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Prevention and treatment of magnesium deficiency in athletes

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INTRODUCTION

As an essential mineral element, Mg^{2+} is involved in a range of biochemical, cellular and physiological functions[1-4]. Some of these roles include biosynthesis and utilization of energy-rich compounds and electron/proton transporters, second messenger systems, energy-dependent membrane transport and transmission of the genetic code. Mg^{2+} is known to activate more than 300 enzymes either directly by interaction between substrate and enzyme or indirectly by induction of conformational change of a molecule. It is required in many enzymatic reactions in which the components of food are metabolized and new compounds are formed. Free intracellular Mg^{2+} concentrations modulate the activity of rate-limiting enzymes. Extracellular Mg^{2+} concentrations maintain electric potentials of nerve and muscle membranes and facilitate transmission of impulses at myoneural junctions. In addition, Mg^{2+} plays fundamental roles in the cardiovascular, renal and reproductive function. These observations support the critical role of Mg^{2+} in regulating cellular and organ system functions.

Because of these critical roles of Mg^{2+} in metabolism, the body exerts homeostatic control of it[5]. For an individual, Mg^{2+} balance or retention depends on the amount consumed in the diet and the regulation of intestinal absorption and renal excretion. Because of the relatively poor absorption from the intestine and the large intracellular distribution in bone and soft tissue, Mg^{2+} economy depends on the integrity of intestinal and renal absorptive processes.

In contrast to the individual whose physical activity is limited, the athlete may place a distinct demand on the homeostatic mechanisms that regulate the body's Mg^{2+} balance. Chronic and prolonged periods of increased energy expenditure, associated with obligatory and augmented turnover of soft tissue and bone and increased urinary excretion[6] and surface losses[7,8] of Mg^{2+}, may predispose physically active individuals to marginal Mg^{2+} deficiency. This situation may be exacerbated when dietary Mg^{2+} is restricted.

This presentation addresses the role of dietary Mg^{2+} as a limiting factor in the determination of Mg^{2+} status of the general population and selected groups of athletes. Sources of Mg^{2+} in food and beverages are described. A basic menu is provided which features a balanced intake of nutrients, with an emphasis on mineral elements. It is concluded that proper food selection is the key to meeting nutrient needs for physically active people.

DIETARY Mg^{2+}

Population studies

Survey techniques are commonly used to estimate the nutrient intakes of a population. One method is to calculate the nutrient content of food items that are available in the food supply. Another approach is to determine the nutrient composition of representative foods generally consumed by the public. A third technique is to estimate nutrient intake from self-reported records of dietary intakes of representative samples of the population. For estimates of Mg^{2+} intake of the US population, all of the above methods have been employed.

The per capita availability (based on food disappearance data) of Mg^{2+} in the US food supply has declined since the first decade of this century from an estimated 410 mg/day to approximately 370 mg/day in 1949; a further decrease to about 350 mg/day was noted in 1980[9]. During this period, the major sources of Mg^{2+} in food supply were dairy products (20%), grain products (18%), vegetables (16%), meat-fish-poultry (15%) and legumes-nuts-soy (13%)[9]. There has been a large decline in the percentage of Mg^{2+} obtained from grain products since 1909-1913.

Analyses of actual food intake data indicate that Mg^{2+} intakes are less than that calculated from food disappearance data. During the period of 1985-6, women consumed less Mg^{2+} than the recommended dietary intake (Table 1). On average, the Mg^{2+} intake was about 207 mg/day or 75% of the recommended dietary allowance (RDA).

