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INFLUENCE OF MAGNESIUM ON THE CARCASS RETENTION OF CADMIUM IN RATS*

WPLYW MAGNEZU NA RETENCJĘ KADMU W KORPUSIE SZCZURÓW

Abstract: The purpose of these studies was to evaluate the bioavailability of cadmium in rats supplemented with magnesium via drinking water. Male Wistar rats divided into 2 groups (25 individuals each) were exposed intragastrically to water solution of cadmium chloride (labelled with ¹⁰⁹Cd) daily at a dose resembling 10 ppm of cadmium in diet. Rats in group I and II were maintained in plastic cages (4 rats per cage) at 22 to 24°C with free access to commercial rodent chow and tap water. Rats in group II were additionally supplemented with magnesium via drinking water (500 mg Mg/dm³). Carcass counting techniques were used to estimate cadmium absorption. The carcass retention of cadmium 109 was counted in a semiconductor german detector (Camberra Packard) with a multichannel analyzer after 1-, 2-, 3-, and 4-week administration. The rats in the two groups revealed a steady state decline with time in the percentage of cadmium 109 in the carcass. However, rats in group II demonstrated a lower cadmium retention throughout the whole experimental period in comparison to that in rats not supplemented with magnesium. The differences were statistically significant after a 4-week exposure. Unlike the percentage content, the total amount of cadmium in the carcass increased with time of exposure. Results indicate that supplements of magnesium reduce gastrointestinal uptake of cadmium. It may be suggested that the beneficial action of magnesium on cadmium reduction in the body increases with the length of time of the two metal co-administration.

Keywords: magnesium and cadmium interaction, retention, carcass, rat

Cadmium considered a toxic metal is not essential for biological function in humans and animals [1-3]. The presence of cadmium in the environment results from various natural sources including volcanic activity and weathering of rocks, and anthropogenic releases such as non-ferrous metal production and fossil fuel combustion [4, 5]. In spite of obvious improvements in controlling cadmium release through low-emission process technologies and cleaning of off-gases and wastewater in developed countries, literature data provide evidence that cadmium retention in human and animal bodies may be still high in several countries [4, 5]. Excessive intake of cadmium may result in numerous health problems including osteomalacia, emphysema, and renal dysfunction in human and animals [4]. The uptake, distribution and elimination of cadmium in the body are influenced by the route of cadmium exposure [1]. However, the intake of cadmium through food is most important for the people and animals do not industrially exposed to this element [6, 7]. It is estimated that food or feed provides over 90% of the total intake irrespective of dietary habits. In most countries, agricultural crops account for most of the intake of cadmium [4]. The bioavailability of dietary cadmium is an important determinant of the potential risk of this toxic metal. Recent works indicate that cadmium bioavailability may be influenced by nutritional status including trace elements [8-10]. It is believed that if the general nutritional status of minerals is low in the consumer, then cadmium absorption may be enhanced [8]. Unlike zinc, calcium, selenium or iron [11, 12], magnesium is a trace element which

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interaction with cadmium has not been studied in detail and much remains to be elucidated [12].

Studies to determine effects of magnesium on cadmium distribution and toxicity are limited. Earlier works reported that feeding magnesium deprived or magnesium supplemented diet failed to affect cadmium metabolism in mice [13]. More recent reports showed that magnesium pretreatment protects kidneys against toxic action of cadmium. The effect of magnesium supplements on the bioavailability of acute doses of cadmium in rabbits and mice have demonstrated that magnesium modifies the organ redistribution of cadmium especially in the kidneys [14-18].

The aim of the present study was to examine how magnesium supplements given concomitantly with moderate cadmium doses to rats affect the whole-body cadmium retention after 1-, 2-, 3-, and 4-week co-administration.

