

Rising Ca:Mg intake ratio from food in USA Adults: a concern?

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Abstract. USDA food surveys from 1977 through 2007-8 show a rising food Ca:Mg ratio for all USA adult age-gender groups. Food Ca:Mg intake ratios rose from 2.3-2.9 in 1977 to 2.9-3.5 in 2007-8. The % rise in mean Mg intakes compared closely with % rise in mean energy intakes while % rise in mean Ca intakes were substantially higher in all groups, suggesting the rising Ca:Mg comes from higher Ca intakes via food selections, rising food Ca contents or both. Original intake data from these surveys need to be accessed to calculate each individual's Ca:Mg for statistical assessment of this ratio rise. Ca:Mg rose from largely below 3.0 in 1994-5 to generally above or approaching 3.0 after 2000, coinciding with a sharp 2% rise in type 2 diabetes incidence and prevalence in the USA population and a 1994-2005 rise in colorectal cancer incidence among young white, non-Hispanic adult men and women in the USA. The intracellular Ca activation response to low Mg is discussed as a possible mechanism linking metabolic and inflammatory syndromes with low dietary Mg and rising dietary Ca:Mg ratio. Adequacy of both Ca and Mg as well as the Ca:Mg ratio are important in assessing study outcomes. Health consequences should be considered for the USA's 64-67% adults not meeting their Mg requirement from foods, many also consuming below their Ca requirements, and their increasing Ca:Mg ratio from foods.

Keywords: magnesium calcium Ca:Mg ratio dietary intake ratio, adults, elderly, metabolic syndrome, inflammation syndrome

The large, genetically variable population of the United State of America (USA) has spent decades consuming a modern, processed food diet. The majority of this population has recently been shown to consume, with foods, well below their daily Estimated Average Requirement (EAR) of nutritional magnesium (Mg) (*table 1*). Many also consume below the amount of calcium (Ca) considered to be an adequate intake with their foods [2]. The ratio between these two nutrients (Ca:Mg) is rarely calculated, monitored or reported.

As early as 1964, in a quantitative review of human balance studies, M.S. Seelig reported dietary Ca to be a factor in the retention of dietary Mg [3]. Seelig further considered the impact of high Ca with low Mg intakes on physiological Ca:Mg ratios affecting myocardium and intravascular coagulation in later reviews [4-6], and in 1978, a population's Ca:

Mg intake ratio was seen as important to ischemic heart disease death rates [7]. In 1989, Durlach warned against excessive Ca relative to Mg intakes and recommended that total dietary Ca to Mg ratios (Ca:Mg) remain close to 2.0 [8]. High cellular Ca:Mg can effect metabolic syndrome dysfunction in various tissues, bringing attention to this ratio's potential importance in the etiology of type 2 diabetes (DM2) [9]. The nutritional Ca:Mg intake ratio has recently been delineated by Dai *et al.* as important in a genetic-dietary interaction study impacting colon cancer [10]. These authors found "that total magnesium consumption was linked to a significantly lower risk of colorectal adenoma, particularly in those subjects with a low Ca:Mg intake, and that subjects who carried ≥ 1 1482Ile allele and who consumed diets with a high Ca:Mg intake (*i.e.* Ca:Mg > 2.76) were at a higher risk of adenoma

Table 1. Estimated Average Requirement (EAR) and Recommended Daily Allowance (RDA) for USA adults [1] and proportion of USA adults consuming less than EAR for Mg with their daily food diet according to NHANES 2001-2002 [2].

Age	EAR for Mg (mg/day)	% consuming < EAR	RDA for Mg (mg/day)
Men			
19-30 yrs	330	55%	400
31-50 yrs	350	61%	420
51-70 yrs	350	70%	420
71+ yrs	350	81%	420
All Men 19+ yrs	—	64%	—
Women			
19-30 yrs	255	64%	310
31-50 yrs	265	65%	320
51-70 yrs	265	64%	320
71+ yrs	265	82%	320
All Women 19+ yrs	—	67%	—

(odds ratio: 1.60; 95% CI: 1.12, 2.29) and hyperplastic polyps (odds ratio: 1.85; 95% CI: 1.09-3.14) than were the subjects who did not carry the polymorphism”.

It's appropriate to assess any trend of dietary Ca:Mg ratio in human populations. This study is a preliminary attempt to assess the Ca:Mg intake ratio from food over time in USA adults, a large, genetically variable population with decades on a modern, processed food diet which does not provide adequate Mg intake for many.

Methods

Seven United States Department of Agriculture (USDA) nutritional surveys, beginning in 1977 to date (*table 2*), have reported Mg intakes from food [11-17]. USDA surveys before 1977 reported Ca but not Mg intakes from food (*table 3A*). Mean Mg (mg/day) and Ca (mg/day) intake data from these 7 USDA surveys were tabulated and used to calculate Ca:Mg intake ratios from food for the various age-gender groupings reported in the 7 surveys.

The earliest two surveys that included Mg intake (1977 and 1985) cover adults up to and including age 50 yrs; surveys starting in 1994-5 expanded to include adults aged 50+ years. Thus, this calculation of Ca:Mg intake ratio from food over the 30-year time span (from 1977 to 2007-8) only includes adults ≤ 50 years of age, and the Ca:Mg intake ratio for USA adults 50+ years of age covers only a 13-year time span (from 1994-5 to 2007-8) (*table 3B*).

All 7 USDA surveys reported mean Ca (mg/day), Mg (mg/day) and energy (kcal/day) intake from

food per individual for several age-gender groupings (*table 3B*), and provided the number (N) or relative % (%N) of individuals in each group. These data were used for two age comparisons of Ca and Mg intakes: – a 30-yr comparison of adults aged 19-50 yrs using all surveys with varying age groupings that required calculation of some weighted means (see below), and a 13-yr comparison of adults 50+ yrs using the 5 surveys from 1994-5 forward which all reported means for the same age groupings. For each age-gender grouping in both comparisons, mean Ca and Mg intakes from food were used to calculate the Ca:Mg ratio for that age-gender group. Trend of mean Ca and mean Mg intake from food for each age-gender group was assessed for both the 30-yr and 13-yr comparisons by calculating the % rise over time (see below for method).