Table 1 Mg^{2+} intakes of US women aged 20–49 years (adapted from USDA[10])

Age (years)	*n*	*Intake* (mg/day)	*RDA** (%)
20–29	661	204 ± 4	73
30–39	812	210 ± 4	75
40–49	583	207 ± 4	74

*RDA = Recommended Dietary Allowance, 280 mg/day[11]

Table 2 Dietary Mg^{2+} intakes determined by calculation and chemical analysis (adapted from Pennington and Wilson[12])

	Calculated		*Analyzed*	
	mg/day	% RDA*	mg/day	% RDA
14- to 16-year-olds				
Girls	206	69	194	65
Boys	317	79	297	74
25- to 30-year-olds				
Women	203	73	189	68
Men	311	89	294	84
60- to 65-year-olds				
Women	201	72	187	67
Men	276	76	250	71

*RDA = Recommended Dietary Alownce, 280 mg/day[11]

The estimated dietary intake of Mg^{2+} among segments of the US population has also been estimated as part of the Total Diet Study[12]. This study estimated nutrient intake based on computerized calculations using a standardized nutrient data base and chemical analyses of foods commonly consumed in the USA from 1982 to 1989. Mg^{2+} intakes were greater for males as compared to females, regardless of age (Table 2). In a comparison of the recommended Mg^{2+} intake, young adults had greater intakes than either the adolescents or older adults. All groups had Mg^{2+} intakes that, on average, exceeded 70% of the recommended intake.

Data on food sources of Mg^{2+} indicate an interesting pattern of consumption related to age (Table 3). Among the adolescents, dairy products and eggs, vegetables, grains and animal products contribute the majority of Mg^{2+} in the diet. However, mixed dishes (similar to a personal recipe for a standard meal component such as meat sauce or vegetable

Table 3 Contribution (% daily intake) of foods to Mg^{2+} intake (adapted from Pennington and Young[13])

	14-16 years		*30-35 years*		*60-65 years*	
	Female	*Male*	*Female*	*Male*	*Female*	*Male*
Vegetables	16	15	18	17	18	17
Fruits	6	5	7	5	10	7
Grains	17	18	16	15	17	18
Nuts	2	3	2	3	2	3
Dairy produce and eggs	21	22	14	13	12	12
Animal	14	13	16	17	14	16
Mixed meals	10	11	8	9	6	6
Desserts	11	10	6	7	6	7
Beverages	4	4	12	15	15	15

soup) and desserts are also significant sources of daily Mg^{2+} intake. For the adults, the major sources of Mg^{2+} are vegetables, grains, animal and dairy products. In contrast to the finding among the adolescents, beverages, not mixed dishes and desserts, were a significant source of Mg^{2+} for the adults.

Interpretation of the significance of estimated Mg^{2+} intakes at 70% of the recommended intake is hampered by the lack of clinical or biochemical evidence available in these surveys to indicate and confirm Mg^{2+} deficiency. Indeed, an accurate and sensitive index of Mg^{2+} status is lacking[5,11]. Mg^{2+} deficiency has not been reported to occur in response to low dietary intake[8]. Thus, it may be concluded that Mg^{2+} is not considered a public health issue in the USA despite the finding that dietary intakes are low.

Studies of athletes

Unequivocal evidence of impaired Mg^{2+} status of athletes is lacking. Separate experimental findings indicate reduced concentrations of serum or plasma Mg^{2+} following bouts of exercise[14] and increased urinary Mg^{2+} excretion after exercise[6]. Supplementation of competitive athletes with Mg^{2+} salts has been reported to improve indices of cellular energy metabolism[15]. Indeed, impaired work performance has been reported in conjunction with decreased serum Mg^{2+} concentrations in two case studies[16,17]. Also, increased sweat losses of Mg^{2+} have been reported[18,19]. Interpretation of these observations suggests an adverse effect of exercise on body Mg^{2+} status. However, whether these observations are related to Mg^{2+} intake or are an adverse response to chronic physical training has not been addressed.

