Sports Sci*; 32(5):438-45.
91. Eisenberg MJ (1992). Magnesium deficiency and sudden death (editorial), *AM Heart J*; 124(2): 544-549.
92. Marion BJ. (2003). Sudden death in young athletes. *NEJM* 349:1064-1075S.
93. Stendig-Lindberg G. (1992). Sudden death of athletes: is it due to long-term changes in serum magnesium, lipids and blood sugar. *J Basic Clin Physiol Pharmacol;* 3(2):153-64.
94. Beller GA, Maher JT, Hartely LH, Bass DE, Wacker WEC (1975). Changes in serum and sweat magnesium levels during work in the heat. *Aviat Space Environ Med*; 46: 709-12.
95. Volpe SL. Magnesium. In: Erdman JW, Macdonald IA, Zeisel SH (2012). *Present Knowledge in Nutrition*. 10th ed. Ames, Iowa; John Wiley & Sons; pp459-74.
96. Elin RJ. (2010). Assessment of magnesium status for diagnosis and therapy. *Magnes Res* ; 23:1-5.
97. Gibson, RS. (2005). *Principles of Nutritional Assessment*, 2nd ed. New York, NY: Oxford University Press.
98. Witkowski M, Hubert J, Mazur A. (2011). Methods of assessment of magnesium status in humans: a systematic review. *Magnesium Res;* 24: 163-80.
99. Terblanche S, Noakes TD, Dennis DC, Marais DW, Eckert M (1992). Failure of magnesium supplementation to influence marathon running performance or recovery in magnesium-replete subjects, *Int J Sports Nutr;* 2:154-164 .
100. Natural Medicines Comprehensive Database (2013). Magnesium.
101. Spencer H, Norris C, Williams D. (1994). Inhibitory effects of zinc on magnesium balance and magnesium absorption in man. *J Am Coll Nutr; 13*: 479-84.
102. Hassan Younes, Christian Demigné and Christian Rémésy (1996). Acidic fermentation in the caecum increases absorption of calcium and magnesium in the large intestine of the rat. *British Journal of Nutrition*; 75: 301-314.
103. Ranade VV, Somberg JC. (2001). Bioavailability and pharmacokinetics of magnesium after administration of magnesium salts to humans. *Am J Ther*; 8: 345-57.
104. Firoz M, Graber M. (2001). Bioavailability of US commercial magnesium preparations. *Magnes Res*; 14: 257-62.
105. Mühlbauer B, Schwenk M, Coram WM, Antonin KH, Etienne P, Bieck PR, Douglas FL. (1991). Magnesium-L-aspartate-HCl and magnesium-oxide: bioavailability in healthy volunteers. *Eur J Clin Pharmacol*; 40: 437-8.
106. Lindberg JS, Zobitz MM, Poindexter JR, Pak CY. (1990). Magnesium bioavailability from magnesium citrate and magnesium oxide. *J Am Coll Nutr*; 9: 48-55.
107. Walker AF, Marakis G, Christie S, Byng M. (2003). Mg citrate found more bioavailable than other Mg preparations in a randomized, double-blind study. *Mag Res;* 16: 183-91.
108. Blitz M, Blitz S, Hughes R (2005). Aerosolized magnesium sulfate for acute asthma: a systematic review *Chest.;* 128(1): 337-344.
109. Proksch, E., Nissen, H.-P., Bremgartner, M. and Urquhart, C. (2005). Bathing in a magnesium-rich Dead Sea salt solution improves skin barrier function, enhances skin hydration, and reduces inflammation in atopic dry skin. *International Journal of Dermatology*; 44: 151–157.
110. Friedman Michael, Vidyasagar Ramakrishnan, Joseph Ninos (2006). A Randomized, Prospective, Double-Blind Study on the Efficacy of Dead Sea Salt Nasal Irrigations *The Laryngoscope*; 116(6): 878–882.
111. Sukenik S, Neumann L, Buskila D, Kleiner-Baumgarten A, Zimlichman S, Horowitz J (1990). Dead Sea bath salts for the treatment of rheumatoid arthritis. *Clinical and Experimental Rheumatology*; 8(4): 353-357.
112. Wediga, J.H. Feldmanna, R.J. Maibach H.I. (1977). Percutaneous penetration of the magnesium sulfate adduct of dipyrithione in man *Toxicology and Applied Pharmacology*; 41(1): 1–6.

113. Waring RH (2004). Report on Absorption of magnesium sulfate (Epsom salts) across the skin uploaded to *The Magnesium Web Site* on January 10, *http://www.mgwater.com/*
114. Watkins K, Josling PD (2010). A Pilot Study to determine the impact of Transdermal Magnesium treatment on serum levels and whole body Ca/Mg Ratios *European Journal of Nutraceutical Research. www.aucoeurdestraditions.com/*

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