Changes in dietary assessment methods over the years of these surveys were made with progress in methodology. To help assess any impact these changing methods may have had on changes in Ca and/or Mg intakes over the survey years, mean daily energy intakes from foods (kcal/day/individual) were gathered using the same methods used to determine mean Ca and Mg intakes and their % rise over time.

These comparisons are for food intakes only and do not include Mg or Ca intake from supplements.

30-year trend (1977 through 2007-8 surveys) for adults age ≤ 50 yrs

The earliest two surveys that included Mg intake (1977 and 1985) did not include adults > 50 yrs and used 15-year age-gender groupings to report mean

Table 2. USDA Surveys reporting both Ca and Mg intakes. Source data for mean dietary (Food only) Ca, Mg and energy Intakes in USA, 1977-2006; used to calculate mean Ca:Mg intake ratio from foods.

Survey year(s)	Website data source with Table/Page numbers	Citation
1977 & 1985; Men	www.ars.usda.gov/ba/bhnrc/fsrg USDA Food Surveys, 1935-1998; 1985-86 Continuing Survey of Food Intakes by Individuals; 1985 Report: Men 19-50 yrs, 1 day; Men: Table 2.1A. – Nutrient Intakes: Mean per Individual in a Day, by Income Level, Summer 1977 and Summer 1985, Pg. 21 – Men: All Income Levels	[11]
1977 & 1985; Women	www.ars.usda.gov/ba/bhnrc/fsrg USDA Food Surveys, 1935-1998; 1985-86 Continuing Survey of Food Intakes by Individuals; 1985 Report: Women 19-50 yrs and Children 1-5 yrs, 1 day; Women: Table 2.1A. – Nutrient Intakes: Mean per Individual In a day, By Income Level, Spring 1977 and Spring 1985, Pg. 23 – Women: All Income Levels	[12]
1994-1995	http://www.ars.usda.gov/Services/docs.htm?docid=14531 Report 5 Food and Nutrient Intakes & Diet Knowledge by Gender and Age, 1994-95 Table 1. Nutrient Intakes: Mean amount consumed per individual, by sex and age, 1 day, 1994-5, pp. 2, 4-5	[13]
2001-2002	www.ars.usda.gov/ba/bhnrc/fsrg What We Eat In America; Data Tables; 2001-2; Nutrient Intakes from Food, 1. Mean Amounts, by Gender and Age; Table 1. Nutrient Intakes: Mean Amount Consumed per Individual, One Day, 2001-2002	[14]
2003-2004	www.ars.usda.gov/ba/bhnrc/fsrg What We Eat In America; Data Tables; 2003-4; Nutrient Intakes from Food, 1 By Gender and Age; Table 1. Nutrient Intakes from Food: Mean Amounts consumed per Individual, One Day, 2003-2004	[15]
2005-2006	www.ars.usda.gov/ba/bhnrc/fsrg What We Eat In America; Data Tables; 2005-6; Nutrient Intakes from Food 1 by Gender and Age; Table 1. Nutrient Intakes from Food: Mean Amounts Consumed per Individual, One Day, 2005-2006	[16]
2007-2008	www.ars.usda.gov/ba/bhnrc/fsrg What We Eat In America; Data Tables; 2007-8; Nutrient Intakes from Food 1 by gender and age; Table 1. Nutrient Intakes from Food: Mean Amounts Consumed per Individual, by Gender and Age, in the United States, 2007-2008	[17]

Table 3.**A) USDA Food Intake Surveys that include Ca and/or Mg.**

Survey Year	Includes Ca intake	Includes Mg Intake
1936	Yes	No
1948	Yes	No
1955	Yes	No
1977	Yes	Yes
1985	Yes	Yes
1994-5	Yes	Yes
2001-2	Yes	Yes
2003-4	Yes	Yes
2005-6	Yes	Yes
2007-8	Yes	Yes

B) Different age groupings reported in the 7 USDA Food Intake Surveys that report Mg intake.

Survey years	Adult age groupings reported	
1977 & 1985	19-34 yrs	Data for 30-yr trend of adults ≤ 50 yrs; weighted means calculated for 30-49 yrs. <i>Table 4.</i>
Reported 15-yr age groupings	35-50 yrs	
	19-50 yrs	
1994-5 } 2001-2 } 2003-4 } 2005-6 } 2007-8 }	20-29 yrs	
	30-39 yrs	
	40-49 yrs	
	50-59 yrs	Data for 13-yr trend of adults 50+ yrs.
	60-69 yrs	
	70 yrs	
	20+ yrs	

intakes (*table 3B*) while the 5 USDA surveys from 1994-5 through 2007-8 included all adults age 20+yrs and used 10-year age/gender groups to report mean intakes (*table 3B*). To provide somewhat comparable mean intakes for Mg, Ca and energy for a full 30-yr trend, four age-gender groups were designated: Young Adult Men, Young Adult Women, Adult Men and Adult Women. "Young Adult" men and women for this 30-yr trend compared age groups 19-34 years from the 1977 and 1985 surveys with the groups aged 20-29 yrs in the later 5 surveys. "Adult" men and women included age groups 35-50 yrs from the earlier surveys and a calculated weighted mean for ages 30-49 from the latter 5 surveys (*table 4*). Thus, for this 30-yr comparison, groups aged 50+ had to be excluded and weighted means for age-groupings 30-49 yrs had to be calculated for surveys after 1985 using 30-39 yr and 40-49 yr means plus their N or %N (*table 4*). Mean Ca and mean Mg intakes for these four designated age-gender groups are charted in *figures 1* and *2* along with % rise for Ca, Mg and energy calculated using the following formula:

$$\% \text{ rise} = [(2007-8 \text{ survey year value} - 1977 \text{ survey year value}) / 1977 \text{ survey year value}] \times 100.$$

13-year trend (1994-5 through 2007-8 surveys) for adults age 50+ yrs

The 5 USDA surveys from 1994-5 through 2007-8 included groups aged 50+yrs, and all used the same 10-year age/gender groups (*table 3B*) so their reported means for Mg, Ca and energy intakes over those years are fully age-comparable, unlike the 30-yr trend. Ca and Mg mean intakes/individual are charted in *figures 3* and *4* along with % rise in each (as well as % rise in kcal) calculated using the formula:

$$\% \text{ rise} = [(2007-8 \text{ survey year value} - 1994-5 \text{ survey year value}) / 1994-5 \text{ survey year value}] \times 100.$$

Ca:Mg intake ratio from foods over time

Using mean Ca and mean Mg intakes for each adult age-gender group in all 7 surveys, the Ca:Mg intake ratio for each group was calculated using the formula:

$$\text{Ca:Mg ratio} = \text{mean Ca intake (mg/day)} / \text{mean Mg intake (mg/day)}$$

and is presented in *table 5*. The 13-yr % rise in Ca:Mg was calculated for each age gender group using the formula

$$\% \text{ rise} = [(2007-8 \text{ Ca:Mg value} - 1994-5 \text{ Ca:Mg value}) / 1994-5 \text{ Ca:Mg value}] \times 100$$

and charted in *figure 5*.