Table 4 Reported energy and Mg^{2+} intakes among athletes

				Mg^{2+}		
Source	*Activity*	*n*	*Energy* (kcal/day)	mg/day	*RDA**	mg/1000 kcal
Hickson *et al.* 1986[20]	Basketball	13 F†	1995	204	73	102
	Gymnastics	9 F	1827	204	73	112
Hickson *et al.* 1986[21]	Soccer	18 M**	4492	469	134	104
		18 M‡	3346	361	103	107
Hickson *et al.* 1987[22]	Football	11 M	3593	277	73	77

*RDA = Recommended Dietary Allowance, 280 mg/day for women; 350 mg/day for men[11]; †F = female, M = male; **Preseason; ‡Competitive season

Initial attempts to estimate Mg^{2+} intakes of athletes utilized 3-day dietary histories of female and male athletes whose diets were surveyed at various times during the competitive season (Table 4). Although activities were varied, Mg^{2+} intakes among female and male collegiate athletes generally exceeded 70% of the recommended intake. Men participating in collegiate football had greater daily Mg^{2+} intake than did female collegiate gymnasts and basketball players[20,22]. Male soccer players, who used institutional food services, exceeded the recommended daily Mg^{2+} intake during both preseason training and the competitive season when intakes decreased slightly[21]. The trend was that Mg^{2+} intake approximated 70% of the RDA for most athletes[11]. Although these findings indicate adequate Mg^{2+} intake, they do not provide insight into whether athletes have dietary Mg^{2+} intakes that differ from their non-athletic counterparts in society.

Limited data are available that describe mineral element intakes among athletes and non-training control subjects (Table 5). An assessment of daily Mg^{2+} intakes among female collegiate runners with different menstrual patterns found that nine eumenorrheic runners had greater Mg^{2+} intakes than eight amenorrheic runners and seven eumenorrheic non-runners[23]. There was a positive trend between energy and Mg^{2+} intakes in these women. These data suggest that Mg^{2+} intake may be limiting among some female athletes.

Fogelholm and co-workers[24] reported greater Mg^{2+} intakes among 114 male Finnish athletes than 117 male controls. Similarly, the investigators[25] observed greater Mg^{2+} intakes among Nordic skiers as compared to their sex-matched, non-training control counterparts. Regardless of activity

Table 5 Reported energy and Mg^{2+} intakes among athletes and non-athletes

				Mg^{2+}		
Source	*Activity*	*n*	*Energy* (kcal/day)	mg/day	% *RDA**	mg/1000 kcal
Zierath *et al.* 1986[23]	Running	8 F†	2055	164	59	78
		9 F	2490	276	98	111
	Controls	7 F	1687	92	33	55
Fogelholm *et al.* 1991[24]	Athletes	114 M	2990	548	157	183
	Controls	117 M	2510	436	126	173
Fogelholm *et al.* 1992[25]	Skiers	5 M	3880	646	185	166
	Controls	19 M	2754	407	116	145
	Skiers	7 F	2820	478	170	165
	Controls	20 F	2010	304	108	145

*RDA = Recommended Dietary Allowance, 280 mg/day for women; 350 mg/day for men[11]; †F = female, M = male

Table 6 Energy and Mg^{2+} intakes of female swimmers and age-matched female controls preseason (Pre) and post-training (Post): adapted from Lukaski *et al.*[26]

		Energy (kcal/day)		Mg^{2+} mg/day (% *RDA*)	Mg^{2+} mg/day (% *RDA*)
	n	*Pre*	*Post*	*Pre*	*Post*
Swimmers	16	2338	2569	283 (102)	329 (118)
Controls	13	2077	2055	263 (94)	251 (90)

*RDA = Recommended Dietary Allowance, 280 mg/day[11]

status, the estimated Mg^{2+} intakes exceeded the recommended intake[11] in both studies[24,25].

Another experimental design involves longitudinal assessments during physical training among athletes and non-athletes to evaluate the influences of physical activity and time. The energy and Mg^{2+} intakes of female swimmers before and at the end of the competitive season were compared with similar estimates from non-training, age-matched female controls (Table 6). Although no differences in energy or Mg^{2+} intake were found in the pre-season, the female swimmers increased their energy and Mg^{2+} intakes with training while the controls did not change with time[26].

