

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 20th 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

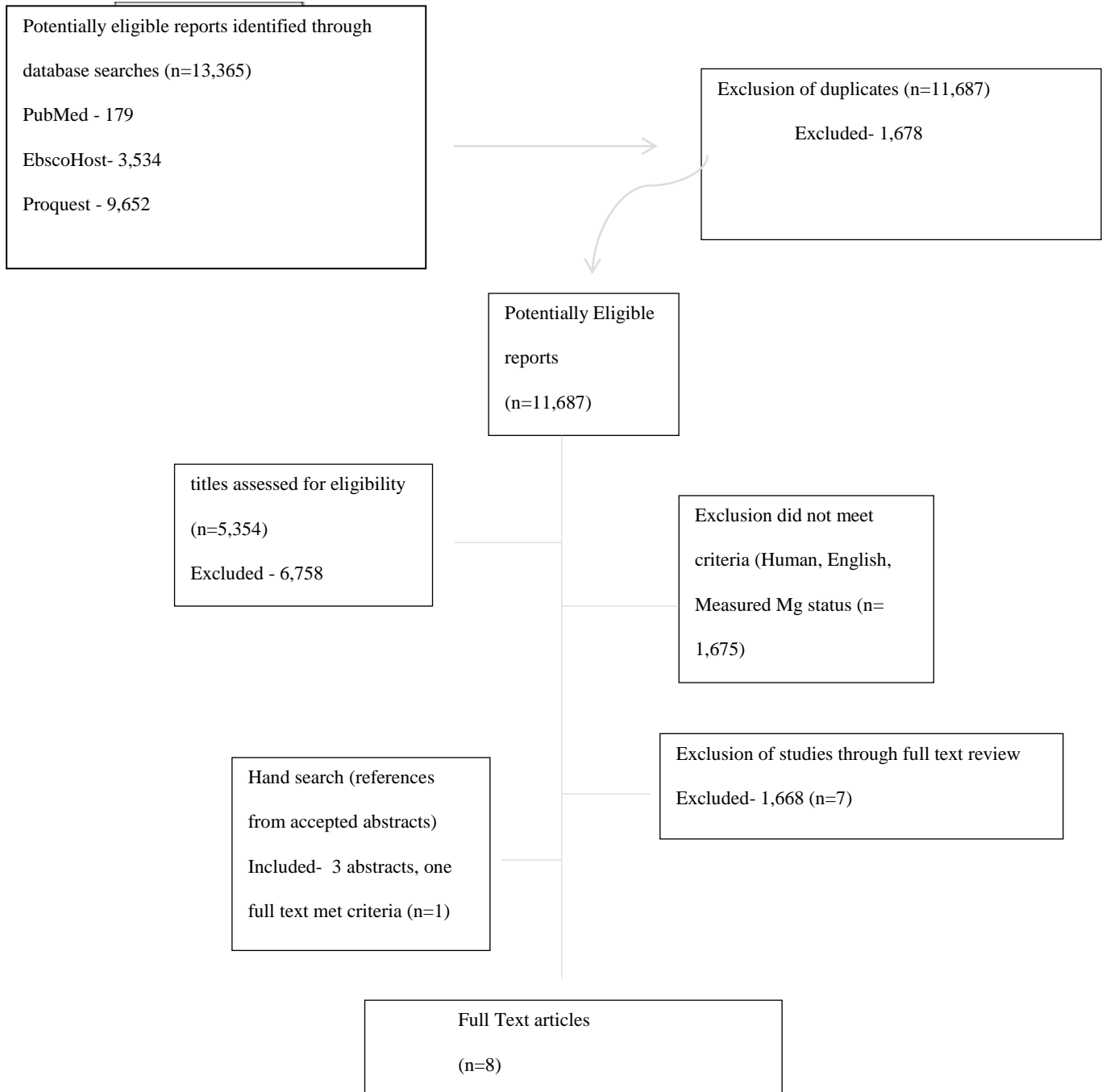
This systematic literature review was conducted in September 2015. Databases used included PubMed, Proquest, EbscoHost, MedLine, and CINHAL. Keywords used in the search were “magnesium”, “bioavailability”, “absorption”, and “supplementation”. Inclusion criteria used were: studies completed using human 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 2. Mg Chloride 3. Mg 1-lactate 4. Mg aspartate	1. 21.12mEq 2. 21.2mEq 3. 21mEq 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 mineral 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, Spinass & Hurrell.	Crossover experimental design.	22 subjects (11 women and 11 men)	26Mg	11 mg 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 Mg ²⁺ during prolonged hypokinesea showed decrease of muscle Mg ²⁺ content and Mg ²⁺ deficient muscle increase. More Mg ²⁺ loss in healthy subjects showed lower Mg ²⁺ utilization with than without Mg ²⁺ supplementation.

Discussion

With diseases such as diabetes showing links to a state of hypomagnesemia 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.

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