Magnesium intake is associated with strength performance in elite basketball, handball and volleyball players

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Abstract. Magnesium plays significant roles in promoting strength. Surveys of athletes reveal that intake of magnesium is often below recommended levels.We aimed to understand the impact of magnesium intake on strength in elite male basketball, handball, and volleyball players. Energy and nutrient intake were assessed from seven-day diet record. Strength tests included maximal isometric trunk flexion, extension, and rotation, handgrip, squat and countermovement Abalakov jump, and maximal isokinetic knee extension and flexion peak torques. Linear regression models were performed with significance at $p<0.1$. Mean magnesium intake was significantly lower than the recommended daily allowance. Regression analysis indicated that magnesium was directly associated with maximal isometric trunk flexion, rotation, and handgrip, with jumping performance tests, and with all isokinetic strength variables, independent of total energy intake. The observed associations between magnesium intake and muscle strength performance may result from the important role of magnesium in energetic metabolism, transmembrane transport and muscle contraction and relaxation.

Key words: magnesium intake, strength performance, elite athletes

Magnesium is an element required in modest amounts for health and optimal performance [1]. Accumulating evidence supports the notion that magnesium plays significant roles in promoting strength and cardiorespiratory function in healthy persons as well as in athletes. Plasma magnesium has been found to strongly affect muscle performance, such as grip strength and muscle power [2]. Previous findings have also suggested relationships between magnesium nutritional status, functional capacity and muscle performance [3-5]. Team sports such as court sports have complex demands; it seems likely that strength and power are critical to many athletes' tasks and team performance [6, 7]. Magnesium deficit is associated with structural damage of muscle

doi:10.1684/mrh.2011.0290

To cite this article: Santos DA, Matias CN, Monteiro CP, Silva AM, Rocha PM, Minderico CS, Bettencourt Sardinha L, Laires MJ. Magnesium intake is associated with strength performance in elite basketball, handball and volleyball players. *Magnes Res* 2011; 24(4): 215-9 doi:10.1684/mrh.2011.0290

cells, probably as a result of increased production of reactive oxygen species, decrease of ATP formation and use, lipid and protein damage, and impaired calcium homeostasis [8]. Studies [9-11] involving the athletic population reveal that intakes of magnesium are lower than the Recommended Daily Allowance (RDA) of 400 mg/day [12]. The same is true for the majority of the population, mainly due to the consumption of processed food diets. The ratio between calcium and magnesium intake (Ca:Mg) is rarely calculated or reported [13]. As early as 1964, in a review of human balance studies, Seelig reported dietary calcium to be a factor in the retention of the dietary magnesium [14]. In 1989, Durlach warned against excessive calcium relative to magnesium intake, and recommended that total dietary calcium to magnesium ratios (Ca:Mg) remain close to 2.0 [15]. Recent studies reinforce these data [16].

Few published data describe the relationship between magnesium dietary intake and strength performance parameters in athletes. To our knowledge, the present investigation is the first to establish a relationship between baseline, pre-season magnesium dietary intake and strength performance profiles of elite players of volleyball, basketball and handball.

The aim of the current study was to understand the impact of magnesium intake on strength in a pre-season training period in a sample of elite, male athletes.

Material and methods

Subjects

In this study voluntarily participated 26 male elite athletes from 3 different team sports: basketball (n=11), handball (n=7), and volleyball (n=8). Body weight (BOD POD, Life Measurement, Inc., Concord, CA, USA) and height (Seca – model 222, Hamburg, Germany) were assessed. These three types of ball games were assessed together once the determinant strength performance characteristics for competition are similar.

Body composition

Fat-Free Mass (FFM), Fat Mass (FM), and % Fat Mass (%FM) were assessed using dual energy X-ray absorptiometry, fan-beam densitometer (Explorer W, Hologic, Waltham, USA, software version 12.4).

Strength tests

All strength tests were carried out in the same afternoon after a standardized warm-up.

Maximal isometric force for lumbar-thoracic column (Trunk Flexion, extension, and rotation) were assessed at 15° using F110, F130, and F120 David devices (David Fitness & Medical Ltd., Karitie 9, 01530 Vantaa, Finland).

