

Effects of Oral Magnesium Supplementation on Submaximal Effort Test: Preliminary Data

P. Ripari, G. Pieralisi, M. A. Giamberardino, L. Vecchiet

Zusammenfassung

Die Auswirkungen einer längeren Verabreichung von Magnesium wurden bei mäßig gut trainierten Probanden anhand bestimmter kardiorespiratorischer Parameter 30 Minuten bei submaximaler Belastung getestet. In der doppelblind angelegten Prüfung bekamen 20 Tage lang je 8 Probanden Magnesium oder Placebo. Der Test wurde einmal vor der Behandlung durchgeführt und am 7., 14. und 21. Behandlungstag wiederholt. Bei den mit Magnesium behandelten Probanden sanken der systolische Blutdruck, VE, VO₂ und VCO₂ schon ab der ersten Behandlungswoche signifikant, die Herzfrequenz ab der zweiten Woche. Bei den Probanden, die Placebo bekommen hatten, wurde keine Schwankung der untersuchten Parameter nachgewiesen. Diese Prüfung scheint zu zeigen, daß Magnesium die kardiorespiratorischen Leistungen verbessert.

Summary

In moderately trained subjects, the effects of magnesium supplementation were tested on some cardiorespiratory parameters monitored during a 30-min submaximal effort test. In a double-blind design, 8 subjects received magnesium and 8 placebo for 20 days, the test being performed before the treatment and repeated after 7, 14 and 21 days. In the magnesium group, a significant decrease was found in sBP, VE, VO₂ and VCO₂ from the first week and in HR from the second week of treatment. In the placebo group no variations were observed in the parameters monitored. The results seem to indicate that magnesium supplementation induces an overall improvement of cardiorespiratory performance.

Résumé

Les effets de l'administration prolongée du Magnésium ont été testés, chez des sujets modérément entraînés, sur certains paramètres cardiorespiratoires pendant un test d'effort sousmaximal de 30 minutes de durée. En suivant une procédure en double aveugle 8 sujets ont reçu le Magnésium et 8 le placebo pendant 20 jours. Le test a été effectué une fois avant le traitement et répété aux 7^{me}, 14^{me} et 21^{me} jours du traitement. Chez les sujets traités par le Magnésium, sBP, VE, VO₂ et VCO₂ ont diminué de façon significative à partir de la première semaine de traitement, HR à partir de la seconde semaine. Chez les sujets ayant reçu le placebo, aucune variation des paramètres considérés n'a pu être mise en évidence. Cette étude tend à démontrer que le Magnésium améliore les performances cardiorespiratoires.

Introduction

Many investigations have indicated that magnesium plays an important role in the processes of synthesis and utilization of energy rich compounds, such as ATP, UTP, CTP and in all energy output processes in general, as well as in regulating the permeability of the cell membrane [1-4]. Magnesium helps, in fact, to maintain a normal intra-extracellular electrolyte balance and to stabilize the membranes, with concomitant control of excitability, the latter process being particularly pronounced in the nervous cell and muscular fibre [5-7].

Being essentially an intracellular element, Mg⁺⁺ acts as a modulator in the dynamics of muscular contraction thanks to its two-fold action on nervous conduction and its calcium antagonist activity in the muscular fibre. On this basis, it is not difficult to explain the effects of Mg⁺⁺ deficiency on athletic performance. Some of the most common symptoms observed in Mg⁺⁺-deficient subjects are, in fact, asthenia, reduced resistance to and capacity to recover from effort, and the appearance of muscular fasciculations or sometimes cramps [8-11]. It is well known that exogenous Mg⁺⁺ administration in these cases promptly resolves the symptomatology and restores complete physical potential. It is not known, on the contrary, what

result Mg⁺⁺ supplementation has on the physical performance of subjects without a documented Mg⁺⁺ deficiency.

The aim of this study was therefore to assess the effects of prolonged administration of a magnesium salt (pidolate) on some cardiorespiratory parameters evaluated during submaximal effort in moderately trained healthy volunteers.

Method

Healthy medical students being moderately trained were considered i. e. they practised physical activity from time to time but not on a regular basis.

