Leukocytosis and Thrombocytosis Caused by Consumption of a Low Magnesium and High Calcium Diet Elevates Whole-Blood Taurine Concentration in Cats\textsuperscript{1,2}

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EXPANDED ABSTRACT

KEY WORDS: • cat • plasma • taurine • white blood cell • platelet

The initial association of feline central retinal degeneration with low plasma taurine concentration led to the establishment of taurine as an essential nutrient in cats and to recognition of the usefulness of blood taurine measurement in determining dietary taurine requirement in cats.

Research has since shown with plasma and whole-blood taurine measurements that dietary factors, including heat treatment, protein source, and protein concentration affect the need for taurine in the diet of cats (Morris et al. 1994). For those dietary factors found to have an effect, a decrease rather than an increase in blood taurine concentration is typically observed. However, exceptions to this may occur. The consumption of a diet deficient in magnesium substantially elevated the serum taurine concentrations of rats (Robeson et al. 1980). It was suggested that this effect resulted from stimulation of taurine synthesis from sulfur amino acids or inorganic sulfate. The present research was prompted by this finding and was undertaken with the objectives of determining whether dietary magnesium affects blood taurine concentration in cats and, if so, the nature of the cause.

Materials and methods. Thirty female and 30 male specific-pathogen–free kittens, 10–12 wk in age, were randomly assigned to 10 groups of six cats each, in a 5 × 2 randomized block design. All kittens originated and were housed in the Nutrition and Pet Care Center at the Davis campus of the University of California. As determined by the Animal Use and Care Administrative Advisory Committee, the husbandry and treatment of the kittens was in compliance with the Animal Welfare Act and the NIH guidelines (NRC 1996). The kittens received continuously a purified diet containing either a high (23 g/kg) or adequate (6 g/kg) level of calcium (NRC 1986) and one of five levels of magnesium (100, 200, 300, 400 and 500 mg/kg) of which 400 mg/kg was considered adequate (NRC 1986). The diet also contained (g/kg) lactalbumin (New Zealand Milk Products, Santa Rosa, CA), 222.5; lactalbumin (New Zealand Milk Products), 222.5; animal tallow (Florin Tallow, Dixon, CA), 300; cornstarch (Westco Products, Sacramento, CA), 145–192; mineral mixture, 48; vitamin mixture (Hoffman-La Roche, Nutley, NJ), 10; taurine (Taisho Pharm, Torrance, CA), 1.5; and choline chloride (Dupont, Highland, IL), 3. Magnesium sulfate and calcium carbonate were added in place of cornstarch so as to adjust dietary magnesium and calcium concentrations to required levels. The mineral mixture contained (g/kg diet) CaHPO\textsubscript{4}, 19.60; K\textsubscript{2}HPO\textsubscript{4}, 4.52; KCl, 12.82; NaHCO\textsubscript{3}, 5.02; NaCl, 5.03; MnSO\textsubscript{4} · H\textsubscript{2}O, 0.192; ferric citrate, 0.504; NaF, 0.0072; Ca\textsubscript{3}(IO\textsubscript{6})\textsubscript{2}, 0.00384; SnSO\textsubscript{4} · 7H\textsubscript{2}O, 0.2208; CuSO\textsubscript{4} · 5H\textsubscript{2}O, 0.0384; SnCl\textsubscript{2} · 2H\textsubscript{2}O, 0.0048; Na\textsubscript{2}SeO\textsubscript{3}, 0.0144; (NH\textsubscript{4})\textsubscript{2}Mo\textsubscript{2}O\textsubscript{24} · 4H\textsubscript{2}O, 0.00192; CrCl\textsubscript{3} · 6H\textsubscript{2}O, 0.0144; NiCl\textsubscript{2} · 6H\textsubscript{2}O, 0.0144; and NH\textsubscript{4}VO\textsubscript{3}, 0.001.

Jugular venous blood was collected by syringe from all cats after 13 wk and immediately placed in tubes containing anticoagulant. Taurine concentrations in heparinized whole blood and plasma samples were determined with an automated amino acid analyzer (121MB, Beckman, Fullerton, CA). Routine complete blood counts were conducted on whole-blood samples placed in K\textsubscript{3}EDTA- coated tubes by the Veterinary Medical Teaching Hospital Clinical Hematology Service. Platelet counts were determined rapidly after sampling with an automated cellcounter (Baker Instruments System 9000, Allentown, PA) on fractions of platelet-rich plasma (Serono-Baker Plateletfuge).

During the fourth experimental week, one cat in the group receiving the diet high in calcium and lowest in magnesium was necropsied after an acute episode of hyperactivity characteristic of magnesium deficiency. A general linear model multiple ANOVA (SAS version 6.1, SAS Institute, Cary, NC) was used to evaluate effects of magnesium, calcium, block and their respective interactions on blood taurine concentrations and cell counts. Least-squares means analysis with significance
level set at 0.05 was used in determining the significance of mean differences.

Results. With the exception of lower plasma taurine concentrations in cats from the group given the high calcium-200 mg/kg magnesium diet, plasma taurine concentrations among cats of all groups were not significantly different from those observed in cats receiving a diet with adequate calcium and magnesium, 6 g/kg and 400 mg/kg, respectively (Fig. 1). The variance in mean concentrations of taurine in whole blood was greater than that for plasma. The whole-blood taurine concentrations in cats given the two high calcium-low magnesium diets (100 and 200 mg/kg) were substantially greater than those in cats that received all diets with adequate calcium and the diets that were high in calcium but contained 300, 400 or 500 mg/kg magnesium.