Maximal isometric handgrip strength was determined using a handgrip dynamometer (Jamar model 30 J4, Country technologies).

Squat jump (SJ) and Countermovement jump Abalakov (CMJA) were evaluated using customized software and platform (BioPlux System, version 1.0, Lisbon, Portugal). Isokinetic peak torque at 60° (PT60), and 180°·s-1 (PT180) was measured with an isokinetic dynamometer (Biodex System 3 Advantage Software; Biodex Medical Systems, Inc., Shirley, NY).

Energy and nutrients intake

Energy and nutrients intake were assessed from 24-h diet records during a 7-day period, after the assessment of body composition. Subjects were instructed regarding portion sizes, supplements, food preparation, and others aspects pertaining to an accurate recording of their intake. After the 7-day period athletes were interviewed by a qualified nutritionist in order to clarify the records. Diet records were analyzed by the software package Food Processor SQL (Salem, Oregon, version 10.5.0, 2009).

Statistical analysis

Data were analyzed with IBM SPSS Statistics for Windows version 19.0 (SPSS Inc, an IBM company, Chicago). Statistical significance was set at $p<0.1$. Linear regression analyses were performed to analyze the association between magnesium and strength parameters. The same statistical test was conducted in order to understand if significant associations were independent of energy intake. Normality of residuals was verified with Shapiro-Wilk test.

Table 1. Physical characteristics and body composition of the athletes.

	Mean±SD
Age (yrs)	20.1±4.9
Weight (kg)	81.9±8.9
Height (cm)	190.2±7.9
BMI (kg/m^2)	22.6±2.1
FFM (kg)	69.36±6.89
FM (kg)	11.87±3.30
% FM	14.47±2.92

BMI: body mass index; FFM: fat-free mass; FM: fat mass.

Results

In *table 1* are summarized subjects physical characteristics and body composition.

Means and standard deviations from energy and nutrients intake and strength variables are shown in *table 2A, B*, respectively.

Magnesium intake in these athletes was significantly lower than the recommended daily allowance ($p<0.001$) and the ratio Ca:Mg was higher than the recommendations. Regression analysis indicated that magnesium intake was directly associated with trunk flexion, trunk rotation, and handgrip maximal strength. Direct associations were also observed between magnesium intake and jumping performance tests: SJ and CMJA and with all isokinetic strength variables: PT60 (extension), PT60 (flexion), PT180 (extension) and PT180 (flexion) *(figure 1)*.

These associations remained significant even adjusting for energy intake *(table 3)*.

Discussion

These athletes consume an unbalanced diet with less magnesium than the RDA (400 mg/day) [12], which is in agreement with other authors [14, 15], in association with a high Ca:Mg intake ratio which may decrease magnesium uptake and consequently compromise the cellular availability of magnesium [15]. Moreover, surveys of athletes often report inadequate dietary intake and this is consistently observed across both genders and different types sports [9-11], which is in accordance with the results observed in this study. Our previous results revealed a relationship between plasma magnesium and strength indices [2]. These results may be explained by the important role of magnesium in energy metabolism, transmembrane transport, and muscle contraction and relaxation. Although direct correlations between plasma magnesium and magnesium intake have not been frequently reported, our results show direct associations between magnesium intake and different muscle performance indices, in a group of athletes ingesting low magnesium diets, even when adjusting for energy intake. The determinant role of magnesium ingestion on muscle strength performance in males participating in court sports seems to be independent of the total dietary energy intake. With these results, not only is the importance of magnesium in muscle performance outlined, but it may also be suggested that performance can be improved with adequate magnesium intakes. Dietary guidelines could be used to improve the pattern of magnesium and

Table 2. Energy and nutrients (A) intake and strength variables (B) of the athletes.

