Original Article

Magnesium deficiency and its lack of association with asthma in Taiwanese elementary school children

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The purpose of this study was to investigate magnesium nutritional status and its association with asthma in elementary school children (1277 boys and 1109 girls) participating in the Nutrition and Health Survey in Taiwan (NAHSIT children 2001-2002). Dietary magnesium intake was based on 24-hour dietary recalls. Serum magnesium was measured. Average magnesium intake was 247 mg and 228 mg for the boys and girls, respectively, which is equivalent to 135-123% of the relevant Taiwanese Dietary Reference Intakes (DRIs). Mean serum magnesium concentration was 0.87 mmol/L and 0.86 mmol/L, respectively. The prevalence of serum magnesium <0.8 mmol/L was 10.5-13.5% in both gender in our sample of elementary school children. In Taiwan, asthma was diagnosed in about 5.8% and 4.7% of boys and girls, respectively. In this study, there were no associations between asthma prevalence, dietary magnesium and serum magnesium concentration. In about 40% of our sample of school children, however, dietary magnesium may be suboptimal. This deficit should be targeted though improved intake of magnesium-rich foods such as whole grains, green vegetables and soybean products, particularly in Taiwanese school children whose dietary intakes are below the DRIs and/or who have low serum magnesium levels.

Key Words: magnesium intake, serum magnesium, elementary school children, asthma, nutrition and health survey in Taiwan

INTRODUCTION

Magnesium is of considerable importance in organic synthesis. It has been established that magnesium ions are required by a diverse range of enzymes involved in energy metabolism, protein synthesis, ions transport, signal transduction and cell proliferation.[1-3] In humans, the amount of magnesium absorbed is almost in linear proportion to magnesium intake, with increased fractional absorption observed only at low dietary intakes.[4]

Various nutrients, high fiber and high phosphate diets may reduce magnesium absorption.[5,6] The level of blood magnesium is remarkably constant in healthy individuals, maintained by a poorly understood homeostatic mechanism.[7] Although magnesium is found in a variety of foods and beverages, a number of surveys have shown that dietary intake of the elementary school children is inadequate in many countries.[8-12] This finding is also supported by the prevalence of low serum magnesium levels shown in other reports.[13-15]

Asthma is one of the most common chronic diseases worldwide, with up to 150 million people currently suffering the disease. Further, this number has been climbing steadily since the 1950s. In the last 10 years, asthma cases have risen 50% globally.[16] Magnesium is involved in numerous biochemical and physiological processes that directly influence lung function and indirectly influence respiratory symptoms. The mechanisms underlying the effects on lung function and symptoms include alteration of smooth muscle function, neuromuscular excitability, immune function, oxidative stress, DNA and RNA synthesis, and enzymatic activity.[17-21] Epidemiological evidence from population-based study indicates that low dietary intake of magnesium is associated with increased incidence of asthmatic symptoms, wheezing, reduced lung function, and lower lung volume and flows.[17-21] It appears reasonable to assume, therefore, magnesium status may be a causal factor in asthma, with some investigations of parenteral magnesium supplementation in acute asthma producing evidence of benefit.[17,18] Overall, however, the results of these studies have been inconclusive.[19]

Hypomagnesemia has been found in the blood of patients with chronic, stable asthma.[22] Further, magnesium deficiency in blood cells and low urine magnesium excretion have also been demonstrated in these patients.[23]

The prevalence of asthma is increasing in many countries, especially in children.[16] In Taiwan, the prevalence of childhood asthma has increased dramatically during the last 30 years, climbing from 1.3% in 1974 to 19.0% in 2003. Currently, childhood asthma is a major health problem in Taiwan.[24,25]

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However, no population-based studies have been conducted to explore the relationship between magnesium-status and asthma in Taiwan elementary school children. Therefore, the aim of this investigation was to assess dietary magnesium and blood levels and to determine the association between magnesium status and asthma in a sample population of elementary school children.

