A Comparison of Magnesium Kinetics during Workload between Healthy Probands, Hypertensive Patients and Patients with a Heart Insufficiency

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Zusammenfassung

Ziel und Methoden: Mißt man bei gesunden Probanden Mg-Fraktionen vor und nach einer Streßbelastung, so kann man je nach Dauer und Intensität des Stresses signifikante Veränderungen feststellen. Unser Ziel war es herauszufinden, ob eine Fahrradergometrie bei gesunden Probanden (Gruppe 1: n = 16; durchschnittliches Alter: 39,5 J.), herzkranken Patienten (Gruppe 2: n = 17; durchschnittliches Alter: 59 J.) und Hypertonikern (Gruppe 3: n = 7; durchschnittliches Alter: 51,9 J.) eine unterschiedliche Reaktion der einzelnen Mg-Fraktionen verursachen würde. Blutproben wurden vor, während und sofort nach Beendigung der Fahrradergometrie abgenommen. Aus diesen Blutproben wurde totales, ionisiertes und daraus berechnetes gebundenes Magnesium bestimmt.

Resultate: Die gesunden Probanden zeigten nach Belastung einen signifikanten Anstieg der ionisierten (p = 0,002) und totalen Mg-Fraktion (p = 0,017), wobei anfangs – während Belastung – eine deutliche Verminderung der totalen Magnesiumkonzentration beobachtet werden konnte. Die Resultate zeigen einerseits die Schnelligkeit der Mg-Fraktionsveränderungen, und andererseits zeigen sie auch die Nützlichkeit einer zusätzlichen Blutabnahme während der Belastung. In der zweiten Gruppe (herzinsuffiziente Patienten) zeigte nur die ionisierte Mg-Fraktion zum zweiten und dritten Abnahmezeitpunkt einen signifikanten Anstieg (m.p.2: p = 0,003; m.p.3: p = 0,039), während sich die gebundenen und totalen Mg-Fraktionen nicht signifikant änderten. Die Patienten mit einem arteriellen Hypertonus reagierten mit keiner einzigen signifikanten Veränderung.

Schlußfolgerungen: Der Anstieg der ionisierten Mg-Fraktion in der Gruppe der herzinsuffizienten Patienten könnte auf eine höhere Permeabilität der bereits geschädigten Herzmuskelzellen zurückzuführen sein. Daher kam es vielleicht auch – trotz gleicher Belastung wie bei den herzinsuffizienten Patienten – bei den Hypertonikern zu keinen signifikanten Veränderungen.

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Summary

Aim and Methods: When Mg subfractions of healthy people are measured before and after stress, significant changes depending upon duration and intensity of stress become visible. Our aim was to examine whether a difference in the reaction of the Mg subfractions provoked by cycle ergometry could be established between healthy people (group 1), patients with a heart insufficiency (group 2) and hypertensive patients (group 3). Group 1 consisted of 16 healthy people (mean age 39.5 y), group 2 of 17 patients (mean age 59 y) and group 3 of 7 patients (mean age 51.9 y). Blood samples were taken before, during and after cycle ergometry. From those samples we measured: 1. total Mg (Kodak dry chemical method), 2. ionized Mg, 3. by subtraction of the ionized Mg from total Mg, a bound fraction was characterized, which consisted of a small complexometric and a much bigger protein bound part.

Results: In healthy probands we observed a pronounced reaction of total and ionized Mg to the workload, which initiated a significant counteraction after provocation. Quickness of Mg subfraction changing and usefulness of sample collection during provocation is thus established. In contrast to the healthy probands, patients with a heart insufficiency showed no significant reaction of bound and total Mg after ergometric provocation (e.g. group 1 [bound]: p = 0.001, group 2 [bound]: p = 0.393). In both groups there was a significant increase of ionized Mg (group 1: p = 0.004, group 2: p = 0.039). The changes of ionized Mg were more often significant in the second group, the reaction of total and bound Mg subfractions was only significant in the first group. The third group did not show any significant changes.

Conclusions: Considering the fact that there is, in contrast to the healthy probands, no significant change in bound Mg in the group with a heart insufficiency, it seems that the increase of ionized Mg in this second group does not change the protein bound buffer system, but is characterized by a quicker loss of magnesium through membranes of higher permeability out of cells with already lowered magnesium reserves. Interestingly, purely hypertensive patients subjected to the same workload did not react with magnesium subfraction alterations. A development for diagnostical purposes of this method may be useful.