Inclusion criteria for admission into the study were:

Institute of Medical Pathophysiology, University of Chieti, Italy

a. no clinical (*Chvostek* and *Trousseau*) and/or electrophysiological (ECG, EMG) signs of neuromuscular hyperexcitability;

b. serum magnesium, sodium and calcium concentration within normal range (mmol/l: 0.75–1.65 for magnesium; 135–155 for sodium; 2.25–2.75 for calcium);

c. fitness to perform physical effort verified by complete physical examination, ECG at rest and after effort, respiratory functional tests (RFT) and complete hematochemical test.

Sixteen male subjects, aged 18–35 years (mean age: 29 ± 2) were selected from 20.

All of them performed a preliminary maximal effort test on a mechanically braking *Fleish* cycloergometer. The work-load was increased by 25 watts every 3 min and the test was interrupted when the expected maximal heart rate for age (220-age) was reached or in the event of muscular exhaustion or dyspnoea.

After a 5-day interval, the subjects performed a 30-min submaximal ergospirometric test on the cycloergometer at a work-load corresponding to 70 % of their max. heart rate assessed in the course of the preliminary maximal effort test. During the rectangular-type exercise, the following parameters were monitored every 3 min: heart rate (HR), expiratory gas volume/min ($\dot{V}E$), systolic and diastolic blood pressure (sBP, dBP), oxygen consumption/min ($\dot{V}O_2$), volume of carbon dioxide/min ($\dot{V}CO_2$) and cellular respiratory quotient (RQ).

Throughout the trial, the subjects were connected to a computerized spirometer (*Jaeger* ergopneumotest) by a mask for evaluation of respiratory parameters, while a PE 2000 digital telemetric pulse rate monitor was employed for HR recording.

In a double blind design (magnesium vs placebo), 4.5 g of magnesium pidolate/day (corresponding to 387 mg of Mg^{++} ion) were administered to 8 subjects (in 3 doses of 1.5 g of soluble preparation, at 8. a. m., 2 p. m. and 8 p. m.). The same amount of placebo was given, in the same pattern, to the

other 8 subjects following a listing at random.

The composition of magnesium preparation, per 10 ml, consisted of magnesium pidolate (1.5 g) and excipients: saccharose (3.5 g), orange juice (2 g), tangerine flavoring (0.06 g), sodium methyl-p-hydroxy-benzoate (0.012 g), sodium propyl-p-hydroxy-benzoate (0.004 g), H₂O (to 10 ml). The composition of placebo consisted of the same excipients as above.

The treatment lasted 20 days. Control submaximal effort tests were repeated on the 7th, 14th and 21st day of treatment.

All tests were performed in the conditions recommended for the ergometric trials: the room temperature was not higher than +20° C with humidity at 70 %; the subjects were lightly dressed, had fasted for at least 4 hours, had not smoked for a minimum of 1 hour and had been at complete rest during the hours immediately preceding the test.

Statistics

In all the tests, HR, sBP, $\dot{V}E$, $\dot{V}O_2$ and $\dot{V}CO_2$ showed the normal pattern expected in rectangular type effort tests: the curve rose rapidly in the first minutes (adaptation phase) and fluctuated, in the following interval, around an asymptotic value which signalled the reaching of the steady state. To assess this value, the mean of the data obtained from the 9th to the 30th minute was calculated for each subject. Statistical comparisons for the parameters mentioned were performed between the means of these asymptotic values for the two groups of subjects. For the remaining two parameters (dBP and RQ), comparisons were made between mean values of the two groups recorded at each detection time during the test.

The analysis was divided into three stages:

1. check for homogeneity of the two groups in basal conditions regarding parameters of age, weight, height, spirometric parameters (VC, FVC, FEV, MEF₁₅, MEF₅₀, MEF₂₅), HR (maximal predicted

for age and 70 % of maximal), work-load (corresponding to 70 % of maximal HR) and the considered cardiorespiratory parameters during the first effort test (basal test) (HR, sBP, dBP, $\dot{V}E$, $\dot{V}O_2$, $\dot{V}CO_2$, RQ);

2. separate assessment of possible changes in each considered parameter during the various tests performed in the two groups;
3. assessment of possible differences between the two groups (and thus the two treatments) for all parameters at the time of the different tests.

Comparisons for points 1 and 2 were made by means of Student's t-test for unpaired and paired samples, respectively. Comparisons for point 3 were made by the ANOVA analysis performed on the difference between the results obtained at the various detection times of the tests on the 7th, 14th and 21st day and the corresponding results of the basal tests.

Statistical significance was assessed at $p < 0.05$.