The 30-yr % rise in Ca:Mg was calculated for only the 20-29 and 40-49yr age groupings (using the 1977 means for 19-34 and 35-50 yr group means, see *table 4*) and charted in *figure 6*.

Statistical analysis was not possible for Ca:Mg ratio, the focus of this investigation, as this ratio for individuals was not calculated in the original surveys. One must go back to the original data, compute individual Ca:Mg ratios in order to assess any statistical significance of these rises in mean Ca : mean Mg ratio.

Results

Adults ≤ 50 yrs, 30-yr trend

From the 1977 to the 2007-8 survey, mean Ca intakes from food rose substantially more than mean Mg intakes in all age-gender groups. Mean Ca intake rose 43% in Young Women and 32% in Young Men while mean Mg for these two groups

Table 4. Age-gender groupings used for 30-yr comparison of mean Ca, Mg and energy intakes; as presented in *figures 1, 2* and *8*.

Population Survey Yr	Young Adults	Adults	Source of data
1977	19-34*	35-50*	Direct from survey
1985	19-34*	35-50*	Direct from survey
1994	20-29*	30-49**	Direct and calculated weighted mean
2001-2002	20-29*	30-49**	Direct and calculated weighted mean
2003-2004	20-29*	30-49**	Direct and calculated weighted mean
2005-2006	20-29*	30-49**	Direct and calculated weighted mean
2007-2008	20-29*	30-49**	Direct and calculated weighted mean

* Values for mean intakes of Ca, Mg and Kcal taken directly from surveys; ** Values for mean intakes of Ca, Mg and Kcal calculated using reported means and N (number of individuals) or %N for 30-39 and 40-49 age groupings.

rose only 16% and 11% (figure 1, also see table 4 for age ranges from survey years used for this 30-yr comparison). Energy intake rises of 13% and 14% were comparable to the rises in mean Mg intakes (figure 1). Results are similar for adults >30/35 and < 50 yrs (figure 2): women’s mean Ca intake rose 64% while their mean Mg intake rose only 18% (mean kcal/day rose 24%), and men’s mean Ca intake rose 48% over the 30 years while their mean Mg and energy intakes both rose only 12% (figure 2). The % rises in mean energy intake for the 4 age-gender groups of 12% to 24% (figures 1, 2) are smaller than the % rises in mean Ca intake (32-64%) and comparable to the % rises in Mg intake (11-18%) over this 30-yr time period. Both Men and Women Adult groups plus Young Adult Women showed the trend for rising Ca intakes to level off or decrease slightly in 2007-8, while this leveling off appears to occur in Young Men with the 2005-6 survey (figures 1, 2).

Adults 50+ yrs, 13-yr trend

From the 1994-5 through the 2007-8 surveys, mean Ca intakes rose substantially more than mean Mg intakes from food. Mean Ca and Mg intakes for

3 age groups of older adult women over the 13 years of 1994-5 through 2007-8 are shown in Figure 3; those for men appear in figure 4. The 3 age groupings, 50-59 yrs, 60-69 yrs and 70+ yrs, are fully comparable over all 5 surveys (table 3B).

Ca Rise, Men: Between the 1994-5 USDA survey and that of 2007-8, mean Ca intake from foods for USA older men rose from a range of 754-792 mg/day to 837-1,005 mg/day, an 11 to 30.7% rise in the 3 age groupings of 50+ yrs (figure 4). Elderly Men > 70 yrs had the lowest mean Ca intakes of all adult men for each survey year, rising steadily from 754 mg/day in 1994-5 to 881 mg/day in the 2005-2006 survey, dropping slightly to 837 mg/day in 2007-8, an 11% rise over 13 years. Men in the 3 age groups covering 20 to 49 yrs (not shown) in these fully comparable surveys had mean Ca intakes of 890-1,005 mg/day in 1994-5 that rose 13-22.8% in 13 years to 1,077-1,150 mg/day in 2007-2008. Men aged 50-59 showed the largest % rise in Ca intake over the 13 years, from 769 mg/day to 1,005 mg/day for a 31% rise, followed by 40-49 yrs who showed a 22.8% rise in Ca intake.

Mg Rise, Men: These same older age groups experiencing an 11 to 30.7% rise in mean Ca intake