Because dietary calcium and magnesium concentrations substantially affected taurine concentration in whole blood more than in plasma, the taurine content of blood cells was examined. An estimate of the distribution of taurine in cat blood was made from taurine concentrations reported in human blood cells by Vinton et al. (1986) and the mean packed cell volume, total and differential blood cell counts, and taurine concentrations found in cats given the diet with adequate calcium and 400 mg/kg magnesium (Table 1). Results of the estimate indicated that, although erythrocytes were by far the most abundant cell type, leukocytes and platelets contained most of the taurine in the cellular fraction of whole blood.

The apparent cellular distribution of taurine prompted analysis to determine whether whole-blood taurine concentration varied with blood cell counts. A mean (± SEM) leukocyte count of 34,000 ± 1700/μL and mean platelet count of 890,000 ± 75,000/μL were found in cats given the high calcium and lowest (100 mg/kg) magnesium diet. These counts were greater than the mean leukocyte and platelet counts found in all other groups except for the high calcium and 400 mg/kg magnesium diet. Linear regression analysis of whole-blood taurine concentration on leukocyte counts in all cats revealed a positively sloped (P < 0.001) relationship between the variables (Fig. 2). A similar relationship was found between whole-blood taurine concentration and platelet counts (P < 0.001).

In cats given the high calcium and 100 or 200 mg/kg magnesium diets, erythrocyte counts were low (4.0 – 6.5 × 10⁶/μL), and significantly less than the erythrocyte counts found in cats given the diet with adequate calcium and 400 mg/kg magnesium (6.9 – 10.9 × 10⁶/μL). Comparison of observed erythrocyte counts with the VMTH laboratory reference range of 6.0 – 10.2 × 10⁶/μL indicated that several of the cats that received high calcium diets containing either 100 or 200 mg/kg magnesium were anemic. The anemia appeared to be of the macrocytic, normochromic and responsive type because mean corpuscular volume, mean corpuscular hemoglobin concentration, and numbers of reticulocytes and nucleated erythrocytes per 100 erythrocytes in the anemic cats were (mean

![FIGURE 1](https://academic.oup.com/jn/article-abstract/128/12/2581S/4724311)

**FIGURE 1** Plasma and whole-blood taurine concentrations in kittens given a purified diet with different magnesiu and calcium concentrations. Values represent means ± SEM calculated from taurine concentrations of six cats, or five cats in the case of means from the group of kittens that received the high calcium-100 mg/kg magnesium diet. Mean whole-blood taurine concentrations marked with an asterisk are greater (P < 0.05) than those not marked.

### TABLE 1

*Estimate of the distribution of taurine in the plasma and cellular fractions of whole blood in cats given a purified diet with 6 g/kg calcium and 400 mg/kg magnesium*

<table>
<thead>
<tr>
<th>Blood fraction</th>
<th>Fractional volume¹</th>
<th>Cell type</th>
<th>Cell Counts</th>
<th>Relative taurine content²</th>
<th>Estimated taurine distribution in whole blood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td></td>
<td>μL⁻¹</td>
<td>μmol/L³</td>
<td>%</td>
</tr>
<tr>
<td>Plasma</td>
<td>60.1</td>
<td>Erythrocytes</td>
<td>8,680,000</td>
<td>1</td>
<td>58.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Granulocytes</td>
<td>7,578</td>
<td>1,682</td>
<td>97.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lymphocytes</td>
<td>7,632</td>
<td>1,001</td>
<td>142.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Platelets</td>
<td>343,333</td>
<td>32</td>
<td>85.6</td>
</tr>
</tbody>
</table>

¹Calculated from mean packed cell volume.

²Derived from results reported for human blood cells by Vinton et al. (1986), Table 4.

³Plasma value = mean plasma taurine concentration (96.4 μmol/L) × [100 - mean % packed cell volume]/100. Blood cell value = [mean whole blood concentration (507.8 μmol/L) - mean plasma taurine concentration (96.4 μmol/L)] × (mean cell count × relative taurine concentration of cell type)/[mean cell count<sub>erythrocytes</sub> × relative taurine concentration of cell type<sub>erythrocytes</sub> + (mean cell count<sub>granulocytes</sub> × relative taurine concentration of cell type<sub>granulocytes</sub> + (mean cell count<sub>lymphocytes</sub> × relative taurine concentration of cell type<sub>lymphocytes</sub> + (mean cell count<sub>platelets</sub> × relative taurine concentration of cell type<sub>platelets</sub>)].
respectively.

...diet high in calcium that contained either 100 or 200 mg/kg magnesium, laying whole-blood taurine concentration of kittens. Plotted points with over-laying concentrations of inflammatory cytokines are elevated in magnesium deficiency. Weglicki et al. (1992) reported that circulating concentrations of inflammatory cytokines are elevated in magnesium deficiency. The leukocytosis and thrombocytosis appeared to be a consequence of increased demand for taurine-rich blood cells. As indicated by the regressions of whole-blood taurine concentration, these symptoms should be considered if whole-blood taurine concentration is used in evaluation of body taurine status or in determinations of the adequacy of diets in providing taurine.

In conclusion, magnesium deficiency in cats significantly elevates whole-blood taurine concentration, but does not substantially affect plasma taurine concentration. The effect on whole-blood taurine concentration appears to result from increased numbers of taurine-rich blood cells. As indicated by slopes determined in linear regression analyses, whole-blood taurine concentration is increased by approximately 100 mg/L for every increase of 6500 leukocytes/μL or 200,000 platelets/μL. These findings should be considered if whole-blood taurine concentration is used in evaluation of body taurine status or in determinations of the adequacy of diets in providing taurine. As a case in point, high concentrations of whole-blood taurine have been observed recently in flat-chested Burmese kittens (Sturgess et al. 1997). Because pneumonia is often observed in animals with chest deformities, high leukocyte counts may explain the finding.

LITERATURE CITED