Results

1. Comparison of Basal Conditions

The two groups of subjects (treated with placebo and Mg pidolate respectively) proved to be homogeneous for age, body weight, height, spirometric parameters, HR (maximal and 70 % of maximal) and work-load corresponding to 70 % of maximal HR, as well as for the values of the considered cardiorespiratory parameters (during the first effort test; basal test – $p > 0.05$ for all comparisons; [tab. 1]).

2. Comparisons Within Each Group

A) The subjects administered pidolate presented a progressive decrease over the three-week treatment in all the considered parameters. This decrease was not significant for dBP and RQ; it was significant for the other parameters, from the first week for sBP, $\dot{V}E$, $\dot{V}O_2$ and $\dot{V}CO_2$ and from the second week for HR (tab. 2, fig. 1, fig. 2, fig. 3, fig. 4, fig. 5).

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Tab. 1: Values of age, body weight, height (section A), spirometric parameters (section B), maximal HR, 70 % of maximal HR, work-load corresponding to maximal HR (section C), serum electrolytes (section D), cardiorespiratory parameters (section E) (Means \pm SD, range) in basal conditions in magnesium and placebo groups. No significant difference between the 2 groups for all parameters.

PARAMETERS	MAGNESIUM GROUP		PLACEBO GROUP	
	Mean \pm SD	Range	Mean \pm SD	Range
A				
AGE (years)	29.0 \pm 2.0	27-32	29.5 \pm 2.8	26-34
WEIGHT (Kg)	79.1 \pm 6.4	68-85	76.7 \pm 8.7	65-88
HEIGHT (cm)	179.7 \pm 6.2	172-190	177.3 \pm 6.5	167-190
B				
VC (l)	5.6 \pm 0.4	5.1-6.1	5.9 \pm 0.6	5.1-7.3
FVC (l)	5.3 \pm 0.3	4.8-5.9	5.6 \pm 0.8	4.9-7.4
FEV 1.0 (l)	5.1 \pm 1.5	4.2-8.8	4.5 \pm 0.4	4.1-5.4
MEF 75 (l)	8.5 \pm 0.3	8.0-9.0	8.0 \pm 0.6	8.1-10.2
MEF 50 (l)	5.5 \pm 0.3	4.9-5.9	5.5 \pm 0.4	4.8-6.2
MEF 25 (l)	2.8 \pm 0.5	2.0-3.9	2.4 \pm 0.3	1.8-2.9
C				
MAX HR (b/min)	190.1 \pm 2.4	186-193	190.5 \pm 2.8	188-194
70 % of MAX HR (b/min)	134.8 \pm 2.5	133-140	133.7 \pm 2.1	130-136
WORK-LOAD (watts)	116.2 \pm 12.4	100-130	120.6 \pm 16.3	100-150
D				
Serum Mg (mmol/l)	1.1 \pm 0.1	0.9-1.4	1.2 \pm 0.2	0.9-1.5
Serum Na (mmol/l)	145.3 \pm 4.5	139-150	142.2 \pm 5.4	137-149
Serum Ca (mmol/l)	2.3 \pm 0.04	2.3-2.4	2.4 \pm 0.08	2.3-2.5
E				
HR (b/min)	138.5 \pm 4.2	133.1-144.7	137.9 \pm 4.9	130.5-145.8
sBP (mmHg)	146.7 \pm 7.3	135.0-157.5	148.6 \pm 12.3	134.3-169.3
dBP (mmHg)	72.6 \pm 6.1	62.5-81.2	77.7 \pm 7.9	70-90
VE (l/min)	43.9 \pm 3.5	39.6-48.4	48.2 \pm 7.2	36.5-57.0
$\dot{V}O_2$ (l/min)	1.7 \pm 0.2	1.4-2.1	1.7 \pm 0.2	1.3-2.1
$\dot{V}CO_2$ (l/min)	1.4 \pm 0.1	1.2-1.7	1.5 \pm 0.2	1.1-1.8
RQ	0.8 \pm 0.03	0.7-0.8	0.8 \pm 0.03	0.8-0.9

Tab. 2: Statistical significance in the Magnesium-Treated Group. Statistical comparison of values of heart rate (HR), systolic and diastolic blood pressure (sBP and dBP), expiratory gas volume/min ($\dot{V}E$), oxygen uptake/min ($\dot{V}O_2$), volume of carbon dioxide/min ($\dot{V}CO_2$), respiratory quotient (QR) recorded in the placebo-treated group (8 subjects) during the steady state of submaximal effort tests performed in basal conditions (0), after 7, 14 and 21 days of treatment (7, 14, 21 respectively).