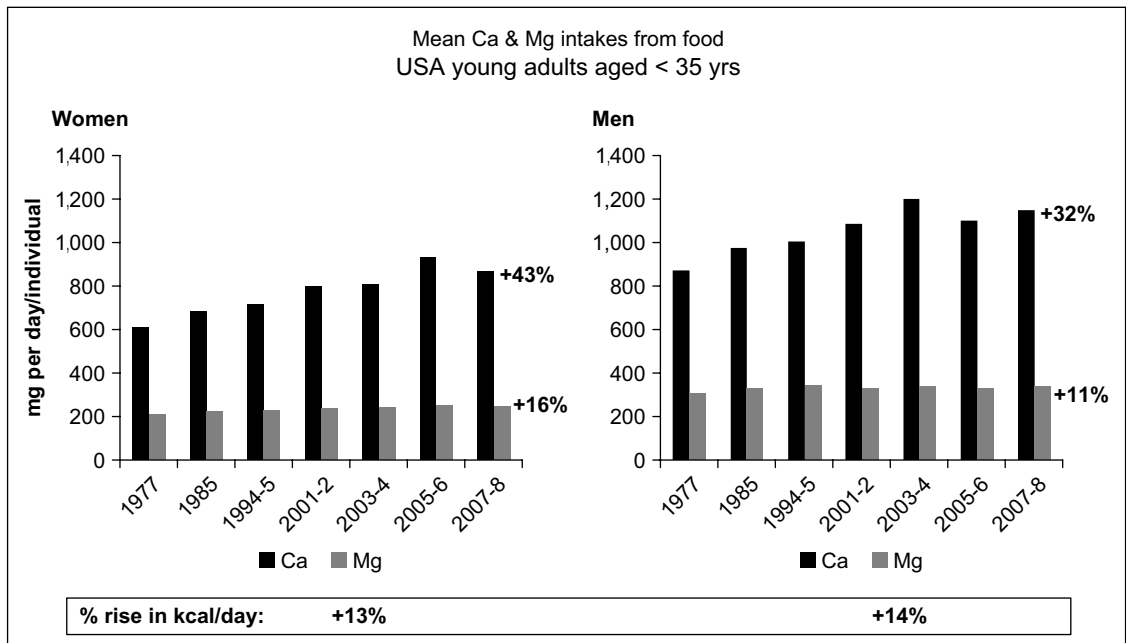


Figure 1. Mean Ca and Mg intakes from food, 1977 to 2007-8, for USA Young Adults, with % rise in mean Ca, Mg and energy (kcal) intakes. Includes ages 19-34 yrs for earliest 2 survey years and 20-29 yrs for later 5 survey years. See Table 4 for age groupings used in this chart.

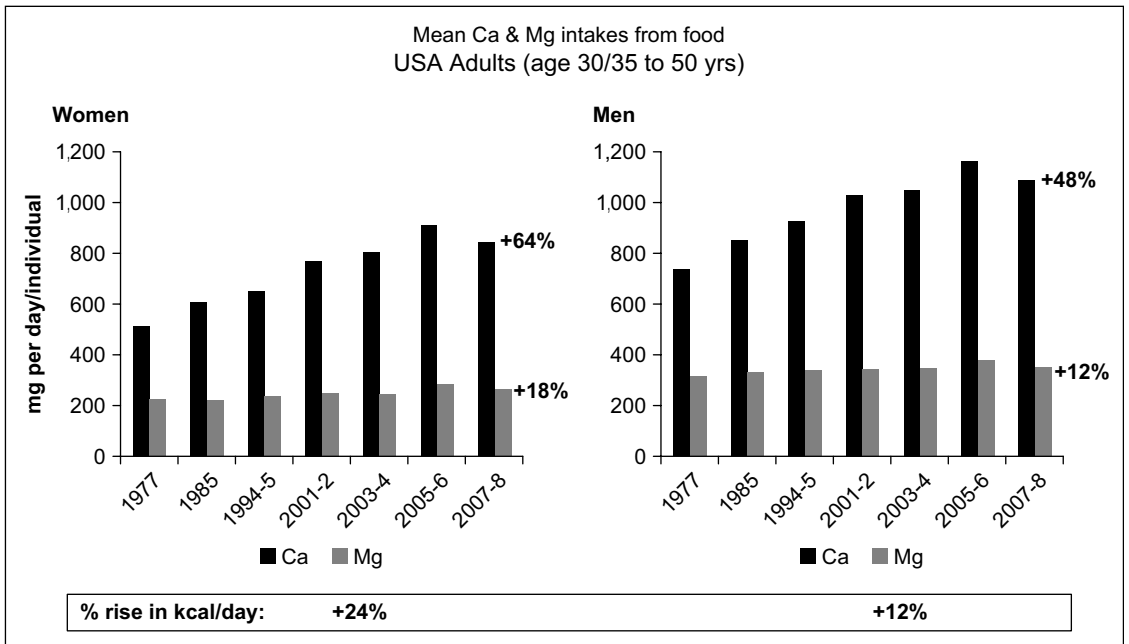


Figure 2. Mean Ca and Mg intakes from food, 1977 to 2007-8, with % rise in mean Ca, Mg and energy (kcal) intakes. Includes ages 35-50 yrs for earliest 2 survey years and 30-49 yrs in later 5 survey years. See Table 4 for age groupings used for this chart.

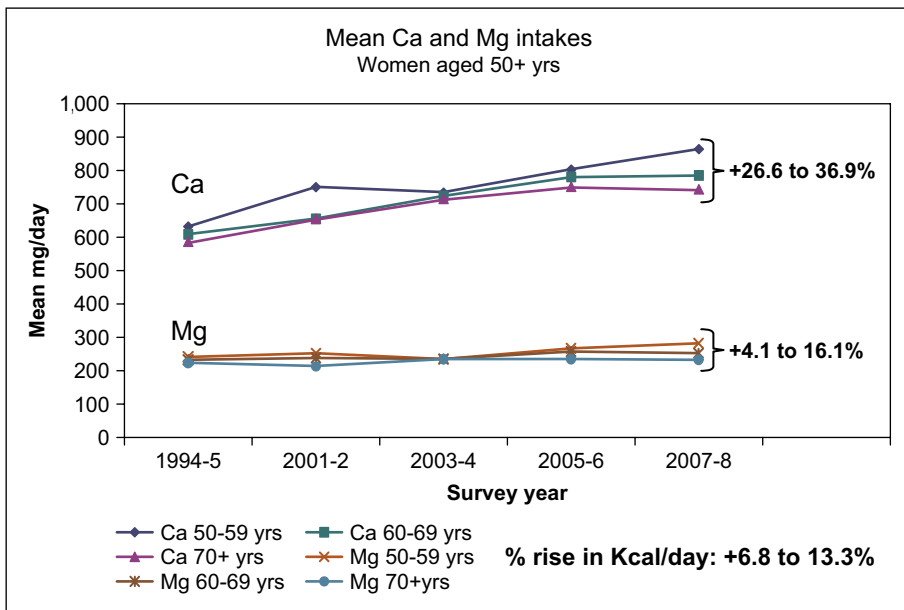


Figure 3. Mean Ca and Mg intakes from food, 1994-5 to 2007-2008, for USA Women, age 50+ yrs, with % rise in Ca, Mg and energy mean intakes.

