# Bioavailability of Magnesium Supplements

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Abstract

USA dietary intake studies document a decreasing and deficient intake of Mg, and an estimated 68% to 80% the US population remaining deficient in this key nutrient. The purpose of this systematic review was to explore the evidence regarding the bioavailability of magnesium (Mg) supplements. An extensive review of five databases originally identified over 13,000 articles was narrowed to eight studies specifically pertaining to Mg absorption rate. The lack of standardized tests to assess Mg status and absorption remains a barrier to quality research on magnesium bioavailability. Through several studies, MgOxide, the most common form used in nutritional supplements, was clearly the least bioavailable. However without replicated results a definitive answer on which forms are best absorbed remains to be established. Clarifying Mg bioavailability would assist the seventy-five percent of the U.S. population who are estimated at being in need of improved Mg nutriture.

***Keywords*****:** magnesium, bioavailability, supplementation, absorption

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# Bioavailability of Magnesium Supplements

Magnesium (Mg) is important to many major functions of the body, over 300 enzymatic processes including bone mineralization, protein synthesis, enzyme action, muscle contraction, nerve function, immunity, and all energy reactions (Sizer & Whitney, 2014). The recommended daily allowance (RDA) is 400 mg/day for young men and 310 mg/day for young women. The average dietary Mg intake in Westernized countries has been reported to have decreased from approximately 400mg/day in early 20$^{th}$ century to about 350 mg/d in the 1980's (Bohn, 2008). According to the 2000 NHANES study, approximately seventy-five percent of the U.S. population has been estimated to have an inadequate Mg intake (Abraham et al, 2015). An estimated 68% to 80% the US population remains deficient in magnesium, even with the increasing utilization of dietary supplements (Ford & Mokdad, 2003).

Absorption of Mg occurs along the entire gastrointestinal (GI) tract, with the majority of absorption occurring in the distal jejunum and ileum (Otten, 2006). Between 2003-2006, an estimated 40 percent of the population reported using a multivitamin or multimineral supplement that contained magnesium. A tolerable upper intake level (UL) of Mg from supplemental forms has been established at 350 mg/day. Exceeding the UL of Mg as a supplement can result in diarrhea however there is no adverse affects of magnesium from natural substances (Otten, 2006). According to the 1986 National Health Interview Survey (NHIS), it was estimated that almost one percent of the adults in the U.S. took a nonfood Mg supplement that exceeded the UL (Otten, 2006).

With dietary intake of Mg below the RDA, determining the bioavailability of Mg in supplements is needed in order to provide evidence-based guidance to consumers. The purpose

of this literature review was to determine what is the evidence regarding bioavailability of Mg in supplements.