A. Nutrients intake	Mean±SD	B. Strength variables	Mean±SD
Energy		Trunk extension (kg)	29.4±8.1
(kJ/day)	11,109±3,437	Trunk flexion (kg)	18.7±6.0
(kcal/day)	2,654±821	Trunk rotation (kg)	14.3±5.0
Carbohydrates (g)	331±123	Handgrip (kg)	46,3±7.8
Protein (g)	121±32	SJ (cm)	27.88±4.55
Fat (g)	88±34	CMJA (cm)	37.13 ± 5.35
Water (g)	2,346±1,149	$PT60_{extension}$ (N/m)	235.5±48.4
Calcium (mg)	93±353	$PT60_{flexion}$ (N/m)	132.0±26.4
Magnesium (mg)*	244.7±78.8	$PT180_{extension}$ (N/m)	172.1±33.5
Ca:Mg ratio*	3.96±1.21	$PT180_{flexion}$ (N/m)	102.8±22.3

Ca: calcium; Mg: magnesium; SJ: squat jump; CMJA: countermovement jump Abalakov; PT60: peak torque at $60^{\circ}.s^{-1}$; PT180: peak torque at $180^{\circ}.s^{-1}$.

* Intake significantly different from the reference (Mg=400 mg; Ca:Mg=2.0).

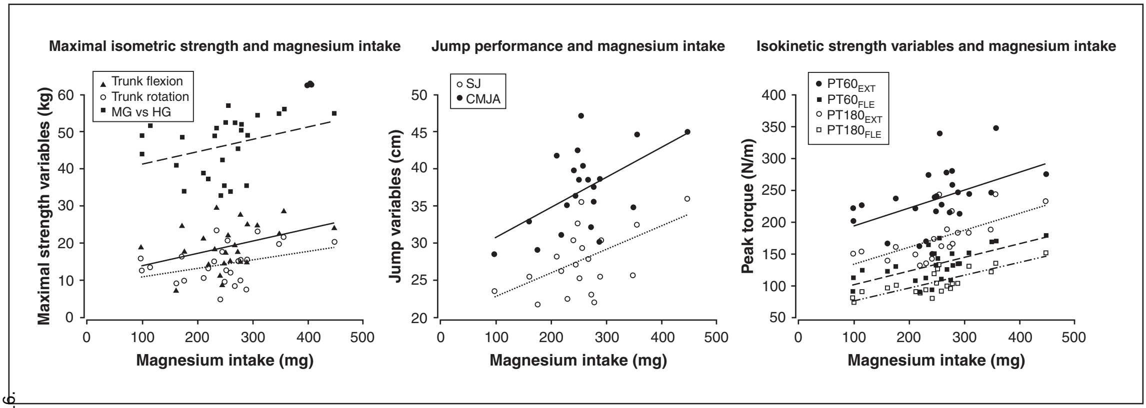

Figure 1. Strength performance and magnesium intake associations.

Table 3. Linear regressions between magnesium and strength performance variables.

Strength performance variables	R^2	p-value	p-value (after adjusting for EI)
Trunk extension	0.013	0.584	0.324
Trunk flexion	0.193	**0.025**	**0.028**
Trunk rotation	0.357	**0.073**	**0.055**
Handgrip	0.111	**0.096**	**0.027**
SJ	0.254	**0.020**	**0.070**
CMJA	0.290	**0.012**	**0.075**
PT60$_{extension}$	0.214	**0.020**	**0.016**
PT60$_{flexion}$	0.411	**0.001**	**0.002**
PT180$_{extension}$	0.431	**0.001**	**<0.001**
PT180$_{flexion}$	0.589	**<0.001**	**<0.001**

SJ: squat jump; CMJA: countermovement jump Abalakov; PT60: peak torque at $60^{\circ}.s^{-1}$; PT180: peak torque at $180^{\circ}.s^{-1}$; EI: energy intake [12].

calcium intake, particularly in athletes, for whom magnesium needs to be above the normal recommendations [17] in order to improve strength and muscle performance. Supplementation may be important for the correction of inadequate diets in male athletes participating in court sports.

Acknowledgments

We would like to express our gratitude to the athletes for their time and effort.

Disclosure

This work was supported by the Portuguese Foundation for Science and Technology (PTDC/DES/098963/2008) and by the Interdisciplinary Center for the Study of Human Performance (CIPER).

None of the authors has any conflict of interest to disclose.

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