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Effects of Magnesium, Sodium, Calcium or Potassium Intakes on Magnesium Content in Rat Skeletal Muscle

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Magnesium skeletal (myocardium and gastrocnemius) content has been studied in rats supplemented with 30 mM dissolutions of Mg^{2+}, Na^{+}, Ca^{2+} and K^{+} in drinking water, for 7 or 30 days. In both muscles, the ingestion of Mg^{2+} for 30 days increased Mg^{2+} content, while Ca^{2+} and K^{+} supplementation caused a significant drop. The increase in Na^{+} ingestion reduced Mg^{2+} content in gastrocnemius. There were no significant differences between control and animals supplemented for 7 days. These results suggest that, in the case of supplementation situations, the control mechanisms of the Mg^{2+} tissular content have a lower gain than those of Na^{+} and K^{+} of one order of magnitude.

Key words: Mg^{2+}, Na^{+}, Ca^{2+}, K^{+}, Myocardium, Gastrocnemius, Skeletal muscle.

Mg^{2+} is the fourth most abundant cation in the organism and the second within the cell where it intervenes in multiple processes related to the cellular function (5). Magnesium level is controlled by the kidneys and gastrointestinal tract. It appears closely linked to calcium, potassium and sodium balance (23). It is known that a Mg^{2+} deficit situation can result in metabolic alterations and cardiovascular and/or neuromuscular manifestations (10). Hypermagnesemia situations are also accompanied by cardiovascular and CNS alterations (20), hypocalcemia appearing by direct action of the Mg^{2+} as PTH suppressor (13).

Furthermore, Mg^{2+} presents a complex play of interactions with other cations in the organism, having thus an influence on the intra and extracellular K^{+} balance (3).

With respect to Ca^{2+}, hypocalcemia has also been observed in extreme situations of Mg^{2+} depletion, which disappears when this is corrected. It seems clear that

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the reductions in the Mg^{2+} content produce alterations in PTH synthesis and/or liberation, as well as in the drop of the response level of certain tissues faced with the hormone (21).

Moreover, the results of ICHIHARA *et al.* (16) suggest that magnesium stimulates renin release through the elevation of prostaglandins and suppresses aldosterone production through the intracellular calcium movilization.

In addition Mg^{2+} is considered as a natural antagonist of Ca^{2+} affecting the entry, content and distribution of this cation in the cells of the smooth muscle (2). It has beem reported that, calcium supplementation inhibits magnesium absorption in a fibre-free diet (25).

There is further an Mg^{2+}-Na^{+} relationship, which due to the depletion of Mg^{2+}, brings about an increase in the content of intracellular Na^{+} in muscle, heart and lymphocyte (22); on the contrary the reduced ingestion of Na^{+} increases the secretion of aldosterone, which implies an increase in the excretion of Mg^{2+} in urine (14). Finally, DØRUP *et al.* (8) have shown that, oral magnesium supplementation may restore diuretic-induced disturbances in the concentrations of magnesium, potassium and sodium potassium pumps in skeletal muscle.

Taking into account that all the interactions have mostly been studied in depletion situations, and that, Mg^{2+} status is best evaluated by measurement of skeletal muscle magnesium content (12), this work is focused on quantifying the effect of an overload ingestion of cations (Mg^{2+}, Na^{+}, Ca^{2+} and K^{+}) on the composition of Mg^{2+} in muscular tissue, which represents 25.5 % of the total amount in the organism.

Materials and Methods

Wistar male rats, weighing 250-300 g in groups of 6 each have been used. The control group was kept for 30 days drinking tap water, the supplementation groups took 30 mM dissolutions of Mg^{2+}, Na^{+}, Ca^{2+} and K^{+}, respectively for 7 or 30 days. The animals were fed diet A04 (Panlab S. L., Barcelona, Spain) described in table I.

The amount of drink and food ingested by each group was measured, as well as the cationic content of both, to find out the mean cationic ingest of each rat according to the supplementation group to which they belonged (table II).

