Magnesium status and dietary intake of mid-old people in a rural area of China

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Abstract. To evaluate the status and dietary intake of magnesium in mid-old people in a rural area of China, a total of 324 mid-old people (111 males and 213 females) aged 55-70 were randomly selected. All the subjects were divided into four groups: a normal group (N), a hypertension group (H), an impaired fasting glucose group (IFG) and a diabetic group (D). Magnesium, sodium, potassium, calcium, iron, zinc, and copper concentrations in red blood cells (RBC) were measured by emission spectroscopy (ICP-OES), and dietary intakes were surveyed by 24-hr recall questionnaires. The data were analyzed between groups and also between genders. The average body weight and BMI were 59.4 kg and 22.1 in subjects with IFG, and 62.4 kg and 23.5 in the diabetics, which were higher than those of the normal group (p < 0.05 and p < 0.01). The average magnesium concentration in RBC was significantly lower in the hypertension group than in the normal group (2.0 mmol/L vs 2.2 mmol/L, p < 0.05). Groups H, IFG and D took less magnesium than group N (315.9 mg/d, 331.6 mg/d and 323.3 mg/d vs 371.54 mg/d, p < 0.05). Women took less magnesium than men (326.2 mg/d vs 373.7 mg/d, p < 0.05). There were no significant differences in other mineral concentrations in RBC and dietary intakes. Results of this study show that magnesium concentration in RBC is lower in mid-old people suffering hypertension as compared to healthy subjects. Dietary intakes of magnesium are lower in mid-old people suffering hypertension, IFG and diabetes as compared to healthy subjects. This indicates that an increase in the magnesium supply would be beneficial to mid-old people.

Key words: magnesium, mineral, dietary intake, hypertension, diabetes, China

Magnesium is the fourth most abundant extracellular cation, and the second in intracellular fluid. It is an important cofactor in many enzymatic reactions [1] and thus plays a key role in many biological processes [2]. Accumulating evidence suggests that magnesium deficiency is associated with the development of poor metabolic control, increased free radical dependent-oxidative tissue damage, and chronic complications in patients with type 2 diabetes [3, 4]. Lower magnesium intake and lower serum magnesium concentration are associated with many chronic diseases such as metabolic syndrome, hypertension, type 2 diabetes mellitus, and cardiovascular diseases [5, 6]. Studies indicate that magnesium supplementation can benefit people by preventing metabolic syndrome and its components. Increased magnesium intake is considered to have the effect of protecting people against the incidence of diabetes, hypertension and cardiovascular diseases [7, 8].

Dietary survey data suggest that the average magnesium intake in western countries has been declining during the last century and is often below the recommended dietary allowances (RDA). In France, Galan et al. [9] found that 77 per cent of women and 72 per cent of men had dietary magnesium intakes
lower than the RDAs; 23 per cent of women and 18 per cent of men consumed less than 2/3 of the RDAs. There is a strong positive correlation between energy and magnesium intake \( (r = 0.79, p < 10^{-4}) \). Among US adults, 68% consumed less than the RDAs of magnesium, and 19% consumed less than 50% of the RDAs [10].

Unfortunately, there are very few epidemiological or clinical studies on magnesium status and related topics reported in China up to now. There is only an AI (Adequate Intakes) but still not a RDA available in China.

The aim of this study was to evaluate the status and dietary intake of magnesium of mid-old people in a rural area of China, and to compare the magnesium status between people with hypertension or hyperglycemia and healthy subjects, and so to provide evidence and directions for mid-old people to take adequate magnesium.

Subjects and method

Subjects and dietary intake assessment

The study was a cross-sectional survey carried out in a rural area of Qingdao, China. A total of 324 mid-old people, 111 males and 213 females, aged 55-70 were randomly selected as subjects. All the subjects accepted a body check, including measurement of height, body weight, and blood pressure. They were divided into 4 groups: the normal group (N, normotensive + normoglycemic), the hypertension group (H, systolic blood pressure, SBP \( \geq 140 \) mmHg or diastolic blood pressure, DBP \( \geq 90 \) mmHg), the impaired fasting glucose group (IFG, fasting blood glucose, FBG \( \geq 6.1 \) mmol/L and \( < 7.0 \) mmol/L), and the diabetic group (D, FBG \( \geq 7.0 \) mmol/L). The data were also analyzed between genders.

All the subjects were questioned about their food consumption status. The food intakes and ingredients were surveyed by a 24-h recall questionnaire. Major nutrient intakes of the diet were calculated according to the Chinese Food Composition Table 2004 [11].

The study was approved by the Research and Ethics Committee of the Institute of Human Nutrition, Medical College of Qingdao University. An informed consent was obtained from each subject prior to the study.

Mineral concentrations analysis

Venous blood samples (5 mL from each subject) were taken in the morning after an overnight bed rest for measurements. The samples were stored in ice in a specialized box and sealed up for transportation to the laboratory. Magnesium, sodium, potassium, calcium, iron, zinc, and copper concentrations in red blood cell (RBC) were measured by an Optical Emission Spectrometer (710-ES ICP, Varian, Palo Alto, USA).