A subtle point in the Mg^{2+} intake data is the role of nutrient density (e.g. Mg^{2+} intake per 1000 kcal) as a factor associated with reduced Mg^{2+} intake, and perhaps indicative of compromised Mg^{2+} status. As shown in Tables 4 and 5, athletes and control subjects who consumed diets exceeding 70% of the RDA for Mg^{2+} generally had a Mg^{2+} concentration in the diet of at least 80 mg/1000 kcal. When the Mg^{2+} nutrient density was less than this value, as in the data of Zierath and co-workers[23], daily Mg^{2+} intake expressed as a percentage of the RDA was considered suboptimal (< 70% RDA).

Comparison of Mg^{2+} nutrient density data from two studies lends some support to this hypothesis. As shown in Table 5, Fogelholm and co-workers[25] found that Nordic skiers had greater Mg^{2+} intakes relative to energy intake than non-training control subjects (165 vs. 145 mg Mg^{2+}/1000 kcal). Similarly, unpublished data from my laboratory indicate greater Mg^{2+} intakes normalized for dietary energy content for competitive swimmers than weight-matched control subjects (178 vs. 138 mg/1000 kcal). These preliminary observations suggest that when athletes consume nutrient-dense diets, the probability of nutritional deficiency is minimized.

The use of self-reported diet histories to estimate nutrient intake is not without limitations. Some of these drawbacks include reliance on subject motivation to record accurately and completely all food and beverages consumed, proper number of sampling days during which to obtain a representative estimate of usual intake, assessment of the validity of the entries recorded, and a reliable data base for the calculation of nutrient intake. It must be assumed that the reported Mg^{2+} intakes are valid and accurate representations of the usual intakes of the athletes and non-training subjects.

PREVENTION AND TREATMENT OF Mg^{2+} DEFICIENCY

Mg^{2+} deficiency, whether in sedentary or physically active individuals, is not considered to be the result of inadequate dietary intake of Mg^{2+} *per se*[5, 11]. It has been reported to occur secondarily in conjunction with gastrointestinal or renal disease, general malnutrition and alcoholism, use of parenteral and enteral solutions deficient in Mg^{2+} and use of specific pharmcological agents and drugs[5]. Therefore, the role of diet in the prevention and treatment of Mg^{2+} deficiency will be emphasized.

Absorption

The percentage absorption of ingested Mg^{2+} by healthy individuals is influenced by its dietary concentration and by factors affecting its absorption. Human studies using $^{28}Mg^{2+}$ indicate that fractional Mg^{2+}

absorption is inversely related to intake. At low Mg^{2+} intakes (7–35 mg), absorption was 65–70%. At greater intakes (960–1000 mg), absorption declined 10–14%[27,28]. Average net Mg^{2+} absorption is about 50% (range 40–60%) of intake[29]. Studies of free-living adults consuming self-selected diets indicate the percentage absorption of Mg^{2+} averaged 21% by men and 27% by women with mean Mg^{2+} intakes of 323 and 234 mg/day, respectively[30].

Bioavailability

Interest in factors that affect the absorption of Mg^{2+} has focused on dietary components that have the capacity to reduce intestinal uptake of this mineral element. Some dietary factors purported to affect intestinal absorption of Mg^{2+} will be reviewed briefly.

Fiber

Fiber, particularly cellulose and hemicellulose, added to the diet increases fecal Mg^{2+} excretion and may result in a negative Mg^{2+} balance[31]. When fruits and vegetables were used as the source of fiber, small reductions in Mg^{2+} balance were observed[32]. Foods containing large amounts of oxalic acid, such as spinach, exacerbated the negative Mg^{2+} balance[33]. Overall, any adverse effect of dietary fiber is negligible unless dietary fiber is present in excessive amounts without concomitant increases in Mg^{2+}.

Protein

Because the western diet is high in protein, and Mg^{2+} intake is considered to be marginal, an interaction between protein intake and dietary Mg^{2+} has been investigated. Studies in animals suggest that diets high in protein increase the Mg^{2+} requirement[34]. In contrast, boys fed 93 g protein/day had increased apparent Mg^{2+} absorption as compared to when they received a diet containing 43 g protein/day[35]. The apparently beneficial effect of protein was enhanced when dietary Mg^{2+} was low. In men, no difference in Mg^{2+} absorption, urinary excretion and Mg^{2+} balance was found when protein intakes of 65 and 94 g/day were compared[36].