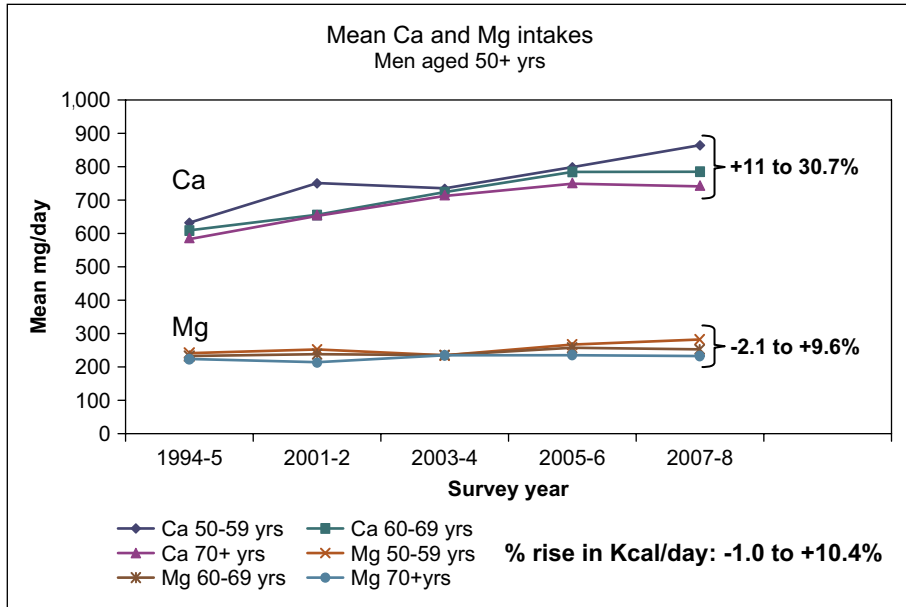


Figure 4. Mean Ca and Mg intakes from food, 1994-5 to 2007-2008, for USA Men, age 50+ yrs, with % rise in Ca, Mg and energy mean intakes.

showed a much smaller change in both mean Mg and mean energy intakes over the 13 years: 50-59 year old men showed the highest rise in mean Mg intake at + 9.6% while elderly men over age 60 experienced a slightly lower (or steady) mean Mg intake over this time period, from - 2.1% to - 0.7%. Mean energy intakes for these groups changed by - 1.0 to + 10.4%, comparable to the %changes in mean Mg intakes. The younger men's age groups (not shown) over the 13 years of comparable surveys all showed changes in mean Mg intake of - 1.5 to + 4.9%, similar to that of the change in energy for these age groups, -3.1 for 20-29 yrs, -1.8% for 30-39 yrs, and + 11.7% for 40-49 yrs.

Ca Rise, Women: Mean Ca intakes for the 3 older age groupings rose from 587-632 mg/day in the 1994-1995 survey to 743-865 mg/day in the 2007-8 survey for a 26.6 to 36.9% rise in mean Ca intake over the 13 years (*figure 3*). The lowest mean Ca intake from foods appeared in the elderly women > 70 yrs, and the highest mean Ca intake from foods were seen in the younger adult women, aged 20-29 and 30-39 yrs (not shown).

Mg Rise, Women: Mean Mg intake for the 3 older age groups of adult women rose from a range of 224-243 mg/day in the 1994-5 survey to 233-282 mg/day in the 2007-2008 survey, a + 4 to 16.1% rise over

the 13 years, quite comparable to the concurrent % rise in kcal/day for these age groups, *i.e.* + 6.8 to 13.3%.

Ca:Mg Ratio intake ratios from food over time

In each age-gender group, for both the 30-yr and 13-yr comparisons, the % rise over time for mean Ca intake from food was several times larger than the % rise for Mg, resulting in a Ca:Mg intake ratio that rose 10-22% in the 13-yr comparison (*table 5, figure 5*) and 20 to 37% for the 30 year comparisons (*table 5, figure 6*). The greatest rises in Ca:Mg ratio occurred for women 40-49 yrs, 60-69 yrs and those > 70 yrs and for men aged 50-59 yrs.

Younger women were the first group to show a Ca:Mg intake ratio > 3.0, as early as 1985 for the 19-34 yr group and remaining > 3.0 for all 5 later surveys for ages 20-29 yrs. Ca:Mg for Women aged 30-39 yrs rose to > 3.0 with the 2001-2 survey, and all other women age groups showed a Ca:Mg ratio rising from < 3.0 to > 3.0 by the 2003-4 survey. For men, the Ca:Mg intake ratio rose to > 3.0 by 2001-2 for ages 20-39 yrs, by 2003-4 for men 40-49 yrs and only approached 3.0 in groups aged 50+ yrs by the 2007-8 survey.

Using the weighted age-gender groupings charted in *figures 1 and 2 (table 4)*, the Ca:Mg intake ratio

Table 5. Ca:Mg ratios from food intake by USA adult age-gender groupings, calculated from mean Ca and Mg intakes reported in USDA surveys, 1977 through 2007-2008.

A) Females Ca:Mg							
Survey year	19-34 yrs	35-50 yrs	50 + yrs	19-50 yrs			
1977	2.88	2.32	Not reported	2.64			
1985	3.06	2.76	Not reported	2.93			
	20-29 yrs	30-39 yrs	40-49 yrs	50-59 yrs	60-69 yrs	70+ yrs	20+ yrs
1994-1995	3.13	2.83	2.67	2.60	2.61	2.62	2.76
2001-2002	3.39	3.26	2.90	2.97	2.74	3.07	3.08
2003-2004	3.33	3.47	3.12	3.12	3.07	3.04	3.21
2005-2006	3.72	3.17	3.24	2.99	3.04	3.20	3.24
2007-2008	3.53	3.27	3.18	3.07	3.11	3.19	3.23
13-yr % rise	12.8	15.6	19.1	18.1	19.2	21.8	17.1%
30-yr % rise	22.6		37.1				22.4%
B) Males Ca:Mg							
Survey year	19-34 yrs	35-50 yrs	50 + yrs	19-50 yrs			
1977	2.86	2.34	Not reported	2.64			
1985	2.96	2.59	Not reported	2.79			
	20-29 yrs	30-39 yrs	40-49 yrs	50-59 yrs	60-69 yrs	70+ yrs	20+ yrs
1994-1995	2.95	2.77	2.70	2.44	2.51	2.64	2.72
2001-2002	3.31	3.20	2.88	2.90	2.81	2.89	3.03
2003-2004	3.56	3.07	3.03	2.69	2.88	3.04	3.08
2005-2006	3.37	3.22	2.95	2.88	2.97	3.05	3.08
2007-2008	3.42	3.05	3.16	2.91	2.96	2.99	3.11
13-yr % rise	16.0	10.1	17.1	19.3	18.0	13.3	14.4%
30-yr % rise	19.6		35.1				17.8%