## Methods

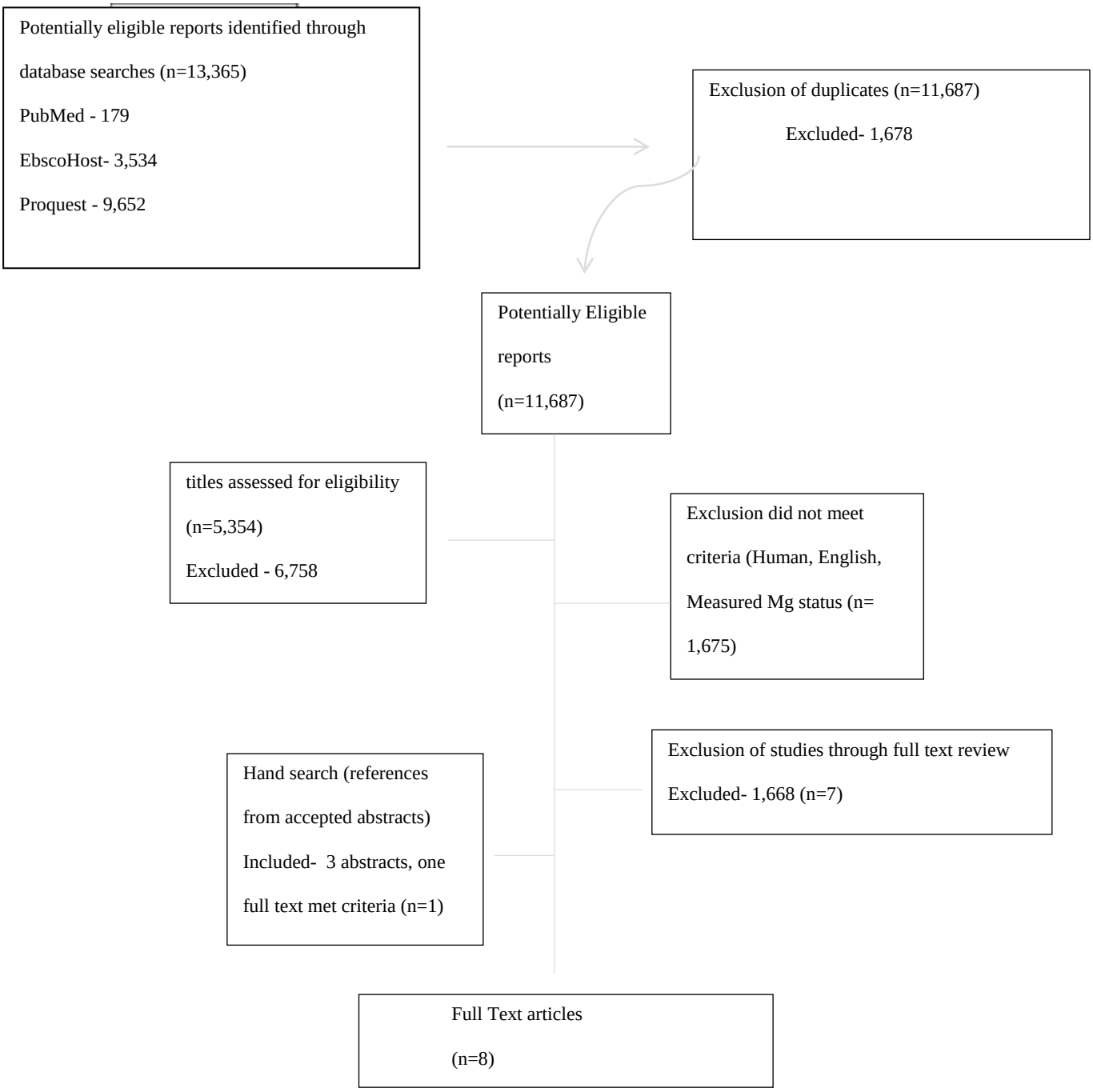
This systematic literature review was conducted in September 2015. Databases used included PubMed, Proquest, EbscoHost, MedLine, and CINHAL. Keywords used in the search were “magnesium”, “bioavailability”, “absorption”, and “supplementation”. Inclusion criteria used were: studies completed using human subjects, measuring Mg status and absorption. Exclusions were made using the criteria: did not measure Mg bioavailability, measured minerals but did not specify Mg levels, studies completed on patients with gastrointestinal illnesses, and studies conducted using animal subjects. Steps included a title review, abstract review, and full text article review. A hand search was then conducted of the references found in articles to determine if additional articles might be identified.

## Results

During the initial search through the databases 13,365 potential articles (abstracts) were found. Exclusions (including duplicates) were then applied leaving 11,687 abstracts. After a comprehensive review of abstracts eight articles met all inclusion / exclusion parameters. A hand search was completed of references and identified three potential additional articles. After full text review a final eight articles were included for review. See Figure 1 for search details.

All articles were of a cross-over design and tested Mg levels in human subjects. One study conducted on ten women tested the bioavailability of Mg from mineral water proved that the absorption was higher when taken with food and lower when taken without food.