MATERIALS AND METHODS

Subjects and data source

The Nutrition and Health Survey in Taiwan Elementary School Children (NAHSIT children 2001-2002) was a government-sponsored survey that included information on 24-hour dietary recall and health status assessed by interviewer-administered questionnaires. The complex sampling scheme used is detailed elsewhere,[26] so is the assessment of dietary intake.[27] Estimates of dietary magnesium were obtained for 2386 school children aged 6-12 years who had completed dietary assessment. Estimates of the population distribution of serum magnesium concentrations were calculated for 2141 school children aged 6-12 years who had participated in physical examinations including measurement of anthropometric and blood biochemical parameters. An informed consent was signed by one of the parents of each participating child. The study was approved by reviewers invited by the Department of Health in Taiwan. Asthma status was based on major caretaker's report on physician's diagnosis. A subgroup of subjects with complete data for both dietary recall and blood parameters were used for analysis of the association between magnesium parameters and asthma prevalence.

Serum magnesium analysis

Venous blood samples were collected from fasting subjects using vacuum tubes. The serum samples were then frozen and shipped to the laboratory for biochemical analysis. The serum magnesium concentration was measured using colorimetric assay involving xylidylblue reaction which forms a complex with absorption at 520 nm. The measurement was performed with Olympus System Reagent on an Olympus Autoanalyzer (Olympus AU640, County Clare, Ireland).

Statistical analysis

All variables were weighted to represent the general Taiwanese Elementary population.[26] Values were expressed as mean ± standard error. Gender and age group differences were assessed using the t-test. Linear regression was used to evaluate trends across seven groups. Logistic regression analysis was performed to evaluate the association between low serum magnesium and asthma. SAS (version 9.1) and SUDAAN (version 9.0) software were used for statistical analysis. The level for statistical significance was set at $p < 0.05$ for all tests.

RESULTS

Dietary magnesium intake stratified by gender and age is presented in Table 1. The average daily magnesium intake of 247±6 mg for boys and 228±6 mg for girls, represent 135% and 123% of the Dietary Reference Intakes (DRIs), respectively. Average daily calorie intakes of 2113 kcal and 1904 kcal were 103% and 101% of the DRIs for boys and girls, respectively. Magnesium density was 118 mg/1000 kcal in boys and 123 mg/1000 kcal in girls. Boys had a significantly higher magnesium intake than girls, and it increased with age and the trend was only significant for girls (p for trend=0.0024). About 35.2% boys and 44.3% girls whose one-day dietary magnesium estimated by one 24-hour recall were under DRIs level, it increased with age and the trend was significant both for both sexes (p for trend<0.0001).

Sample distribution of serum magnesium concentrations is depicted in Figure 1. The median value of serum magnesium was 0.863 mmol/L for both boys and girls. Serum magnesium concentrations stratified by gender and age are presented in Table 2. Mean concentration was 0.87±0.00mmol/L and 0.86±0.00 mmol/L for the boys and girls, respectively, and the boys was significant higher than girls (p<0.05). The prevalence of magnesium deficiency defined as serum magnesium<0.8 mmol/L[15] was 10.5% in boys and 13.5% in girls. The prevalence of asthma was 5.8% in boys and 4.7% in girls (Table 3). The dietary magnesium intake was lower in girls with asthma relative to those without. However, no significant difference was demonstrated comparing subjects with and without asthma for magnesium intake and serum concentration, irrespective of gender (Table 4).

Table 1. Daily magnesium intake by age and gender in Taiwanese elementary school children

age	Boys				Girls			
	N	Mean±SE (mg)	DRIs† (%)	<DRIs‡ (%)	N	Mean±SE (mg)	DRIs† (%)	<DRIs‡ (%)
All	1277	247±6¶	135	35.2	1109	228±6¶	123	44.3
6	103	244±16	203	4.2	98	221±17	184	23.7
7	232	242±9¶	147	27.6	179	192±9§¶	117	44.1
8	217	222±10	135	35.6	184	223±11	135	33.2
9	208	245±9	148	25.1	180	219±1§	133	36.3
10	212	258±12	112	48.5	193	239±12	100	56.5
11	221	260±11	113	48.5	177	255±18	106	58.5
12	84	262±17	114	46.4	98	255±14	106	52.5
p for trend††		0.0815		<0.0001		0.0024		0.0001