Statistical analysis

Categorical data were presented as frequencies, such as prevalence of hypertension, IFG, and diabetes, whereas continuous data were expressed as mean \( \pm \) SD. Differences of FBG, RBC mineral concentrations, and mineral dietary intakes between males and females were analyzed by independent sample t-tests. Differences of prevalence of hypertension, IFG, and diabetes between males and females were analyzed by the Chi-Square test. Differences of RBC mineral concentrations and dietary intakes between groups were analyzed by one-way ANOVA test using SPSS-11.5 software. The correlations between RBC magnesium concentrations, magnesium dietary intakes and blood pressure or FBG were analyzed by Pearson and Spearman bivariate correlation analyses. Significant differences were determined at the level of \( p < 0.05 \).

Results

The characteristics of the different groups studied are shown in Table 1. The average body weights

| Table 1. Characteristics of the different groups in the mid-old population studied. |
|--------------------------------------|------------|-----------|------------|-----------|
|                                     | Normal (n = 142) | Hypertension (n = 150) | IFG (n = 11) | Diabetics (n = 21) |
| Age (years)                         | 64.0 ± 4.8 | 63.8 ± 3.7 | 64.1 ± 3.4 | 63.6 ± 4.1 |
| Height (cm)                         | 163.3 ± 6.2 | 163.1 ± 4.5 | 162.6 ± 5.5 | 163.1 ± 3.4 |
| Weight (kg)                         | 56.7 ± 10.3 | 57.4 ± 8.4 | 59.4 ± 8.6* | 62.4 ± 6.4** |
| BMI (kg/m²)                         | 19.1 ± 4.0 | 19.5 ± 3.2 | 22.1 ± 3.7* | 23.5 ± 3.2** |

Means \( \pm \) SD. * \( p < 0.05 \); ** \( p < 0.01 \) compared to the normal group. IFG-impaired fasting glucose.
and BMIs of the IFG and diabetic groups were higher than those of the normal group (table 1). The average fasting blood glucose (FBG) of the mid-old people studied was 5.4 ± 2.0 mmol/L. Prevalence of hypertension, IFG and diabetes of the mid-old people was 46%, 3.40%, and 6.48%, respectively. There were no differences in prevalence of hypertension, IFG and diabetes between males and females (table 2).

The average magnesium concentration in RBC of the mid-old people studied was 2.1 ± 0.7 mmol/L. It was significantly lower in the hypertension group as compared to normal subjects (table 3). There was no difference in the average magnesium concentrations between males and females (table 4).

The average magnesium dietary intake of the mid-old people was 342.5 ± 187.6 mg/d (98% of AI - Adequate Intakes). Groups H, IFG and D took less magnesium than group N (table 5). Women took less magnesium than men (table 6).

There were no significant differences in other mineral concentrations and dietary intakes between males and females.

**Table 2.** Prevalence of hypertension, impaired fasting glucose (IFG) and diabetes in males and females from the mid-old population studied.

<table>
<thead>
<tr>
<th></th>
<th>Hypertension</th>
<th>IFG</th>
<th>Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n Prevalence (%)</td>
<td>n Prevalence (%)</td>
<td>n Prevalence (%)</td>
</tr>
<tr>
<td>Males (111)</td>
<td>52 46.85</td>
<td>4   3.60</td>
<td>7   6.31</td>
</tr>
<tr>
<td>Females (213)</td>
<td>98 46.01</td>
<td>7   3.29</td>
<td>14  6.57</td>
</tr>
</tbody>
</table>

There are no statistically significant differences in the prevalence of hypertension, IFG and diabetes between males and females.

**Table 3.** Mineral concentrations in red blood cells (mmol/L) of the different groups of the mid-old population studied.

<table>
<thead>
<tr>
<th></th>
<th>Normal (n = 142)</th>
<th>Hypertension (n = 150)</th>
<th>IFG (n = 11)</th>
<th>Diabetics (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>2.2 ± 0.7</td>
<td>2.0 ± 0.7</td>
<td>2.1 ± 0.9</td>
<td>2.1 ± 0.6</td>
</tr>
<tr>
<td>Potassium</td>
<td>24.4 ± 15.9</td>
<td>28.3 ± 19.0</td>
<td>27.8 ± 18.2</td>
<td>25.7 ± 17.6</td>
</tr>
<tr>
<td>Sodium</td>
<td>20.1 ± 6.8</td>
<td>18.7 ± 4.4</td>
<td>17.9 ± 5.4</td>
<td>18.4 ± 6.1</td>
</tr>
<tr>
<td>Calcium</td>
<td>3.7 ± 2.2</td>
<td>3.6 ± 2.8</td>
<td>3.2 ± 3.8</td>
<td>3.5 ± 5.8</td>
</tr>
<tr>
<td>Copper</td>
<td>0.2 ± 0.1</td>
<td>0.2 ± 0.3</td>
<td>0.2 ± 0.2</td>
<td>0.2 ± 0.4</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.2 ± 0.1</td>
<td>0.2 ± 0.1</td>
<td>0.2 ± 0.2</td>
<td>0.2 ± 0.1</td>
</tr>
<tr>
<td>Iron</td>
<td>6.1 ± 3.9</td>
<td>6.8 ± 3.8</td>
<td>6.4 ± 1.8</td>
<td>6.7 ± 2.68</td>
</tr>
</tbody>
</table>

Means ± SD. *p < 0.05 compared to the normal group. IFG-impaired fasting glucose.