The influence of legumes, particularly soy protein with a high phytic acid content, on Mg^{2+} requirements has also been examined. It was shown that Mg^{2+} is highly available from soy products[37].

Available evidence indicates that the typical, high protein intakes of the western diet do not adversely affect the Mg^{2+} absorption and balance of humans.

Fat

As with protein, dietary fat can represent a significant component of the diet. For athletes who require in excess of 4000 kcal/day, fat intake can be large[38]. In a balance study, it was shown that Mg^{2+} balance, as well as urinary and fecal Mg^{2+}, did not change in men fed diets composed of conventional foods and ranging in fat from 22 to 42% energy[39]. Therefore, unless fat malabsorption is present, dietary fat apparently does not affect Mg^{2+} absorption and excretion[40].

Ca^{2+} and phosphate

The influences of Ca^{2+} and phosphate have been studied in humans because of their reported antagonism on Mg^{2+} absorption in animals[41]. The detrimental effects of Ca^{2+} and phosphate on Mg^{2+} metabolism observed in animals have not been confirmed in human studies. Norman and co-workers[42] fed healthy humans either a low (300 mg/day) or a high (2000 mg/day) Ca^{2+} diet for 4 weeks, then perfused jejunal and ileal segments *in vivo* with solutions containing either no Ca^{2+} or 5 mmol/l magnesium chloride. They observed a significant decrease in Mg^{2+} absorption in the ileum of the subjects fed the high Ca^{2+} diet. In contrast, Spencer and co-workers[43] found no significant effect on fecal Mg^{2+} excretion when dietary Ca^{2+} was fed at 200–2000 mg/day for periods of 29–43 days, respectively. Similarly, Leichsenring and co-workers[44] found no correlation between fecal Ca^{2+} and Mg^{2+} output when dietary Ca^{2+} was increased from 300 to 1200 mg/day in healthy women. Balance studies in men demonstrated an increase in fecal Mg^{2+} when Ca^{2+} intake increased from 780 to 2382 mg/day[45]. However, because urinary Mg^{2+} output decreased, Mg^{2+} balance was unchanged. In their review of long-term, Mg^{2+} balance studies in healthy individuals, Spencer and Osis[46] concluded that increasing dietary Ca^{2+} intake did not affect Mg^{2+} absorption or retention. In those experimental circumstances when fractional absorption of Mg^{2+} was increased, Mg^{2+} retention was not increased because of the concomitant increase in urinary Mg^{2+} excretion.

The effects of dietary phosphate on Mg^{2+} metabolism of humans are also not unequivocal. Heaton and co-workers[47] reported that increasing phosphate intake decreased apparent Mg^{2+} absorption. Greger and co-workers[45] found that subjects lost significantly more Mg^{2+} in the feces when they consumed a high dietary phosphate intake (2443 mg/day) as compared with when they consumed a moderate phosphate intake (843 mg/day). Although apparent Mg^{2+} absorption decreased from 43 to

Table 7 Mg^{2+} content of selected foods; adapted from Durlach *et al.*[48]

<25 mg/100 g	*25–100 mg/100 g*	*>100 mg/100 g*
Meat	Shellfish	Dry beans, split peas
Fish	High oil fish	Shrimp
Eggs	Spinach	Clams, snails
Milk	Green beans	Whole cereals
Butter	White flour	Bran
Vegetables	Hard cheeses	Nuts
Fruit	Dried fruit	Chocolate
	Bananas	Cocoa

34% on the high-phosphate diet, urinary Mg^{2+} also decreased on the high-phosphate diet, so that overall Mg^{2+} retention was not affected by phosphate intake. Similarly, both Spencer and co-workers[43] and Leichsenring and co-workers[44] observed no effect of increased dietary phosphate on Mg^{2+} metabolism in men or women regardless of the Ca^{2+} or Mg^{2+} intake. Thus, alterations of dietary Ca^{2+} and phosphate within the ranges of intakes usually consumed by humans apparently do not appreciably influence Mg^{2+} balance.