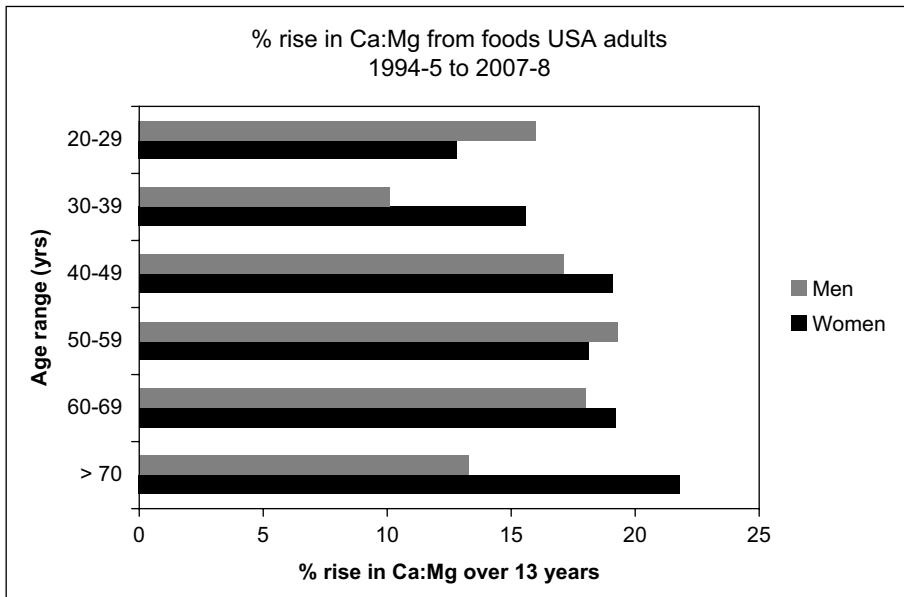


Figure 5. 13-yr % rise in Ca:Mg Ratio from foods, USA Adults, age 20 to 70+ yrs, 1994-5 through 2007-8 surveys. See *table 5* for source of data.

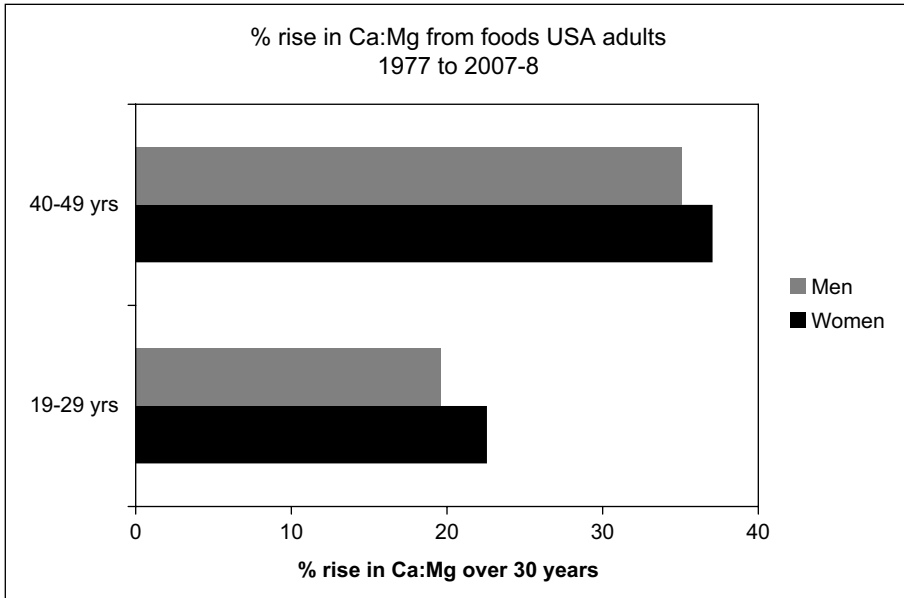


Figure 6. 30-yr % rise in Ca:Mg Ratio from foods, USA Adults, age 19-29 and 40-49 yrs, 1977 through 2007-8 surveys. See *table 5* for source of data.

from food rose 20% in young adult males, 23% in young adult females, 33% in adult males and 40% in adult females between the 1977 and 2007-8 surveys. For “all-adults” groupings over the 30 years from 1977 to 2007-8 (which includes only ≤ 50 yrs for 1977 and 1985), the Ca:Mg intake from foods increased 22% for women and 17.8% for men (*table 5*), with the Ca:Mg intake ratio rising to >3.0 between the 1994-1995 and 2001-2002 surveys for both men and women.

Discussion

This assessment is not precise.

–The earliest two surveys’ age groupings do not match those of the latter 5 surveys, and are not strictly comparable in the 30-yr comparison (*table 3B*).

–As already mentioned, no statistical analysis is possible from these data on the possible rise in Ca:Mg ratio over time. For variance to be truly measured and statistically tested, original intake data from individuals in these surveys must be used to calculate Ca:Mg ratio for each individual and means and variance for age/gender groupings calculated for appropriate statistical testing.

–This apparently increasing Ca:Mg intake ratio calculation does not include supplements which highly favor Ca intake over Mg in this population: Ca supplements sales were 10+ times Mg supplement sales in 2007, and although 2008 Mg supplement sales increased 14% while Ca supplement sales grew by only 6%, Ca sales accounted for 54% and Mg 15% of all nutritional mineral sales for that year [18]. In addition, one study including Ca and Mg supplements [19] showed that USA adults using Ca and Mg supplements all raised their Mg intake from below their EAR to above that average daily requirement, but the data show that all, and especially adult women, increased their Ca:Mg ratio substantially via supplement use.