Figure 1. Search Process to identify studies on Magnesium Bioavailability



In a different study Mg retention was determined through urinary excretion of Mg isotopes. (Sabatier, et al., 2002). Firoz and Graber (2001) tested the bioavailability of four types of Mg supplements: Mg oxide, Mg Chloride, Mg 1-lactate, and Mg aspartate. The study was conducted using eight males and eight females and showed that the Mg Chloride, Mg 1-lactate, and Mg aspartate had the highest bioavailability (Firoz & Graber, 2001). Siener, Jahnen, & Hesse (2011) studied the bioavailability of Mg oxalate capsules versus effervescent tablets, demonstrating better bioavailability from the effervescent tablets.

Intravenous MgCl was administered to eleven women and eleven men. Urinary excretion was then measured to detect marginal Mg deficiency. The test was too small and results were unclear (Walti et al, 2006). Researchers conducted a study on the effects of oligo-fructose enriched insulin on intestinal absorption of calcium and Mg and bone turnover in fifteen postmenopausal women for six weeks. 298mg of Mg and 198mg of sodium a day were administered and the women showed significant increase in Ca and Mg absorption compared to the placebo group (Holloway et al, 2007). The bioavailability of Mg oxide and Mg-1-aspartate were tested in 24 healthy individuals. The Mg Oxide showed lower absorption (Muhlbaur et al, 1990). Nestle Research Center reported during a study of 12 healthy men that absorption was increased when Mg rich mineral was consumed throughout the day when compared with a larger serving size (Sabatier et al, 2011). See Table 1 for more summaries of findings.

Table 1: Summary of Findings on Magnesium Bioavailability

| Author | Type of Study | Sample Size | Mg tested | Amount | Results |
|---|---|---|---|---|---|
| Firoz & Graber | Crossover experimental design. | 16 healthy volunteers, 8 males and 8 females ranging from 25-55 years of age. All participants receive all 4 preparations | 1. Mg oxide<br>2. Mg Chloride<br>3. Mg 1-lactate<br>4. Mg aspartate | 1. 21.12mEq<br>2. 21.2mEq<br>3. 21mEq<br>4. 21.64mEq | Poor bioavailability of Mg oxide (4%) and a significantly higher bioavailability of Mg chloride, Mg 1-lactate & Mg aspartate (9-11%) |

| | | | | | |
|---|---|---|---|---|---|
| Holloway, Moynihan, Abrams, Kent, Hsu & Friedlander | Crossover experimental design | 15 postmenopausal women | Mg | 298mg Mg/day Sd 198mg Mg/day | Postmenopausal women on the 6 week treatment showed a significant increase in Ca and Mg absorption relative to placebo treatment |
| Muhlbauer, Schwenk, Corarn, Antonin, Etienne, Bicck,&. Douglas | Crossover experimental design | 24 healthy individuals | Magnesium-l-Aspartate-hcl and Magnesium Oxide | 60mEq and 90mEq | Mg Oxide showed significantly lower absorption rates the Mg-l-aspartate |
| Sabatier, Arnaud, Kastenmayer, Rytz, & Barclay | Crossover experimental design | 10 women aged 25 – 45 y | Magnesium-rich mineral water | 1L of mineral water and 110mg of Mg | Absorption was higher with food than with water alone. |
| Sabatier, Grandvuillemin, Kastenmayer, Aeschilman, Bouisset,. Arnaud, & Dumoulin | Crossover experimental design | 12 Male volunteers (18-40) | Mg rich mneral water | 2 x 750ml or 7x 212ml | Absorption was significantly increased when water was consumed in 7 servings throughout the day |
| Siener, Jahnen, & Hesse | Crossover experimental design | 13 male volunteers (22–31 years) | Mg Oxalate MgO-capsules and MgO-effervescent tablets | 450 mg | The results indicate better bioavailability of magnesium from the effervescent tablets than from the capsules. This may be attributed to the fact that the tablets have to be dissolved in water before ingestion so that magnesium becomes ionized, which is an important precondition for absorption. |
| Walti, Walczyk, Zimmermann, Fortunato, Weber,. Spinas & Hurrell. | Crossover experimental design. | 22 subjects (11 women and 11 men) | 26Mg | 11mg of 26Mg (as MgCl 2 in 14ml water) | No association between muscle Mg contraction and administer dose of Mg in Subjects with normal Mg status. Subjects with Mg deficiency may have a correlation. This test was too small to get clear results. |
| Zorbas, Kakuris, Federenko, &. Deogenov. | Crossover Experimental | 40 healthy men | Magnesium-chloride | 3.0 mmol per kg of body weight | Dose of Mg2+ during prolonged hypokinesea showed decrease of muscle Mg2+ content and Mg2+ deficient muscle increase. More Mg2+ loss in healthy subjects showed lower Mg2+ utilization with than without Mg2+ supplementation. |