Dietary sources of Mg^{2+}

Food items

A broad range of Mg^{2+} content is found in commonly consumed foods (Table 7). In general, food items with the lowest relative Mg^{2+} content are those that are consumed in the greatest quantity and hence contribute most of the Mg^{2+} in the US diet. In contrast, the foods with the greatest Mg^{2+} content are those with the greatest caloric density and are consumed the least, thus they contribute the least to Mg^{2+} intake[9,10].

In addition to food selection, another factor that contributes to a reduced Mg^{2+} intake is the unfavorable effect of processing and refining of raw foods[49]. It has been shown that the majority of the Mg^{2+} is removed during the processing of table sugar (a common component of many processed foods and beverages), flour, starch and during the polishing of white rice[49].

Depending on the method used, food preparation can also remove significant amounts of Mg^{2+}[49]. A potato that is baked in its skin does not experience a loss in Mg^{2+} content whereas a boiled potato can lose about

Table 8 Mg^{2+} concentration of selected beverages*

Item	*Mg^{2+}* (mg/l)
Tap water	11
Mineral water	0–11
Milk, skimmed	112
Cola	12
Beer	
US	64
Lite	52
Wine	
dry	90
red	130
white	100

*Estimated by using GRAND[51]

15% of its pre-preparation Mg^{2+} content. Similarly, boiling peas and carrots results in a loss of 30–40% of the Mg^{2+} content. Thus, consumption of raw vegetables and whole grains, and use of preparation methods that minimize boiling, are recommended to maintain the Mg^{2+} content of food.

Beverages

Because of the need to maintain water balance and avoid dehydration, beverages represent a potentially useful source of Mg^{2+} for people, particularly athletes. The Mg^{2+} concentration of selected beverages varies considerably (Table 8). As observed previously with food items, the Mg^{2+} concentration of the most frequently consumed beverages is relatively low.

Mg^{2+} intake can be influenced appreciably by water consumption[50]. Because the Mg^{2+} concentration of tap water is related to a variable degree to water hardness (e.g. Ca^{2+} and Mg^{2+} contents), it has been estimated that drinking water can contribute 40–100 mg/day[49]. In addition, the use of bottled water can contribute a significant amount of Mg^{2+} (30 mg/l)[50].

Although alcoholic beverages contain appreciable concentrations of Mg^{2+} (50–130 mg/l), their ingestion should be tempered with moderation. The diuretic effect of alcohol may increase Mg^{2+} loss disproportionately to the amount of Mg^{2+} ingested.

Example of a nutritionally-balanced diet for athletes

With knowledge of the Mg^{2+} content of foods and beverages, one can devise a daily menu for athletes requiring a large energy intake and

Table 9 Example of a 4000 kilocalorie menu for an athlete*

Breakfast	*Lunch*	*Dinner*	*Snacks*
Oatmeal	Turkey sandwich	Spaghetti	Wheat bread
Raisins	Apple sauce	Meat sauce	Peanut butter
Milk, skimmed	Pretzels	Lettuce	Milk, skimmed
Brown sugar	Vanilla wafers	Carrots	
Toast, wholewheat	Milk, skimmed	Sunflower seeds	
Margarine		Italian dressing	Bagel, toasted
Jam		Dinner rolls	Cream cheese
Yogurt, low fat		Margarine	Apple juice
Orange juice		Snack bar	
		Cola	

*Calculated by using GRAND[51]

adequate intakes of essential nutrients with an emphasis on Mg^{2+} and other mineral elements. The menu listed in Table 9 provides 4000 kcal and contains approximately 14% protein, 56% carbohydrate and 30% fat. The micronutrient content includes approximately 594 mg Mg^{2+}, 26 mg iron, 17 mg zinc, about 3 mg copper and 1563 mg Ca^{2+}; it exceeds the recommended and safe and adequate intake of mineral elements[11].