Résumé

But et méthodes: Si on mesure les subfractions de Mg des personnes en bonne santé avant et après un surcharge des stress, on peut constater des changements signifiants selon la durée et l'intensité du stress. C'était notre but de trouver al une ergométrie cycliste chez des personnes en bonne santé (groupe 1: n = 16; âge moyen: 39,5 ans), des patients soffrant d'une insuffiance cardiaque (groupe 2: n = 17; âge moyen: 59 ans) et des hypertendus (groupe 3: n = 7; âge moyen: 51,9 ans) causerait une réaction différente des subfractions de Mg individuelles. On préleve des échantillons du sang avant, pendant et immédiatement après finition de l'ergométrie cycliste. On déterminait le Mg total, ionisé et le Mg lié qui en était calculé.

Résultats: Après le surcharge, les personnes en bonne santé montraient une augmentation signifiante des subfractions ionisées (p = 0,002) et du Mg total (p = 0,017); au commencement – pendant le surcharge – on pouvait remarquer une diminution signifiante de la concentration en Mg totale. Les résultats montrent, d'un côté, la vitesse des changements des subfractions de Mg, et aussi d'autre côté, l'utilité d'un prélèvement de sang additionnel pendant le surcharge. Chez le deuxième groupe (patients avec insuffisance cardiaque), pendant la 2. et la 3.ième fois du prélèvement du sang, seulement la subfraction de Mg ionisé montrait une augmentation signifiante (m.p.2: p = 0,003; m.p.3: p = 0,039), tandis que les subfractions de Mg liées et totales ne changaient pas considérablement. Les patients avec hypertoie artérielle ne réagissaient même pas avec un seul changement signifiant.

Conclusions: On pourrait attribuer l'augmentation de la subfraction de Mg ionisée dans le groupe avec insuffisance cardiaque à une perméabilité plus augmentée des cellules myocardiaques déjà abimées. C'est peut-être pourquoi les patients hypertoniques ne montraient pas des changements signifiants – malgré le même surcharge comme chez les patients avec insuffisance cardiaque.

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Introduction

It has been just recently shown [1] that a ten minutes' cycle ergometry of submaximal workload does not lead to changes in the circulating total magnesium, but that the subfractions of the ionized and bound magnesium did significantly change in opposite directions. Such an unexpected quick reaction of the magnesium subfractions under provocation could mean, that by combining the principle of provocation with the new possibility of determining Mg subfractions, the momentary magnesium status of a person might be characterized in a much more sensitive way than hitherto thought.

Those deliberations inevitably point into the direction of diagnosis, not only of the magnesium status of young and healthy probands, but to detect quickly and sensitively alterations of Mg kinetics under pathological circumstances like hypertonus or heart insufficiency.

Material and Methods

Three different groups of people had to undergo a ten minutes' cycle ergometry. The first group consisted of 16 healthy people (mean age 39.5 y), the second of 17 patients with a certified heart insufficiency (characterized as NYHA 2 and 3, mean age 59 y) and the third of 7 patients with a hypertonus (RR: >160/95 mm Hg, mean age 51.9 y). The first blood samples for Mg determinations were taken before cycle ergometry (measuring point 1), second after reaching a workload of 75 Watts (measuring point 2) and the third immediately after cessation of performance (measuring point 3).

Group 1 had to undergo an average maximum of 184 Watts. Group 2 and group 3 only had to master 120 Watts (fig. 1).

Total magnesium has been measured according to the Kodak dry chemical method, ionized Mg was determined by AVL 9884 magnesium electrode magnesium analyzer, AVL, Graz, and by subtraction of the ionized Mg from the total Mg a bound fraction was characterized [2], which consists of a small complexometric [3] and a much bigger protein bound part.