* p < 0.05

** p < 0.01

*** p < 0.001

N.S. not significant

days	HR	sBP	dBP	VE	$\dot{V}O_2$	$\dot{V}CO_2$	QR
0-7	N. S.	*	N. S.	*	**	*	N. S.
0-14	***	**	N. S.	**	**	**	N. S.
0-21	*	**	N. S.	**	**	*	N. S.
7-14	*	N. S.	N. S.	*	N. S.	N. S.	N. S.
7-21	*	N. S.	N. S.	N. S.	N. S.	*	N. S.
14-21	N. S.	*	N. S.	N. S.	N. S.	N. S.	N. S.

B) The subjects administered placebo presented only slight variations of the considered parameters over the three weeks. The difference with respect to basal values was never significant.

3. Comparisons Between the Two Groups

The results always showed the existence of highly significant differences ($p < 0.01$) in the behavior of the effects between the two groups. In particular, the ANOVA analysis showed the existence of a high significance level for the differences in behavior between the 2 treatments for HR, sBP, VE, $\dot{V}O_2$ and $\dot{V}CO_2$. The two treatments, on the contrary, proved to be equivalent as far as dBP and RQ are concerned (tab. 3).

Tab. 3: Differences between the two treatments. ANOVA analysis performed on the differences between values of the considered parameters on the 7th, 14th and 21st day and basal values (1st day) for evaluation of differences between the 2 treatments. Symbols as for Table 2.

Parameter	F	P
HR	117.3679	0.01
sBP	52.3411	0.01
dBP	0.5603	N.S.
VE	191.6323	0.01
$\dot{V}O_2$	360.4076	0.01
$\dot{V}CO_2$	52.9033	0.01
QR	1.78	N.S.

All subjects reported perfectly tolerating both Mg^{++} and placebo treatments with no side effects.

Discussion

In moderately trained subjects, placebo administration did not modify any of the respiratory and cardiocirculatory parameters evaluated during a submaximal effort test. In contrast, magnesium administration produced a notable significant decrease in most of these parameters.

These results indicate an overall improvement of cardiorespiratory per-

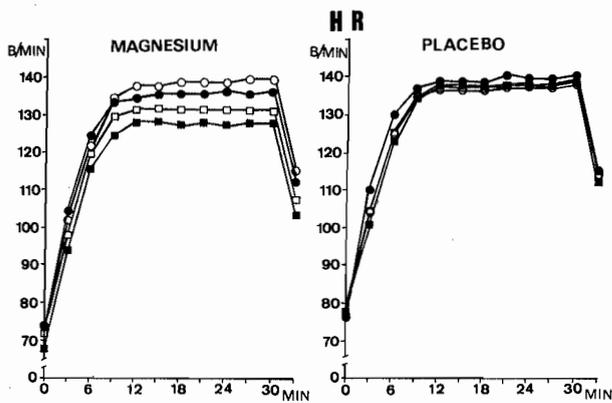


Fig. 1: Time pattern of heart rate (HR) during a 30 min submaximal effort test performed in basal conditions (○—○) and after 7 (●—●), 14 (□—□) and 21 (■—■) days of magnesium (left graph) and placebo (right graph) administration. Two groups of 8 subjects. Mean values.

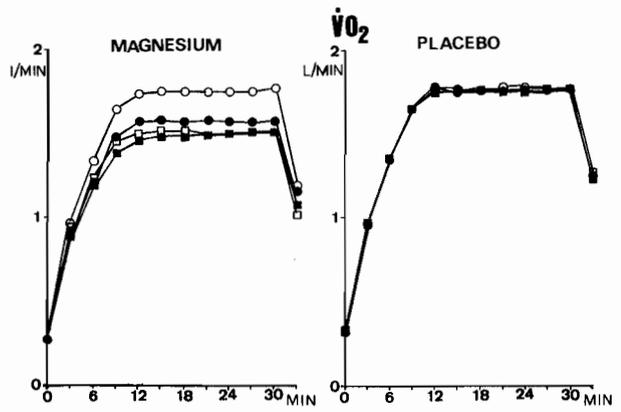


Fig. 4: Time pattern of oxygen uptake/min ($\dot{V}O_2$). Legend see fig. 1.