Values for each age group are expressed as mean±SE. All values are weighted to reflect their representation in the population † Percent of daily magnesium intake/DRIs. ‡ Percent of daily magnesium intake less than DRIs level. §Significantly different (p<0.05) when compared to the group of age 12. ¶Values are significantly different (p <0.05) between gender. †† p value for trend analysis by age.

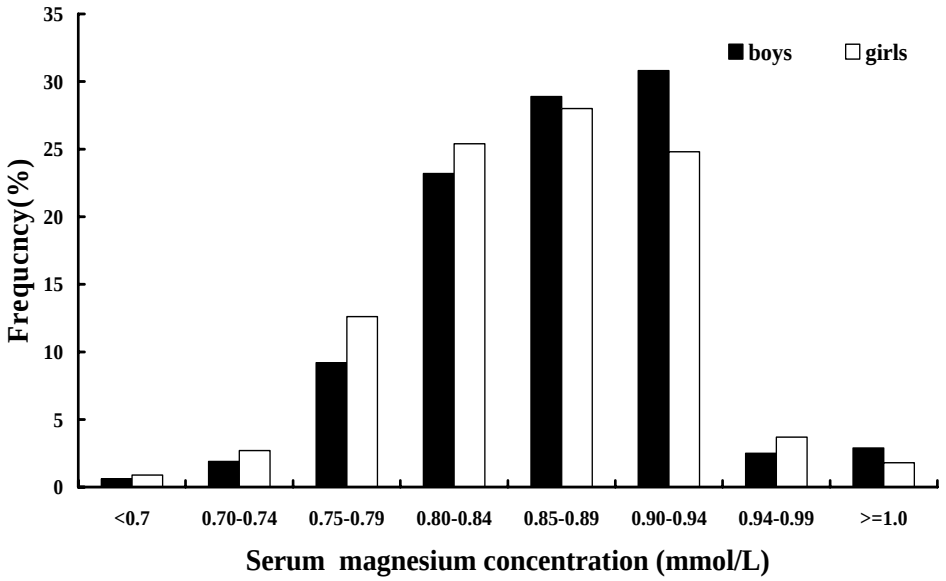

Figure 1. Distribution of serum magnesium concentrations in Taiwanese elementary school children

Table 2. Serum magnesium concentration and the prevalence of magnesium deficiency by age and gender in Taiwanese elementary school children

age	Boys			Girls		
	N	Mean±SE (mmol/L)	<0.8 mmol/L[§] (%)	N	Mean±SE (mmol/L)	<0.8 mmol/L[§] (%)
All	1149	0.87±0.00[‡]	10.5	992	0.86±0.00[‡]	13.5
6	93	0.87±0.01	16.7	76	0.86±0.01	9.1
7	208	0.87±0.01	12.7	160	0.86±0.01	14.8
8	180	0.88±0.01	11.9	162	0.86±0.01	13.3
9	184	0.87±0.01	8.2	163	0.87±0.01	9.2
10	194	0.87±0.01	10.5	176	0.86±0.01	19.3
11	209	0.88±0.01	6.1	169	0.87±0.01	11.3
12	81	0.87±0.01	12.4	86	0.86±0.01	16.9
p for trend[†]		0.557	0.261		0.543	0.268

Values for each age group are expressed as mean±SE All values are weighted to reflect their representation in the population. Not significantly different when compared to the group of age 12. [†] P value of trend analysis by age group. [‡] Values are significantly different (p <0.05) between gender. [§]Percent of serum magnesium value under 0.8 mmol/L.