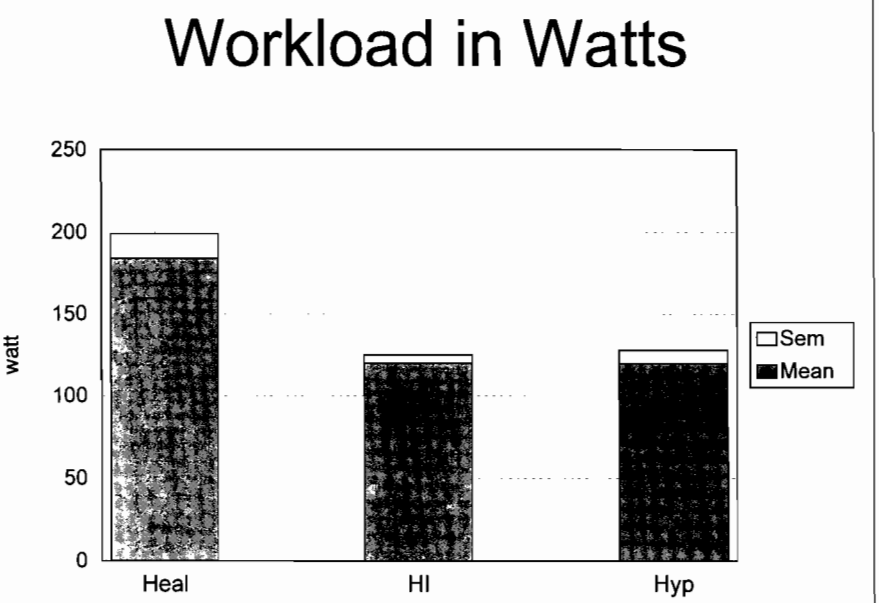

Fig. 1: Workload in Watts: x: Heal: healthy probands, Hyp: hypertensive patients, HI: patients with a heart insufficiency, y: Watts.

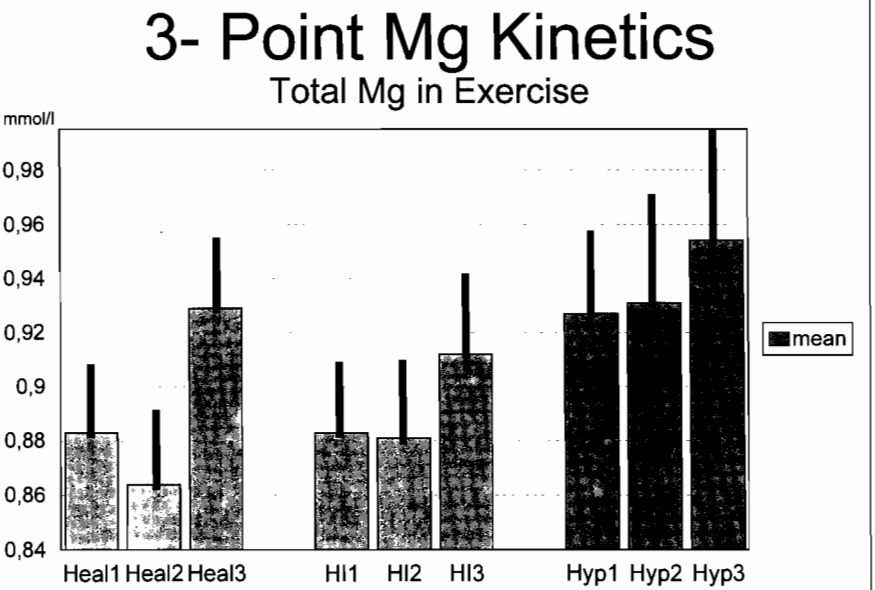

Fig. 2: Total Mg in Exercise: x: 1: measuring point 1, 2: measuring point 2, 3: measuring point 3, Heal: healthy patients, HI: patients with a heart insufficiency, Hyp: hypertensive patients, y: total Mg concentration in mmol/l, significant changes: Heal: m.p.1: m.p.3 p = 0.017; m.p.2: m.p.3 p = 0.000.

Results

1. Total magnesium: In group 1 total Mg concentrations showed a significant increase after cycle ergometry, when compared with the basal level ($p = 0.017$). This is mainly due to a highly significant increase between measuring point 2 and measuring point 3 ($p = 0.0001$). As for group 2 and 3 no significant changes in total Mg concentrations could be seen (fig. 2).

2. Ionized magnesium: The concentration of ionized Mg showed a significant increase in group 1 and group 2, but did not change in the third group at all (fig. 3).