After the relative time had elapsed the animals were sacrificed by decapitation

Table I. *Composition of base diet.*

Component	(g/100g)
Humidity	12
Protein	17.2
Hydrogenated vegetal oil	2.7
Fiber	4.4
Glucides	59.7
Vitamins	**(mg/kg)**
Vitamin A (7,500 UI/g)	3716.5
Vitamin D3 (1500 UI/g)	20.62
Choline chloride	1600
Biotin	0.04
Folic acid	0.5
Niacin	75
Pyridoxine	2
Pantothenate	66.1
Cobalamin	0.02
α tocopherol	30
Riboflavin	6.5
Thiamine	7
Menadione	2.5
Mineral content	**(mg/100g)**
Calcium	8300
Magnesium	2000
Sodium	1900
Potassium	6700
Iron	240
Cooper	30
Zinc	95
Cobalt	1.5
Iodine	0.3

after ether anesthesia, and samples of myocardium and both gastrocnemius were immediately taken, which were homogenized in 3 ml of 5 % trichloroacetic acid (TCA) using an Ultra-Turrax (T-25 Hanke-Hunkel) according to the DØRUP *et al.* method (7). Homogenates were stored frozen with liquid nitrogen until determination of cation content by atomic absorption spectrophotometry (Thermo-Harrell).

The results were treated with the Student's *t* test, considering differences above $p < 0.05$ as significant.

Results

The results of Mg^{2+} content in myocardium and gastrocnemius muscles of control rats and those supplemented with Mg^{2+}, Na^{+}, Ca^{2+} or K^{+} for 7 or 30 days are in table III. When rats were supplemented with Mg^{2+} for 30 days, a significant increase in both muscles was observed.

The increases in Na^{+} or Ca^{2+} ingest caused a significant drop in the Mg^{2+} content in gastrocnemius although with Ca^{2+}

Table II. *Cation content of drink and food ingested by control and supplemented groups.* Amounts of Mg^{2+}, Na^{+}, C^{2+}+ y K^{+} intake per animal. Values are expressed in mmoles of cation/rat/day (mean ± SD; n = 6).

Groups	Mg^{2+}	Na^{+}	Ca^{2+}	K^{+}
Control	1.2 ± 0.25	1.21 ± 0.29	1.03 ± 0.31	1.21 ± 0.11
Mg	2.6 ± 0.39	1.15 ± 0.40	1.51 ± 0.2	1.97 ± 0.23
Na	1.4 ± 0.23	2.75 ± 0.51	1.12 ± 0.19	2.04 ± 0.49
Ca	1.1 ± 0.35	1.33 ± 0.28	2.93 ± 0.49	2.11 ± 0.19
K	1.5 ± 0.22	1.11 ± 0.21	1.73 ± 0.17	3.81 ± 0.63

Table III. *Effect of magnesium, sodium, calcium or potassium intake on magnesium content.* After intake for 7 or 30 days of water with an increased Mg^{2+}, Na^{+}, Ca^{2+} or K^{+} content, myocardium and gastrocnemius muscles from Wistar rats were homogenized and the Mg^{2+} concentration of the diluted extract was determined. Each value is the mean ± S.D. of six rats. *p<0.01; **p<0.001.

Supplementation (mmoles/rat/day)		Period days	Mg^{2+} content (µmol/g wet wt.)	
			Myocardium	Gastrocnemius
Control			8.40 ± 0.26	10.55 ± 0.35
Mg^{2+}	2.6	7	8.81 ± 0.59	10.82 ± 0.29
		30	9.06 ± 0.39**	12.7 2 ± 0.46**
Na^{+}	2.75	7	7.99 ± 0.70	9.96 ± 0.69
		30	8.03 ± 0.34	8.69 ± 0.39**
Ca^{2+}	2.93	7	8.55 ± 0.65	10.88 ± 0.43
		30	6.74 ± 0.86*	9.69 ± 0.20*
K^{+}	3.81	7	7.98 ± 0.46	9.91 ± 0.22
		30	6.66 ± 0.31*	7.70 ± 0.74**

it is accompanied by a parallel change in myocardium.

Compared to the control, the group increasing in K^+ ingest, show a significant drop in Mg^{2+} content in myocardium and gastrocnemius.

Finally, there were no significant differences in Mg^{2+} content between control and animals supplemented for 7 days.