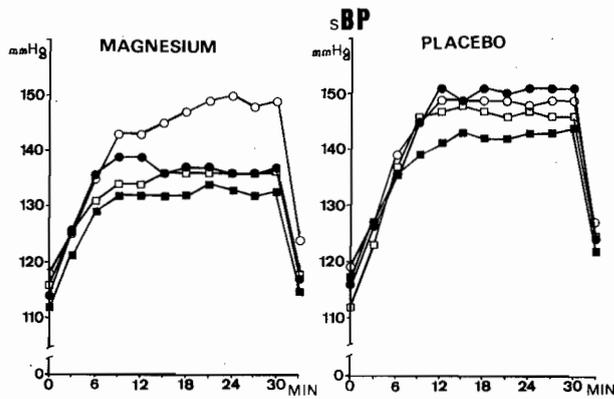


Fig. 2: Time pattern of systolic blood pressure (sBP). Legend see fig. 1.

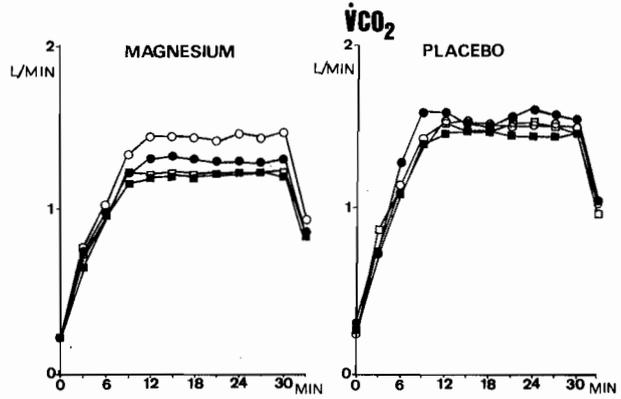


Fig. 5: Time pattern of carbon dioxide/min ($\dot{V}CO_2$). Legend see fig. 1.

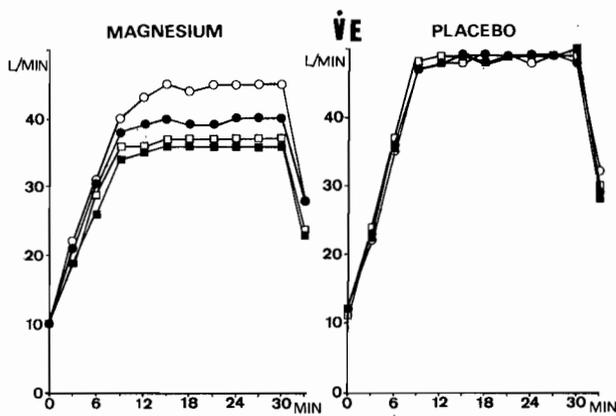


Fig. 3: Time pattern of expiratory gas volume/min ($\dot{V}E$). Legend see fig. 1.

formance induced by magnesium pidolate treatment. In basal conditions, the examined subjects had normal serum magnesium concentrations and did not show

any clinical and/or electrophysiological signs of neuromuscular hyperexcitability characteristic of Mg^{++} deficiency [7, 10, 11]. On this basis, one can assume that they were not Mg^{++}

deprived at the time they were chosen for the study.

Serum magnesium concentration was not remeasured during and at the end of treatment, at various intervals after the effort. Nevertheless, it is unlikely that a Mg^{++} deficiency occurred afterwards, as a consequence of the effort itself, since such an effect seems to be produced only by execution of strenuous physical exercises, such as a 120 km hike [13].

It seems likely, therefore, that the improvement in physical performance observed was determined by magnesium supplementation or, at most, by correction of a slight, subclinical deficiency [12].

One can only hypothesize, as far as the interpretation of the obtained effects is concerned, about an improvement in the employment of energetic sy-

stems involved in aerobic metabolism, as well as a facilitation of O₂ release to the muscular cell during physical activity.

This work being preliminary, further investigation is needed to identify the exact mechanisms underlying the observed phenomena.

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(Correspondence to: Prof. L. Vecchiet, Istituto di Fisiopatologia Medica, Cattedra di Semeiotica Medica, Ospedale „SS. Annunziata“ — Via P. A. Valignani, 66100 Chieti — Italy).