MAGNESIUM IN THERMOREGULATION

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1. ABSTRACT

Nine apparently healthy male subjects, aged 19-25, free from disease, medication or addiction, who gave informed consent underwent 10 days acclimatization process in a heat chamber. They were exposed for 2 h. daily to a temperature of 40°C and 40% relative humidity during low work load. Serum, mononuclear and erythrocyte magnesium (S-Mg, M-Mg and E-Mg respectively) were monitored on day 1, 5 and 10 before and after the heat exposure. S-Mg decreased while M-Mg increased during heat exposures suggesting a shift of S-Mg to mononuclear cells. At the end of the acclimatization process S-Mg was significantly decreased ($p<0.003$). E-Mg increased up to day 5 and decreased gradually approximating the baseline by day 10. Mg appears to play a significant role in heat acclimatization.

2. INTRODUCTION

Body temperature may be regulated by Mg in two ways. One is through its central sedative effect on the hypothalamus and the second through its peripheral effect achieved by reducing the neuromuscular excitibility [1]. Mg is lowered during hyperthermia due to its loss via sweat and Mg diuresis [2,3]. Mg deficiency may constitute an important factor in the pathogenesis of malignant hyperthermia e.g. heat stroke [3]. This made us particularly interested in the possible role of Mg in the etiology of exertional heat stroke [4,5].

We studied 8 unacclimated apparently healthy young males exposed, during 2h, on two consecutive days, in a heat chamber to a temperature of 40°C, and 50% relative humidity, while stepping up and down a 30 cm high bench at the rate of 12 steps/min [6] and found a 12% decrease of S-Mg after the first exposure and a significant ($p<0.01$) decrease of 19% after the second.

We have established that Mg deficiency occurs as a sequel of strenous effort [7-9]. Our findings were confirmed by Deuster et al.[10] and reviewed by Rayssiguier et al., [11], Stendig-Lindberg [12] and others. During our studies we observed that the effect of

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strenous effort on Mg was enhanced when the probands were exposed to high ambient temperatures.

In the present experiment we explored the intracellular as well as the extracellular Mg during the heat acclimatization process in order to observe the dynamics of Mg changes during heat exposure.

3. MATERIAL AND METHODS

Nine apparently healthy male subjects, aged 19-25 free from serious disease, intercurrent infection, ongoing medication, or addiction, who gave informed consent, underwent a 10 day long acclimization procedure consisting of exposure to hot climate (40^0C, 40% relative humidity) in a heat chamber, for 2 h daily. During the exposure the probands walked on a treadmill elevated by 3% at a speed of 5 km/h. Their extrapolated daily mean food Mg content was about 400 mg.

Estimations of serum magnesium concentration (S-Mg), mononuclear magnesium content (M-Mg), and erythrocyte magnesium content (E-Mg), were made before and after the heat exposures on days 1,5 and 10, using methods previously described [13-15].

4. RESULTS

S-Mg - The baseline mean S-Mg was at the lower border of the national reference interval (estimated by substracting only 1 SD from the mean, which is much closer to the reference range found at steady state, than the spurious value obtained after the conventional substraction of 2 SD [15]. The baseline mean S-Mg decreased significantly at the end of the acclimatization procedure (p=0.014, Student's dependent t-test). The fluctuations of S-Mg, i.e. a decrease after a heat exposure with an attempt at a rebound on its termination, were statistically significant on days 5 and 10 (P=0.005 and P=0.046, respectively) and inverse to those of M-Mg. The analysis of variance with repeated masures showed a statistically significant difference between S-Mg values before and after the heat exposures (P=0.019).

M-Mg - The baseline mean M-Mg was significantly below the national mean found in apparently healthy Israeli population (x 164.8, SD 28.3, n=20, reference interval 108.2 - 221.4, % Cl 152.4 - 177.2 fg/cell,p=0.000, Students independent t-test [15]. M-Mg increased during a heat exposure and fell on its termination. Its fluctuations were inverse to those of S-Mg. The baseline value did not differ significantly from the end value, but on analysis of variance with repeated measures a trend towards ~~lower~~ border line significance (p=0.102) was observed.

E-Mg - E-Mg showed a bell shaped curve which peaked after the heat exposure on day 5, followed by a steady decrease which became statistically significant on day 10 (p=0.046, Student's t-test). There was no statistically significant difference between the baseline E-Mg and the end value (NS, Student's dependent t-test).

5. DISCUSSION

The initial mean S-Mg and M-Mg were significantly lower than those reported earlier in apparently healthy Israeli population samples [15,16]. Since the probands were carefully screened to exclude possible presence of concomitant disease, medications or addiction, which may lower Mg, the decrease of the mean S-Mg and M-Mg confirms earlier findings of a relatively high prevalence of Mg deficiency in Israeli apparently healthy population [16] and points to a recent trend to an increased prevalance of Mg deficiency. There was a significant decrease of S-Mg and a trend towards ~~lower~~ border line significant decrease of M-Mg ~~after~~ towards the baseline termination of the experiment which indicates the presence of Mg deficiency. The rise of the M-Mg content occured simultaneously with a decrease of S-Mg after heat exposures indicating a shift of Mg from the extracellular space to the mononuclear cells. The E-Mg content increased up to the fifth day of exposure and thereafter decreased, coming down to lie on the tenth day close to the baseline value. Our findings indicate that Mg plays a significant role in the heat acclimatization process.

The decrease of S-Mg ~~and~~ M-Mg ~~at~~ towards the baseline the end of 10 brief exposures shows a cumulative effect; the longer the duration of heat exposure, the more severe the Mg deficit.

We hypothesize that the energy depletion which characterizes heat stroke [17-19] may be due to the presence of profound Mg deficiency. Since Mg plays a pivotal role in energy metabolism, Mg deficiency should be looked for in conditions of failure of thermoregulation, especially in exertional heat stroke. The latter would appear to constitute the result of the combined effects of 1) the Mg deficiency of strenous effort 2) of the Mg deficiency resulting from its loss via sweat and Mg diuresis in response to high ambient temperature 3) the increased requirement for Mg caused by the increased energy metabolism of hyperthermia.

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