Materials and methods

Forty male Wistar rats weighing from 230 to 255 g were used. The animals were randomly assigned into two dietary groups each of 50 rats after an acclimatisation period of one week. All rats fed a standard commercial rodent chow LSM *ad libitum* (Fodder Manufacture Motycz, Poland) containing about 190 mg Mg/kg according to the manufacturer. Rats in group I were offered a tap water (containing about 19 mg Mg/dm³) whereas rats in group II drunk the same water supplemented with magnesium to bring the total to 500 mg/dm³. The animals were maintained in plastic cages at 21-23°C. The total daily magnesium intake in rats in group II was about 25 times higher than that offered to rats without magnesium supplements. The consumption of feed and tap water was recorded daily. Stock solutions of cadmium chloride (Acros Organics) were prepared in deionized water and ¹⁰⁹Cd (The Institute of Atomic Energy, POLATOM, Poland) was added to prepare dosing solutions of known specific activity. Rats in the two groups examined were given through a gastric tube doses of cadmium chloride corresponding to 10 mg Cd/kg diet in a 0.5 cm³ water solution comprising about 20 kBq/rat/daily. After 7 day-, 14 day-, 21 day-, and 28 day-exposure to cadmium or cadmium and magnesium the rats were killed by immersion in gaseous carbon dioxide. The feed and water intake were assayed daily whereas body weight gains and organ to body ratios were recorded weekly during the 28-day feeding period. The content of cadmium 109 was measured in the carcass (the whole body without the gastrointestinal tract with the contents) in a semiconductor german detector (Canberra Packard) with a multichannel analyzer. The peak energy for cadmium 109 was 88 keV. Reference standards for quantification of carcass radiocadmium were prepared by intraperitoneal injection of the appropriate solution to 10 rats which were killed 45 min thereafter. The carcass distribution of cadmium 109 in the two groups examined was compared as the percentage or amounts of the final retained dose. The area under the curves (AUC) of cadmium 109 carcass content versus time points was calculated by the trapezoidal rule. Data were analysed statistically using Student's *t*-test at *P* < 0.05.

Results

All rats showed similar feed and water intake although distinctly higher water consumption was observed in animals supplemented with magnesium. Moreover, the animals supplemented with magnesium demonstrated higher body gains; the differences were statistically significant after 4-week exposure. No differences were found in the relative weight of the liver, kidneys, heart, spleen and testicles in all examined rats.

Table 1

Body gains of rats during exposure to Cd or Mg plus Cd [g]

Period of Cd or Mg and Cd exposure	0	1- week	2-week	3-week	4-week
Cd	243 ± 11	269 ± 24	301 ± 32	332 ± 29	361 ± 24
Mg plus Cd	235 ± 25	307 ± 32	341 ± 36 (30)	381 ± 39	421 ± 33*

Explanations: * - means statistically significant differences at $P < 0.05$

The results of the carcass distribution of cadmium during the 4-week experimental period and expressed as percentage of the retained cadmium 109 in the two groups tested are shown in Figure 1.

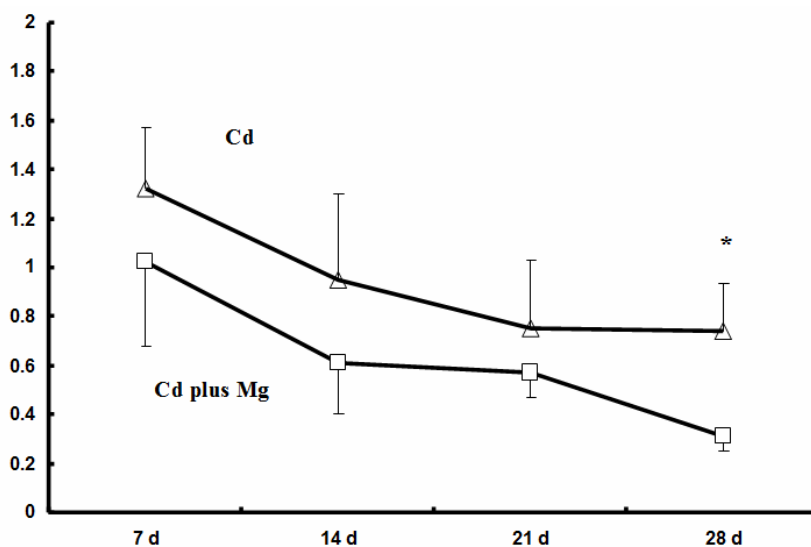


Fig. 1. Total carcass distribution (% of total dose) of cadmium 109 in rats fed with cadmium or cadmium plus magnesium; * - means a statistically significant difference at $P < 0.05$