Table 3. Prevalence of asthma in Taiwanese elementary school children

age	Total		Boys		Girls	
	N	%	N	%	N	%
Total	127	5.3	80	5.8	47	4.7
6-9	70	5.1	45	5.9	25	4.3
10-12	57	5.5	35	5.8	22	5.2

Values are expressed as frequency. All values are weighted to reflect their representation in the population

The asthma prevalence risks by quartile of serum magnesium concentration from logistic regression analysis are listed in Table 5. Since there was no significant difference between the second and third quartiles, so they were combined in our study. Compared to the highest quartile of serum magnesium concentration, the odds ratios of asthma prevalence was 0.80 for boys and 1.50 for girls relative to the lowest quartile (serum magnesium<0.822 mmol/L), but there was no significant difference.

DISCUSSION

Recent dietary surveys have shown that the average magnesium intake is slightly below the appropriate recommended dietary allowance (RDA) in Western countries.[28] For comparison, the dietary magnesium intakes for US boys and girls aged 6-11 yr from the NHANES 1999-2000 data were 233 mg/d and 211 mg/d (RDA: 130 mg/d and 240 mg/d for age 4-8 yr and 9-13 yr, respectively).[10] About one-third of Americans aged 6-18 yr have magnesium intakes below the estimated average requirement (EAR). Mean magnesium intake in Costa Rican adolescents aged 12-19 yr was 273-296 mg/d (71-77%RDA), with intake below RDA in over 25% of this age subpopulation.[8] In Spanish children, the magnesium intake was found to be 282 mg/d and 248 mg/d for boys and girls in aged 6-14 y, respectively.[9] Magnesium was less than two-thirds of the recommend nutrient intake (RNI) in 14.9% of the Canary Islands population aged 6-24 yr.[11] The average magnesium intake of 247 mg/d and 228 mg/d (123-135% RDA) in our sample of Taiwanese boys and girls school children, respectively, is lower than the analogous figures for Spanish children and Costa Rican adolescents, but higher than American children.[9,10] Importantly, although the average magnesium intake for our elementary school children was 23-35% over the recommended daily value, 37% of boys and 45.6% of girls of aged 10-12,

Table 4. The magnesium status of asthma/normal in Taiwanese elementary school children

Variables	Boys				Girls			
	Asthma		Non-asthma		Asthma		Non-asthma	
	N	Mean±SE	N	Mean±SE	N	Mean±SE	N	Mean±SE
Magnesium intake (mg/d)	78	252±20	1199	246±6	47	209±21	1062	229±6
Serum magnesium (mmol/L)	70	0.87±0.01	1079	0.87±0	39	0.86±0.02	953	0.86±0

Values are expressed as mean±SE.

Table 5. Odds ratio of asthma by quartile of serum magnesium in Taiwanese elementary school children

Gender	Odds ratio of asthma by quartile of serum magnesium concentration		
	I	II, III	IV
	<0.822 mmol/L	0.822-0.904 mmol/L	>0.904 mmol/L
All	0.96 (0.42-2.23)	0.72 (0.39-1.35)	1
Boys	0.80 (0.27-2.37)	0.61 (0.31-1.22)	1
Girls	1.50 (0.34-6.56)	0.97 (0.31-3.09)	1

Numbers in parentheses indicate 95% confidence intervals. Models have adjusted for age and BMI. Gender was also adjusted for the model which boys and girls combined.

correcting for daily variations, were under the recommended level.[27]

The inadequate magnesium intakes observed in various countries, including Taiwan, may reflect similar trends in dietary patterns. The occidental "Western diet" is considered relatively deficient in magnesium, while the traditional "Oriental diet" is characterized by greater intake of rice/rice products, green vegetables and soybean products and, therefore, it is richer in magnesium.[29] However, the dietary patterns of school children in Taiwan have been gradually westernized as the nation has become more affluent. We have noted that the top-ranked sources of magnesium in Taiwanese school children in descending order are rice/rice products (10.5% of total intake), dairy products (8.7%), pork/pork products (6.6%), green vegetables (6.6%) and soybean products (6.5%).[27] Consumption of whole grains, green vegetables and soybean products contributed only about 23.6% of the total magnesium intake and was below the recommended serving.[27]

Analysis of the data for our Taiwanese school children confirms other findings and reveals gender differences in magnesium intake, with boys having the higher magnesium intake.[9,10] Boys also have higher energy intakes than girls (2113 Kcal/d vs 1904 Kcal/d, $p<0.0001$),[27] and there is a positive association between dietary magnesium intake and energy intake (r= 0.59, $p<0.0001$).