Nonetheless, mean Ca intake from foods rose substantially compared with changes in mean Mg and mean energy intakes between 1977 and 2007-8 in USDA surveys for all adult age-gender groupings, strongly suggesting a rising Ca:Mg intake ratio for USA adults from foods alone during this 30-yr time-frame. This rise may have leveled off by the 2007-8 survey, but rose from <3.0 in 1977 to >3.0 by 2003-4 for all adult age-gender groupings up to 50 yrs of age. Likewise, in the fully comparable surveys between 1994-5 and 2007-8 that include adult age groups >50 yrs, Ca:Mg intake ratios went

from largely < 3.0 in the 1994-5 survey (all save women aged 29-29 yrs) to > 3.0 in all groups aged 20-39 yrs by 2001-2, to > 3.0 in women of all age groups and men 40-49 yrs and 70+ yrs by 2003-4, and approached 3.0 in men aged 50+ yrs by the 2007-8 survey. The Ca:Mg intake ratios for "all adults" groupings (19-50 yrs for earlier surveys and 20+ yrs for later 5 surveys) rose steadily from 2.64 in 1977 to 3.23 for women and 3.11 for men by 2007-8 (see table 5).

Is this rising Ca:Mg ratio a concern? Conflicting results between Mg, Ca intakes and mortality have been reported. For instance, dietary Ca was associated with a significantly lower rate of all causes mortality while Mg intake was not associated with all cause, CVD or cancer mortality in an informative recent Swedish Study [20]. In this study, Mg intakes were adequate in even the lowest tertile for Mg with the 5 percentile Mg intake (355 mg/day) exceeding the EAR (350 mg/day) for these adult men, leading the authors to conclude that all subjects were adequate in Mg. This was not the case for Ca, however. Ca intakes were largely less than adequate for the $n = 7,786$ men in the lowest tertile at $< 1,230$ mg Ca/day with the 5th percentile Ca intake (798 mg/day) only 2/3 of the 1,200 mg/day Adequate Intake (AI) for Ca. This study thus found that men, all adequate in their Mg nutrition and one out of three inadequate in their Ca intake, showed lower all cause mortality as their Ca intake rose to adequacy levels. This is not a surprising result as Ca is an essential nutrient, necessary in adequate amounts for optimal health, and does not suggest Ca intake is more important than Mg intake in all cause mortality: Both are necessary, in fact, all essential nutrients in balanced adequacy are necessary for optimal health. This study does show that additional Mg above adequacy does not lower mortality for CVD, cancer or all cause, but does not tell us if the higher than adequate intakes of Mg impacted the lower, less than adequate Ca intakes, and this is where calculation of individual Ca:Mg ratios with statistical analysis could further our knowledge. This study also confirms the Seelig finding [3] that above optimal intakes of Ca (in this case $> 1,599$ mg/day) in the face of fully adequate Mg intakes will not cause a negative Mg balance and its concomitant loss of optimal health. This is probably not true in studies with less than adequate Mg intakes: Seelig showed that at all Mg intake levels < 10 mg/kg/day, high Ca intake (> 10 mg/kg/day) decreased Mg retention; given high Ca intakes, those at or above 6 mg/kg/day Mg remained in positive Mg balance

while those at or below 5 mg/kg/day Mg were mostly forced into negative Mg balance. Thus, for studies at barely adequate Mg intakes we might expect positive Mg balance (and thus no negative health impacts due to Mg deficit) on low Ca intakes but not on high Ca intakes for both men and women [3]. Studies below adequacy for Mg intake deal with the complex situation of Mg deficit and the fact that diets low in Mg are often also low in Ca [21]. In such studies, increasing Ca and/or Mg intake can show inconsistent results, *i.e.* both rising and falling Mg and/or Ca balance with concomitant health outcomes. Study of Ca:Mg intake ratios with regards to the degree of Mg as well as Ca dietary adequacy might be a worthy effort and might lead to better understanding of the many studies on Ca, Mg and both intakes on health.

The importance of cellular Ca:Mg ratio on the physiological function of several tissues has been largely elucidated by Resnick and others showing a strong physiological/cellular link between a rising Ca:Mg intracellular ratio and aspects of metabolic syndrome including hypertension, hyperinsulinemia, insulin resistance and left ventricular cardiac hypertrophy [9, 22, 23]. Inflammatory syndrome can also be added to these aspects of possible cytosolic Ca activation as a result of Mg deficit [24] and its concomitant high Ca:Mg ratio. This possible common link between stress, inflammation and metabolic syndrome shows how a Mg deficiency at the cellular level can bring on Ca activation in various tissues that are not an appropriate response to an environmental injury or pathogen but rather a result of Mg deficit. It is possible that this cellular Ca activation is part of the pathology of a dietary Mg deficit caused by low dietary Mg, which can be exacerbated by a high dietary Ca:Mg ratio, and this inappropriate Ca activation at the cellular level can lead to type 2 diabetes, CVD or other manifestations of Mg deficiency if the Mg inadequacy is not corrected.

Considering this background, the following associations are intriguing, and warrant further research with measurement of Ca:Mg ratio in physiological studies as well as nutrient intake studies.

Association of rising Ca:Mg with prevalence of type 2 diabetes

Because diabetes mellitus has been considered a Mg wasting disease, the relationship between Mg status and incidence of this chronic disease is of interest [25, 26]. Many studies indicate that a diet high in Mg-rich foods is associated with a

substantially lower risk of type 2 diabetes [27-29] while other studies indicate that Ca and Mg intake may protect against the development of type 2 diabetes [30].

In addition to their rising Ca:Mg ratio from foods (and presumably supplements), over half of the USA population has been shown to be below their EAR for Mg with many low in Ca intakes as well from foods, at least since 2001 [2]. Between 1980 and 2007 the crude incidence of diagnosed diabetes in this population increased 136%, and the age-adjusted incidence rose 123% [31, 32]. The rate of change in incidence of diagnosed diabetes has not been constant; rather the incidence remained largely unchanged in the 1980's and increased sharply in the mid-1990's through 2007 – the same time frame in which the Ca:Mg intake ratio from foods for this population (with less than adequate Mg intake in 60+%) went from largely below 3.0 to largely above 3.0 (figure 7).