## Discussion

With diseases such as diabetes showing links to a state of hypomagnesia it is crucial to the health of an individual to be able to reverse this depletion as quickly and as efficiently as possible. Dietary approaches to meeting essential needs of this nutrient have not proven sufficient. During this review it became apparent that significantly more research is needed in order to determine the bioavailability of Mg in supplementation. Unfortunately the amount of available information was very limited. Most studies were excluded due to not testing the absorption of Mg, not testing in a human population, included other minerals thus altering absorption, not specifying the amount or type of Mg absorbed, or being a study completed prior to more recent methods to attempt to assess Mg absorption. The studies that did fall within the criteria tested only three types of compounds in a limited number of study participants. A larger crossover style study with the most commonly available compounds is needed. Without such research, only rough estimates can be made on the best compound due to different populations tested in each study completed with their own unique identifiers.

An additional barrier to completed research is the lack of standardized testing for Mg status. The main means of assessment include serum testing, urine analysis, fecal monitoring and using stable isotopes as tracers. (Sabatier, Keyes, Pont, Arnaud, Turnlund, 2003). When measurements from each test are compared, the urine pooling and fecal result are not significantly different. The doubly labeled isotopes was also comparable, but due to the isotopes half life being relatively short any time range outside of 72 hours was found unreliable (Sabatier, et al,2003). If access to appropriate equipment was available using doubly labeled water as an alternative to time, it still results in a limited application due to the time consuming invasive measures such as urine or fecal collection (Bohn, et al , 2004).

One of the major limitations of the tests when determining true Mg status in a clinical setting is that of the 25g of Mg in the adult body (~ 60% ) is stored in bone, around 38% in soft tissues, and 1% is in blood. (Jahnen-Dechent & Ketteler, 2012). As the level of Mg in the blood is highly regulated, serum tests reflect adaptation, not a true picture of the individuals' nutriture status. Though serum magnesium is still a widely used method, even the National Institute of Health Office of Dietary supplements states "serum levels have little correlation with total body magnesium levels or concentrations in specific tissues" (2013). We still do not have an adequate measure of Mg nutrition status.

This review determined that the studies completed are not enough to provide the evidence needed. A standard form of measurement for true Mg status is needed, as well as replicated double-blind cross-over studies with larger sample sizes. The need for better, truly evidenced based recommendations on Mg supplement remains an critical need.

References

Abraham, D., Graff, D., Heaney, R.P., & Newnham, R.E. (2015).Calcium, Magnesium, and Boron: Their Combined Roles in Maintaining Bone Strength All-Natural *Natural Healing Resource Center.* Retrieved from http://all-natural.com/natural-remedies/bone/

Alexander, R. T., Hoenderop, J. G., & Bindels, R. J. (2008). Molecular determinants of magnesium homeostasis: insights from human disease. *Journal of the American Society of Nephrology*, *19*(8), 1451-1458. doi: 10.1681/ASN.2008010098

Armas, L. A. G., Rafferty, K., Hospattankar, A., Abrams, S. A., & Heaney, R. P. (2011). Chronic dietary fiber supplementation with wheat dextrin does not inhibit calcium and magnesium absorption in premenopausal and postmenopausal women. *Journal of International Medical Research*, 39(5), 1824-1833. doi: 10.1177/147323001103900525

Bohn, T. (2008). Dietary factors influencing magnesium absorption in humans. *Current Nutrition & Food Science*, *4*(1), 53-72.