The normal range of blood magnesium concentration is 0.75-1.00 mmol/L.[28] In Germany, low serum magnesium concentrations were found in about 5-8% of the overall population[13] with levels below 0.76 mmol/L observed in 14.5% unselected population.[14] Further, the prevalence of low serum magnesium concentration (<0.8 mmol/L) has been estimated at 23% of US adults aged 25-74 yr.[15] Due to the lack of serum magnesium data for elementary school children elsewhere, we are unable to determine whether the prevalence of low serum magnesium in our sample (10.5-13.5%) in Taiwan is high or low in terms of meaningful international comparisons.

An inverse association between dietary magnesium intake and asthma has been observed in several reports.[17-21] In another study, short-term alteration of dietary magnesium intake produced an effect on clinical control of asthma.[30] By contrast, a randomized placebo-controlled trial of supplementary magnesium showed no evidence of asthma improvement after 4 months supplementation.[31] Associations between asthma and dietary magnesium intake and serum magnesium concentration were not observed by us. This may in part due to not being able to control for the following confounders: household smoking status, pet ownership, and parental social class.[32] In addition, the results of our study appear to indicate that, at the lower end of the reference range, serum magnesium concentration may not be sufficiently low to increase the risk of asthma in elementary school children. Furthermore, it is not optimal to associate asthma status with magnesium profile in a cross-sectional study. Prospective investigation is more likely to reveal a link given the probable temporal nature of any such relationship.

This is the first report of magnesium status in Taiwan elementary school children and found no association between serum magnesium concentration and asthma in a non-Caucasian population. Moreover, a significant difference in serum magnesium was not demonstrated between asthmatic school children and their apparently healthy counterparts. However, Taiwanese school children whose dietary magnesium is under the recommended level may well benefit from an increased intake of magnesium-rich foods such as whole gains products, green vegetables and soybean products. This may be of increasing relevance as the connections between the growing problem of insulin resistance syndromes with energy imbalance in early life are considered in relation to magnesium status.[33]

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AUTHOR DISCLOSURES

Jui-Line Wang, Ning-Sing Shaw, and Mei-Ding Kao, no conflicts of interest.

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Original Article

Magnesium deficiency and its lack of association with asthma in Taiwanese elementary school children

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臺灣國小學童鎂缺乏與氣喘間無顯著相關

本研究目的探討「臺灣地區國小學童營養健康狀況調查 2001-2002」中國小學童（1277 名男學童與 1109 名女學童）鎂營養狀況與氣喘之相關性。研究中以 24 小時回憶法調查飲食鎂攝取量並分析血鎂濃度。男學童平均飲食鎂攝取量 247 mg、女學童 228 mg，相當於 135%~123%之營養素建議參考量(DRIs)。血清鎂濃度男學童平均濃度為 0.87 mmol/L、女學童為 0.86 mmol/L，兩性學童血清鎂濃度＜0.8 mmol/L 之缺乏率為 10.5-13.5 %。臺灣 5.8%男學童經診斷證實為氣喘、女學童為 4.7%。於本研究中學童氣喘盛行率與飲食鎂攝取量、血鎂濃度間並無相關性，但臺灣約 40%學童的飲食鎂攝取狀況並不理想，若能提高富含鎂食物如全穀類、綠色蔬菜及黃豆製品等食物的攝取，對飲食鎂攝取不足的學童應能有效改善其鎂營養狀況。

關鍵字：飲食鎂攝取、血清鎂、國小學童、氣喘、國民營養健康狀況變遷調查。