Discussion

Results show that supplementation with Mg^{2+} for a long period of time causes its accumulation in soft tissue, both in skeletic muscle and cardiac muscle, which is in agreement with the findings of KANDROR and BAIMADZHIEVA (18). HSIEH *et al.* (15) also showed that oral Mg^{2+} supplementation increased magnesium concentration in erythrocyte, aorta and skeletal muscle.

Conversely, there is a Mg^{2+} decrease with Ca^{2+} supplementation, which coincides with the findings of ZAWADA *et al.* (26), for whom an increase in Mg^{2+} excretion occurred after Ca^{2+} administration both acute and chronic. ALCOK *et al.* (1) also suggest a common transport system for Ca^{2+} and Mg^{2+}, which implies a Mg^{2+} absorption decrease when supplemented with Ca^{2+}. However BRANNAN *et al.* (4) do not find modifications in Mg^{2+} absorption in patients with Ca^{2+} absorption increase.

There is also a Mg^{2+} content decrease in myocardium in the group supplemented with K^+. Similarly, CHARLTON and ARMSTRONG (6) found a non significant Mg^{2+} decrease in myocardium, in rats supplemented for 18 days. However DUARTE (9) does not find significant differences in Mg^{2+} content in myocardium when he submits rats to supplementation with K^+.

When Mg^{2+} concentration is analysed in gastrocnemius after a 30 day supplementation with Mg^{2+}, an increase occurs just as in the myocardium. The Mg^{2+} accumulations observed would coincide with those pointed out by KANDROR *et al.* (18) in skeletic muscle when supplemented with this ion. Furthermore, a Mg^{2+} content decrease has been found in the Na^+, Ca^{2+}, K^+ supplemented groups, as well as a lack of parallelism in gastrocnemius and myocardium behaviour when supplemented with Na^+. On the other hand, there is a drop in Mg^{2+} concentration in gastrocnemius in the Ca^{2+} supplemented group. It is possible that the antagonism between Ca^{2+} and Mg^{2+} postulated by ISERI *et al.* (17) and LEVINE *et al.* (19), is responsible for this alteration in Mg^{2+} distribution.

A Mg^{2+} decrease in the K^+ supplemented groups also occurs, as in myocardium, in agreement with SUTTLE *et al.* (24) and FONTENOT *et al.* (11) who observe a reduction in Mg^{2+} absorption in digestive tract in ruminants with a drop in muscle when they are fed with food treated with K^+ rich fertilizers. However CHARLTON and AMSTRONG (6) do not observe any significant differences in Mg^{2+} concentration in rats' muscle submitted to a K^+ increase in the diet for 18 days. A shorter supplementation time may explain this discrepancy, although DUARTE (9) does not find any differences either in Mg^{2+} content in rat muscle when supplemented with K^+.

The results suggest that the control mechanisms of the tissular Mg^{2+} content have a lower gain of one order of magnitude than those of Na^+ and K^+.

P. GROS, J. F. ESCANERO y J. O. ALDA. *Efecto de la ingesta de magnesio, sodio, calcio o potasio sobre el contenido de magnesio en músculo esquelético de rata.* Rev. esp. Fisiol. (J. Physiol. Biochem.), 51 (1), 1-6, 1995.

Se estudia el efecto de la ingesta de Mg^{2+}, Na^{+}, Ca^{2+} o K^{+} sobre el contenido de Mg^{2+} en miocardio y gastrocnemio de rata. Para ello se administran, como agua de bebida, disoluciones acuosas 30 mM de cada uno de los cationes, durante 7 ó 30 días. Los resultados obtenidos muestran que la suplementación con Mg^{2+} durante 30 días provoca una acumulación del catión en ambos músculos, mientras que la de Ca^{2+} o K^{+} lo disminuye. La suplementación con Na^{+} hace disminuir el contenido de Mg^{2+} en gastrocnemio. Cuando el periodo es de 7 días no hay diferencias significativas. Estos resultados sugieren que, con la suplementación, los mecanismos de control del contenido tisular de Mg^{2+} tienen una ganancia inferior en un orden de magnitud a los de Na^{+} y K^{+}.

Palabras clave: Mg^{2+}, Na^{+}, Ca^{2+} y K^{+}, Miocardio, Gastrocnemio, Músculo esquelético.

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