The percentage of retained cadmium 109 in the carcass was estimated by dividing the carcass activity of cadmium 109 by the total radioactivity of cadmium 109 administered to rats. The highest percentage of cadmium 109 was found after a 1-week exposure in the two groups examined (1.32 and 1.02% of the dose, respectively) and then its content decreased steadily to 0.74 and 0.31% after 4 weeks, respectively. Although the two groups of rats

revealed a similar pattern of cadmium disappearance from the body the cadmium plus magnesium fed rats continued to retain less cadmium during the 1st, 2nd, 3rd, and 4th week of exposure as compared to those treated only with cadmium. These differences were visible but not significant during the first three weeks of exposure. However, after 4 weeks, rats exposed to cadmium and magnesium showed a statistically significant reduction in cadmium retention in comparison to that in the rats exposed only to cadmium.

Figure 2 shows the total amount of cadmium deposited in the carcass calculated in micrograms within the 4-week experimental period. The results indicated that the amount of cadmium in the carcass was lowest in groups I and II after 1-week administration (26 μg and 20 μg , respectively) and then increased steadily in group I to 0.74 μg after the 4-week administration. On the other hand, the total amounts of cadmium in group II rose (up to 34 μg) throughout the first 3 weeks of administration and then decreased to 25 μg after the 4-week of administration. The total content of cadmium was found to increase whereas the percentage of the total dose retention decreased (Fig. 2). The calculated AUC values showed that the retention of cadmium in rats supplemented with magnesium was lower by about 35% in comparison with that in cadmium exposed group.

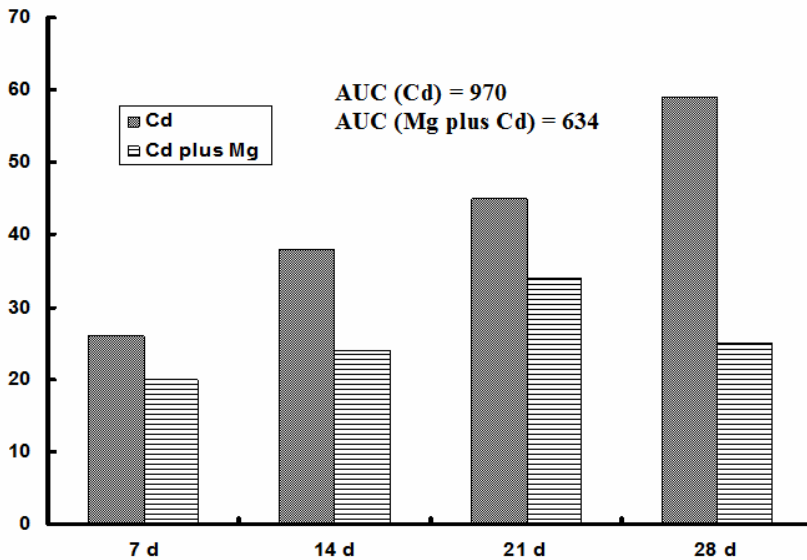


Fig. 2. Cadmium content [μg] in the rat carcass. Explanation as in Figure 1

Discussion

An increase in body gains found in animals exposed to magnesium and cadmium indicates that co-administration of magnesium with cadmium may reduce toxic action of this heavy metal [18]. Moreover, it should be stressed that magnesium protect kidneys from cadmium accumulation [13].

The whole-body counting techniques have been used to determine cadmium absorption [8]. The results of the present studies including the carcass retention of cadmium in rats not

supplemented with magnesium within the 4-week period indicate a low gastrointestinal absorption of cadmium ranging from 1.32 to 0.74%. The results generally agree with those reported that dietary cadmium absorption both from single and chronic exposure in several species is low and may vary from 0.5 to 3%. However, in humans the absorption of cadmium may be higher and vary according to dietary habits: diets rich in fibre and meat from marine animals are associated with high dietary cadmium intake ranged from 5 to 7% [4].