**Table 4.** Mineral concentrations in red blood cells (mmol/L) of males and females of the mid-old population studied.

<table>
<thead>
<tr>
<th></th>
<th>Males (n = 111)</th>
<th>Females (n = 213)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>2.0 ± 0.7</td>
<td>2.1 ± 0.7</td>
<td>0.257</td>
</tr>
<tr>
<td>Potassium</td>
<td>25.7 ± 15.8</td>
<td>27.0 ± 19.0</td>
<td>0.616</td>
</tr>
<tr>
<td>Sodium</td>
<td>18.8 ± 6.0</td>
<td>19.4 ± 5.6</td>
<td>0.458</td>
</tr>
<tr>
<td>Calcium</td>
<td>3.3 ± 1.8</td>
<td>3.8 ± 2.8</td>
<td>0.153</td>
</tr>
<tr>
<td>Copper</td>
<td>0.2 ± 0.1</td>
<td>0.2 ± 0.3</td>
<td>0.482</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.1 ± 0.1</td>
<td>0.2 ± 0.1</td>
<td>0.090</td>
</tr>
<tr>
<td>Iron</td>
<td>6.5 ± 3.5</td>
<td>7.3 ± 4.1</td>
<td>0.905</td>
</tr>
</tbody>
</table>

Means ± SD. There is no difference in the average mineral concentrations between males and females.
groups or between genders. However, the average calcium intake was very low in this studied population \( \text{Table 5} \), only 30.9% of the AI recommended by the Chinese Nutrition Society (308.6 mg vs 1000 mg). Also sodium intake was low and thus sodium/potassium was also very low in the population studied \( \text{Table 5} \) as compared to intake in western countries. There was a significant inverse correlation between the RBC magnesium concentration and the diastolic blood pressure \((r = -0.152, p < 0.05)\). There was also an inverse correlation between both magnesium concentrations and magnesium intakes and the systolic blood pressure and fasting blood glucose, but not significantly.

**Discussion**

This study evaluated the magnesium status and dietary intakes of mid-old people in a rural area of Qingdao, China. The population studied was subdivided to normal, hypertension, IFG and diabetics groups. Both the body weights and BMIs of groups IFG and diabetics were higher than those of the normal group. This is in agreement with the well known correlation between body weight and diabetes mellitus \([12]\). The observed prevalence rate of hypertension appears high, but is consistent with the result of Miao et al \([13]\). This high prevalence of hypertension seems unrelated directly with the present sodium intake which is low. It could be hypothesized that it is rather linked to the past nutritional behavior, \(\text{i.e.}\) high salt ingestion in these coastal area inhabitants. Compared to the results of the census of nutrition and health of the Chinese population \([14]\), mineral intakes are lower, except for magnesium. For example, calcium intake is very low with regard to usual recommendations. The average magnesium dietary intake of these mid-old people is nearly 98% of the Adequate Intakes (AI). The reason why the daily magnesium intakes are adequate and these of calcium low may be related to their nutritional behavior, \(\text{i.e.}\) a diet high in grains and vegetables but poor in dairy products. Our results indicate that women take less magnesium than men. This is in agreement with work of Galan et al. \([9, 15]\) and could be related to higher incidence of hypomagnesaemia in women \([16]\).
Previous works have indicated that lower magnesium intakes and lower serum magnesium concentrations are associated with the metabolic syndrome, insulin resistance, hypertension, and/or type 2 diabetes mellitus [3, 5, 17, 18]. On the other hand, lifestyle changes, including adequate magnesium intake, can benefit blood pressure control, promote weight loss, and improve chronic disease risks [19]. Increased dietary magnesium intake confers protection against the incidence of diabetes, metabolic syndrome, and hypertension [3, 20]. Oral magnesium supplementation improves insulin sensitivity in hypomagnesaemic non-diabetic subjects [21], but results still remain inconclusive [22, 23].

In agreement with the relationship between low magnesium status and hypertension, we have shown that the average magnesium concentration in RBC is lower in the hypertension group. However, despite a lower magnesium intake than in normal group, we show that concentrations of magnesium in RBC in the impaired fasting glucose (IFG) group and the diabetics group are not significantly affected. Because of the small size of these groups, due to the limited prevalence of IFG and diabetes, which is 3.40%, and 6.48%, further studies on a larger population are needed to establish this possible relationship.

In conclusion, the results of this study indicate that the magnesium status is lower in hypertensive subjects and that magnesium intakes are lower in groups of hypertension, IFG and diabetics.

This evidence suggests that increasing the intake of magnesium from consumption of magnesium-rich foods or taking magnesium supplementation may have beneficial effects on preventing or improving hypertension and insulin resistance. Further studies should be conducted to evaluate the possible effects of increased magnesium intake on improving insulin resistance and to define the proper level of magnesium delivery for mid-old people.

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There is no conflict of interest of any of the authors.

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