TREATMENT OF Mg^{2+} DEFICIENCY

Anticipation of marginal nutritional deficiency and its prevention with proper dietary guidance should be the general rule when dealing with athletes. However, if hypomagnesemia is found, then proper intervention will be required to minimize its severity.

The following general guidelines may be instituted for treatment of Mg^{2+} deficiency[5]. These include determination of the etiology of Mg^{2+} deficiency (inadequate dietary Mg^{2+}, malabsorption, use of medications that increase urinary excretion, diabetes, renal disease, etc.) and institution of control of the underlying pathology, if present. Implementation of any therapeutic intervention should not exacerbate the perturbation of body Mg^{2+} status. Initiation of dietary and nutritional changes should minimize Mg^{2+} losses in stool and urine and promote Mg^{2+} retention.

The amount, route and duration of Mg^{2+} therapy will depend on the severity of the depletion, its cause and the observed biological impairments. As a preventive measure, athletes should receive dietary counselling to improve the nutritional quality of their diets and to increase dietary Mg^{2+}. Symptomatic Mg^{2+} deficiency requires parenteral Mg^{2+} therapy[5].

Supplemental Mg^{2+} also may be provided with gelatin capsules packed with Mg^{2+} salts. Many such preparations are available. They include mineral salts of Mg^{2+} (oxide, chloride, sulfate, nitrate and carbonate). In addition, organic salts containing Mg^{2+}, such as acetate, bicitrate, ascorbate, gluconate and lactate, are available. Selection of a Mg^{2+} salt is based on its solubility in enteric fluids. Organic salts of Mg^{2+} are considered to be more biologically active than mineral salts[52]. In general, Mg^{2+} salts have a fractional absorption of about 20%[5].

CONCLUSIONS

Because of its involvement in diverse biological functions required for optimal physical performance, Mg^{2+} retention is important for athletes. Based on data from population surveys and limited data from dietary histories, athletes have low Mg^{2+} intakes (<70% RDA). Unequivocal biochemical evidence of Mg^{2+} deficiency is lacking. However, preliminary evidence suggests improved cellular energy metabolism after Mg^{2+} supplementation of athletes. Daily loss of Mg^{2+} in urine and sweat may be significant for athletes. To prevent development of marginal Mg^{2+} deficiency, athletes are encouraged to consume diets with a high nutrient density of available Mg^{2+} and other mineral elements.

ACKNOWLEDGEMENT

The contributions of Kristin Ewing, LRD, in providing the information on the magnesium content of beverages and preparing the nutritionally balanced diet for athletes are recognized.

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Magnesium & Physical Activity

The Proceedings of an International Workshop,
Pescara, Italy, 26 – 27 February, 1994

Edited by L. Vecchiet

The Parthenon Publishing Group
International Publishers in Medicine, Science & Technology

NEW YORK
LONDON

Published in the UK by
The Parthenon Publishing Group Limited
Casterton Hall, Carnforth,
Lancs LA6 2LA, England

Published in the USA by
The Parthenon Publishing Group Inc.
One Blue Hill Plaza
PO Box 1564, Pearl River,
New York 10965, USA

British Library Cataloguing in Publication Data

Magnesium and Physical Activity
I. Vecchiet, Leonardo
612.01524
ISBN 1-85070-626-3

Library of Congress Cataloging-in-Publication Data

Magnesium and physical activity / edited by L. Vecchiet.
p. cm.
Includes bibliographical references and index.
ISBN (invalid) 1-85070-623-3
1. Magnesium in the body. 2. Magnesium — Physiological effect. 3. Exercise — Physiological aspects. I. Vecchiet, Leonardo.
[DNLM: 1. Magnesium - metabolism - congresses. QU 130 M1956 1994]
QP535.M4M345 1994
612'.01524—dc20
DNLM/DLC
for Library of Congress 94-29624
CIP

First published 1995

Typeset by Lasertext Ltd, Stretford, Manchester
Printed and bound in Great Britain by
J.W. Arrowsmith Ltd., Bristol