Association of rising Ca:Mg with incidence of colorectal cancer in young adults

All four age-gender groups < 50 yrs show mean Ca:Mg > 2.78 after the 1985 survey (table 5). Intakes below this Ca:Mg ratio have been associated with a

significantly decreased risk of colorectal cancer with increasing Mg intake [10]. Additionally, during the time frame in which we have shown the Ca:Mg intake from foods to be rising in the USA ages 19-50 yrs, Siegel *et al.* [33], in 2009, reported a rising colorectal cancer incidence trend among young non-Hispanic white adults, aged 20-49 years between 1992 and 2005 (figure 8).

Conclusion

A study of USDA food intake surveys from 1977 through 2007-8 show a rising Ca:Mg intake ratio from foods for all USA adult age-gender groupings. Ca:Mg intake ratio from foods ranged from 2.3 to 2.86 in the 1977 survey and rose to a range of 2.91 to 3.53 in the 2007-2008 survey. By 2001-2002, the Ca:Mg ratio from foods had risen above the 2.78 ratio found by Dai *et al.* [10] to be associated with an increased risk of colorectal cancer in subjects with decreasing Mg intakes in all but one age-gender group (women 60-69 yrs) and by all age-gender groups by the 2003-4 survey. This rise in Ca:Mg ratio from below 3.0 in 1977 to generally above or approaching 3.0 after 2000 coincides with the rise in incidence and prevalence of type 2 diabetes in the USA population as well as a rise in colorectal

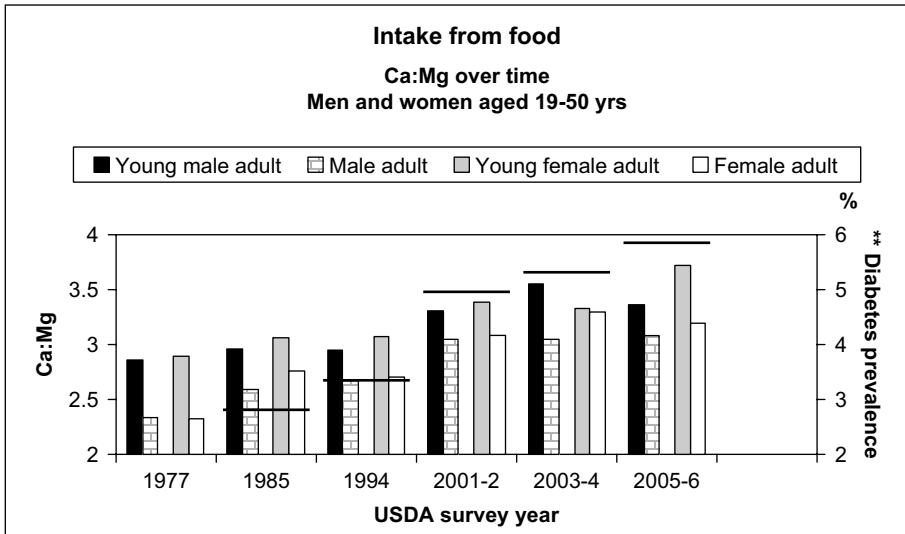


Figure 7. Ca:Mg from foods over time for USA Adults age 19-50 yrs (see table 4 for age ranges) charted with rise in Diabetes prevalence, USA, 1980-2006 (source: CDC [31, 32]).

**Diabetes Prevalence: Crude & Age-Adjusted % of Civilian, Noninstitutionalized Population with Diagnosed Diabetes, United States, 1980-2006.

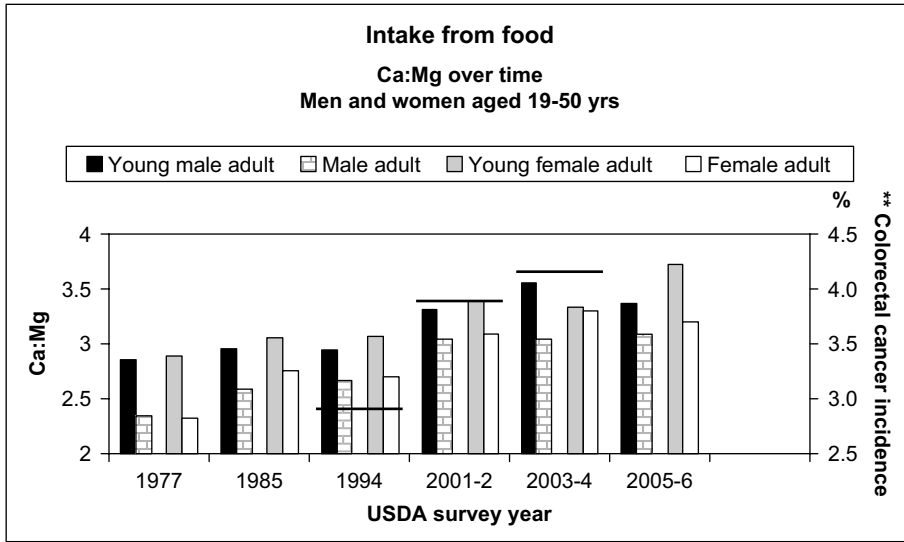


Figure 8. Ca:Mg from foods over time for USA Adults age 19-50 yrs (see table 4 for age ranges) and rising incidence of colorectal cancer in USA non-Hispanic white adults age 20-49 yrs (source: [33]).
**Colorectal Cancer Incidence in Young Adults, USA.

cancer incidence among young white, non-hispanic adult men and women in the USA. The rise in Mg intake over these 30 years is highly comparable to the rise in mean energy intake for these men and women, while the rise in Ca intake is substantially higher, lending credence to the hypothesis that this rise in Ca:Mg over the years is a result of higher intake of Ca from foods either from changes in food selections, a rising content of food Ca or both. Original intake data for individuals from these surveys needs to be accessed, if possible, to calculate Ca:Mg ratio for each individual and do a proper statistical assessment of this ratio's rise over the years and to appropriately compare it with incidence and prevalence of colon cancer in 19-50 yr adults and type 2 diabetes in the adult population to better assess the validity of these associations. Individuals can raise their Mg adequacy plus lower their dietary Ca:Mg ratio by consuming more vegetables, legumes, whole grains and nuts. Calculation of Ca:Mg intake ratio in individual assessments might be added to medical and dietary exams as well as research studies with informative results. Health consequences need to be considered for the 64-67% [2] yr old adults in the USA not meeting their requirement for Mg from foods, many being also below their requirements for Ca, and their increasing Ca:Mg ratio from foods.

Disclosure

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