Bohn T, Walczyk T, Davidsson L, Pritzkow W, Klingbeil P, Vogl J, Hurrel R (2004) Comparison of urinary monitoring, faecal monitoring and erythrocyte analysis of stable isotope labels to determine magnesium absorption in human subjects. *British Journal of Nutrition*, 91, 113–120 DOI: 10.1079/BJN20031023

Firoz, M., & Graber, M. (2002). Bioavailability of US commercial magnesium preparations. *Magnesium research*, (14), 257-62.

Ford, E. S., & Mokdad, A. H. (2003). Dietary magnesium intake in a national sample of US adults. *The Journal of Nutrition*, *133*(9), 2879-2882.

Holloway, L., Moynihan, S., Abrams, S. A., Kent, K., Hsu, A. R., & Friedlander, A. L. (2007). Effects of oligofructose-enriched inulin on intestinal absorption of calcium and magnesium and bone turnover markers in postmenopausal women. *British journal of nutrition*, *97*(02), 365-372. http://dx.doi.org/10.1017/S000711450733674X

Mühlbauer, B., Schwenk, M., Coram, W. M., Antonin, K. H., Etienne, P., Bieck, P. R., & Douglas, F. L. (1991). Magnesium-L-aspartate-HCl and magnesium-oxide: bioavailability in healthy volunteers. *European journal of clinical pharmacology 40*(4), 437-438. DOI:10.1007/BF00265863

Otten, J. (2006). Magnesium. In DRI, dietary reference intakes the essential guide to nutrient requirements (pp. 341-349). Washington, D.C.: National Academies Press.

Sabatier, M., Arnaud, M. J., Kastenmayer, P., Rytz, A., & Barclay, D. V. (2002). Meal effect on magnesium bioavailability from mineral water in healthy women. *The American journal of clinical nutrition*, *75*(1), 65-71.

Sabatier, M., Grandvuillemin, A., Kastenmayer, P., Aeschliman, J. M., Bouisset, F., Arnaud, M. J., ... & Berthelot, A. (2011). Influence of the consumption pattern of magnesium from magnesium-rich mineral water on magnesium bioavailability. *British journal of nutrition*, *106*(03), 331-334. http://dx.doi.org/10.1017/S0007114511001139

Sabatier, M, Keyes W, Pont F, Arnaud M, Turnlund J (,2003) Comparison of stable-isotope-tracer methods for the determination of magnesium absorption in humans. *American Society for Clinical Nutrition* 1206-1212doi: 10.1016/j.jtemb.2010.01.010

Siener, R., Jahnen, A. & Hesse ,A. (2011) Bioavailability of magnesium from different pharmaceutical formulations. *Urol. Res* 39(2):123-7. doi: 10.1007/s00240-010-0309-y.

Sizer, F., & Whitney, E. (2014). 8. In *Nutrition: Concepts and Controversies* (13th ed., pp. 303-305). Belmont, CA: Wadsworth.

Verhas, M., Gueronniere, V. D. L., Grognet, J. M., Paternot, J., Hermanne, A., Winkel, P. V. ... & Rayssiguier, Y. (2002). Original Communications-Magnesium bioavailability from mineral water. A study in adult men. *European Journal of Nutrition 56*(5), 442-447.

Vormann, J. (2003). Magnesium: nutrition and metabolism. *Molecular Aspects of Medicine*, *24*(1), 27-37. http://dx.doi.org/10.1016/S0098-2997(02)00089-4

Wälti, M. K., Walczyk, T., Zimmermann, M. B., Fortunato, G., Weber, M., Spinas, G. A., & Hurrell, R. F. (2006). Urinary excretion of an intravenous 26Mg dose as an indicator of marginal magnesium deficiency in adults. *European journal of clinical nutrition 60*(2), 147-154. doi:10.1038/sj.ejcn.1602278

Zorbas, Y. G., Kakuris, K. K., Federenko, Y. F., & Deogenov, V. A. (2010). Utilization of magnesium during hypokinesia and magnesium supplementation in healthy subjects. *Nutrition 26*(11), 1134-1138. http://dx.doi.org/10.1016/j.nut.2010.01.013