Group 1:
m.p. = measuring point
m.p.1: m.p.3; $p = 0.002$
m.p.2: m.p.3; $p = 0.004$
Group 2:
m.p.1: m.p.3; $p = 0.000$
m.p.1: m.p.2; $p = 0.003$

m.p.2: m.p.3; p = 0.039
3. Bound magnesium showed a significant increase between measuring point 2 and measuring point 3 in group 1 (p = 0.001), but not in the other two groups (fig. 4).

Discussion

In contrast to the data of *Porta* and coworkers [4], we could see significant changes in the total Mg fraction brought about by the ergometric provocation in healthy people, but not in those with the heart insufficiency. Rapid onset and quantity of the reaction of total magnesium to a workload however, may change with its intensity. We find it important to point out, that the Mg concentration measured *during* ergometric work was much better distinguishable from the Mg concentration measured *after* ergometry than from the basal level *before* the workload.

This observation bears out the importance of the introduction of Mg measurement *during* the workload, which provides a much better characterization of Mg kinetics under provocation and underlines the fact, that Mg alterations can be much quicker than hitherto thought. Differences in the behaviour of total magnesium may be well due to different workloads [5]. The most sensible Mg parameter in our investigation proved to be the ionized Mg fraction. Our imposed amount of exercise did provoke a distinct increase in this fraction.

There were even more significant fluctuations in the ionized Mg fraction in patients with a heart insufficiency than in the other groups.

None of those fluctuations were to be observed in the total Mg fractions of those patients with heart insufficiency.

The bound fraction at least, did only show significant fluctuation between the measuring points during and after exercise and then only in healthy probands. This again underlines the importance of Mg determination not only before and after but also during exercise. We find it interesting that under no circumstances any significant difference, neither in total magnesium nor in its subfractions could be provoked in the third group (hypertensive patients), although the workload has been exactly the same.

In conclusion we could see that there was never a significant difference between healthy and heart insufficient persons in their basic Mg value neither in the total nor in the ionized nor in the bound Mg fraction.

The behaviour of those fractions as a reaction to provocation proved to be very different:

In healthy people significant fluctuations could be observed in total Mg as well as in the ionized and in the bound fraction.

People with heart insufficiency did not show significant fluctuations in total and bound Mg, but a very lively reaction of the ionized fraction.

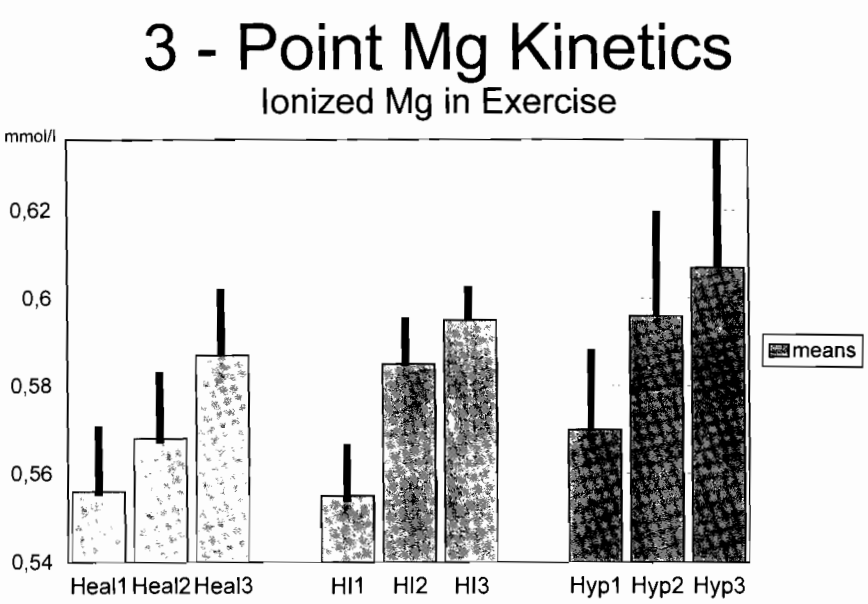

Fig. 3: Ionized Magnesium in Exercise: x: 1: measuring point 1, 2: measuring point 2, 3: measuring point 3, Heal: healthy probands, HI: patients with a heart insufficiency, Hyp: hypertensive patients, y: ionized Mg concentration in mmol/l, significant changes: Heal: m.p.1: m.p.3 p = 0.002; m.p.2: m.p.3 p = 0.004, HI: m.p.1: m.p.3 p = 0.000; m.p.1: m.p.2 p = 0.003; m.p.2: m.p.3 p = 0.039.