This study demonstrated the effect of magnesium supplements via drinking water on cadmium retention in the carcass of rats exposed to moderate cadmium doses resembling those reported in the areas contaminated with the metal [2, 4, 19]. A comparison of the carcass retention of cadmium in the two groups tested indicated that less cadmium was entering the rat's body in the animals supplemented with magnesium. This finding confirmed a beneficial action of magnesium on reducing the retention of cadmium from dietary sources in acute or prolonged cadmium exposure [15, 18]. The mechanism of the gastrointestinal absorption of heavy metals including cadmium has not been elucidated in detail. However, present knowledge indicates that cadmium is transferred from the intestinal lumen into the circulation by two distinct steps involving cadmium binding to mucosal surface and then subsequent release into the entering circulation [22]. There are reports postulated that magnesium may influence cadmium transport from intestinal lumen to portal blood [15, 23]. A significant reduction in cadmium body retention found in the fourth week of cadmium and magnesium co-administration may indicate that the amount of cadmium absorbed from the gastrointestinal tract may be distinctly influenced by the length of time the rats were exposed to the two metals. The finding may also suggest, at least in the present experimental design, that the longer the rats are exposed to concomitant cadmium and magnesium administration the lower is cadmium bioavailability from the gastrointestinal tract. This evidence may seem to some extent inconclusive with an earlier report demonstrating visible but not a significant decrease in the hepatic and renal retention of cadmium in rats intoxicated with cadmium and supplemented with magnesium [11]. However, the report mentioned above did not include cadmium retention in the bones (as it was in the present study) that may concentrate large amounts of cadmium which may decrease when animals were exposed concomitantly to cadmium and magnesium [23].

Conclusion

Results indicate that the diet fortified with magnesium may be an affective factor against cadmium intake to the body and cadmium toxic activities with regard to body gains. The beneficial influence of supplements of magnesium seems to be more pronounced with the length of time of the two metals co-administration.

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WPŁYW MAGNEZU NA RETENCJĘ KADMU W KORPUSIE SZCZURÓW

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Abstrakt: Celem badań była ocena przyswajania kadmu (radiokadm 109) u szczurów eksponowanych na wodę pitną zawierającą dodatkowe ilości magnezu. Szczurom samcom szczepu Wistar podzielonych na 2 grupy zawierające po 25 zwierząt podawano codziennie dożołądkowo za pomocą stalowej sondy wodny roztwór chlorku kadmu (znakowany kadmem 109) przez 1, 2, 3 i 4 tygodnie w dawce odpowiadającej 10 mg Cd/kg diety. W grupie I zwierzęta pojęne były wodą z kranu, zaś w grupie II wodę z kranu wzbogacano w chlorek magnezu (500 mg Mg/dm³). Podczas doświadczenia określano spożycie karmy i wody oraz przyrosty masy ciała. Po 1, 2, 3 i 4 tyg. zwierzęta usypiano w atmosferze dwutlenku węgla, a następnie określano masy względne narządów. W tym samym czasie oznaczano także zawartość kadmu 109 w korpusie, z którego uprzednio usunięto przewód pokarmowy z treścią. Pomiar radiometryczny korpusu wykonano za pomocą półprzewodnikowego detektora germanowego (Camberra Packard) wyposażonego w wielokanałowy analizator. Rozmieszczenie kadmu w korpusie wyrażone w postaci procentu aplikowanych dawek wykazywało tendencję spadkową przez cały okres badań w obu grupach zwierząt. W grupie zwierząt pojęnych wodą z dodatkiem magnezu procentowa zawartość kadmu w korpusie była wyraźnie mniejsza w porównaniu z zawartością u zwierząt nieeksponowanych na magnez. Po 4 tygodniach różnice były statystycznie istotne. W odróżnieniu od procentowej zawartości całkowita ilość kadmu w korpusie wzrastała wraz z długością czasu ekspozycji. Uzyskane wyniki wskazują, że dodatek magnezu do diety szczurów zmniejszał przyswajanie kadmu podawanego drogą pokarmową. Warto również zasugerować, że skuteczność oddziaływania magnezu na zmniejszenie przyswajanego kadmu zwiększała się wraz z upływem czasu ekspozycji na oba te metale.

Słowa kluczowe: interakcja magnezu z kadmem, retencja, korpus, szczura