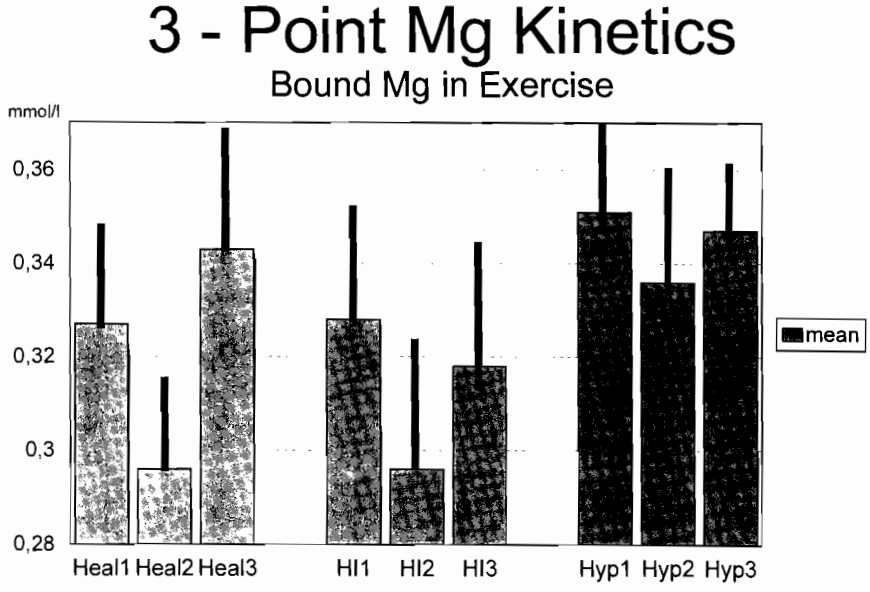

Fig. 4: Bound Magnesium in Exercise: x: 1: measuring point 1, 2: measuring point 2, 3: measuring point 3, Heal: healthy probands, HI: patients with a heart insufficiency, Hyp: hypertensive patients, y: bound Mg concentration in mmol/l, significant changes: Heal: m.p.2: m.p.3 p = 0.001.

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By introducing a third measuring point placed between those before and after exercise, a much more sensitive characterization of the kinetics of the Mg fractions could be achieved. We think that those quick changes in Mg subfractions, which behave very differently in people with a heart insufficiency and healthy people, could be used in future for diagnostic purposes, whereby a strict standardization of exercise and measuring condition is needed. That the very same workload did provoke alterations in circulating magnesium in people with a heart insufficiency but not in hypertensive patients may be due to the better condition of cell membranes in the latter group.

Acknowledgements

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References

[1] *Porta, S.; Fleck, G.; Leitner, G.; Sabin, S.; Liebmann, P.; Wagner, T.; Zirm, B.:* A contribution to the kinetics of bound magnesium in serum. Mg.-Bull. **16** (1994) 19–22.

[2] *Porta, S.; Epple, A.; Leitner, G.; Frise, E.; Liebmann, P.; Vogel, W. H.; Pfeiffer, K. P.; Eber, O.; Buchinger, W.:* Impact of stress and triiodthyronine on plasma magnesium fractions. Life Sciences **55** (1994) 327–332.

[3] *Külpmann, W.; Gerlach, M.:* Abstracts of the German-Swiss-Austrian magnesium congress. Bad Neuenahr 1993.

[4] *Rauter, J.; Emsenhuber, W.; Rinner, I.; Langfort, J.; Helbig, J.; Classen, H. G.; Porta, S.; Felsner, P.:* Epinephrine induced tissue magnesium depletion – a vicious cycle? In: *Kvetnansky, R.; McCarty, R.; Axelrod, J.* (eds.): Stress-neuroendocrine and molecular approaches. Gordon Breach Publishers, New York 1992, pp. 577–582.

[5] *Smetana, R.:* Elektrolytverhalten unter besonderer Berücksichtigung von Magnesium bei Streßbelastungen. Mg.-Bull. **16,** 1a (1994) 29–32.

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