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Serum magnesium behavior in professional cyclists after a multi-stage competition

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ABSTRACT

The aim of this study was to determine the effects of continuous, repetitive and intense exercise, such as the stage cycling race, on the serum Mg. Fourteen male cyclists from two professional cycling teams were recruited to participate in the investigation.The cyclists were tested at three specific points around the "Vuelta a Mallorca": a) before start the race T0, b) In the middle of the race T1 - before start 3rd stage and c) last race T2. Serum Ca and Mg, Creatine kinase (CK) and total proteins (TP) were measured.Red blood cell counts, hemoglobin (Hb), and hematocrit (Hct) were determined. Serum Mg levels have showed a decrease tendency during the race (T0: 22.93±0.96 vs. T2: 20.25±0.49 mg/L).However, serum Ca levels at the end of race was significant lower than at begin of these (T0: 107.79±3.43 vs. T2: 96.88±1.80 mg/L). In summary, long term exercise along a race from 5 days was accompanied by small decrease in serum Mg seemed to be related to the redistribution of Mg. Our main findings support the hypothesis that serum Mg levels decrease during daily strenuous endurance stages of cycling stages race.

Key Words: Mg, exercise, cyclists, Ca, stage race

INTRODUCTION

During the past decade, a sustained interest has developed in trace element nutrition and metabolism as it relates to athletic performance[1].Changes in mineral levels in the organs of the body during vigorous or intense physical activity can cause adverse effects in sport performance and endurance of athletes[2, 3]. When the mineral loss and is not compensated appear clinical symptoms such as fatigue, cramp, difficulty in breathing and aphasia[4].

The effect of exercise on the distribution and excretion of magnesium (Mg) has been extensively studied. From these studies is showed that Mg plays a vital role in regulating in many physiological functions that affect muscle function including oxygen update, energy production and electrolyte balance[5, 6]. Moreover, several studies found that Mg strongly affects muscle performance, such as grip strength and muscle power, probably due to the key role of Mg in energetic metabolism, transmembrane transport and muscle contraction [7, 8, 9, 10].

Frequently, athletes fail to consume a diet that contains adequate Mg[9], together mineral losses in urine and sweat which are more important during exercise than at rest, may contribute to frequent mineral deficits among athletes[9]. If the decrease in serum Mg is not transient, it may indicate that exercise increases the Mg requirement to a point where intake is inadequate and thus results in a sub clinical or deficient status. For example, Mg deficit is associated with muscle weakness, cramps, and structural damage of muscle fibers and organelles [11].

Therefore, maintenance of an adequate Mg status is therefore of utmost importance for optimal exercise performance and recovery[6].Several studies have reported a significant hypomagnesaemia after prolonged exhaustive exercise[12,13, 14], moderate duration, moderate-intensity exercise[15, 16, 17], and short-term high-intensity exercise[18].These low plasma Mg levels due submaximal efforts have been explained by several mechanisms such as redistribution of magnesium to red blood cells, adipocytes or myocytes, loss in urine or for increased lipolysis. In this way, we have communicated [19] that the plasma Mg variations after high-intensity exercises appear to be due in part to the percent change in plasma volume, and the increased erythrocytic Mg concentrations with respect to a resting situation could be due to increased metabolic activity during exercise.

On the other hand, various authors have indicated that high-intensity exercise leads hypermagnesaemia as consequence of a decrease in plasma volume and a shift of cellular Mg resulting from acidosis [20]. Bohl and Volpe [10] indicated that short-term, high intensity exercise transiently increased plasma or serum Mg concentrations by 5-15%; the concentrations returned to baseline within a day. The increase was associated with a decrease in plasma volume. Current studies have also found that sustained moderate physical exercise (80 km march of 18 hr duration) [21], and short-term high intensity (anaerobic) exercise [22], increased serum magnesium concentration. Instead of decreased plasma volume, muscle breakdown was suggested as the cause of increased serum magnesium found shortly after exercise [21] and this suggestion was supported by the finding of a concomitant small increase in serum creatine kinase (CK) activity[23].

However, at present no studies have evaluated of high performance exercise during some consecutives days of competition on Mg status in elite endurance athletes. We attempted to evaluate the changes in serum calcium (Ca) and Mg during a cycling competition lasting 5 days. The aim of this study was to determine the effects of continuous, repetitive and intense exercise, such as the stage cycling race, on the serum Mg.

MATERIALS AND METHODS

Subjects

Eleven male cyclists from two professional cycling teams were recruited to participate in the investigation. The physical characteristics at the start of the *Vuelta a Mallorca* have been shown in Table 1. All participants followed a similar diet constantly supervised by the dietitian/nutritionist of the team and all performed the same training program supervised by the same physician. The athletes took multivitamin pills which included iron, folic acid, vitamin C and B_{12}, branch amino acids, glutamine and Vitamin C. Likewise, they took glicofosfopeptical (AM3).Participants were determined to be free of disease by a medical examination, prior to the onset of the study. Additionally, to the author´s knowledge none of cyclists were using illegal drugs or taking medications. This was the compromise with the members of the teams.

The experimental procedures, associated risks, and benefits were explained to each player, and each player signed a written consent form before commencing participation. None of the players had any pre-existing injuries prior to testing.

The race started in late February at the Mallorca city. It included 5 consecutive daily stages without one day of rest. During these days, 760 km were covered over a Mallorca Island. The total time spent racing by the overall winner was about 20 hours (average speed about 39 km/h). The mean distance covered per daily stage was 152 km at altitudes of about 0–900 m above sea level. To maintain circadian rhythms, nutrition, hydration, timing of food intake, and sleep were kept constant throughout the five days period, which is normal practice in cycling competitions. Mean daily food intake during the "*Vuelta a Mallorca"* is standardized for most professional cycling teams and averages ~840 g of carbohydrate (CHO) (~12 g·kg·d–1), 200 g of protein (~3 g·kg·d–1), and 160 g of fat, corresponding to ~23.5 MJ. Particularly, all the subjects had a high-CHO meal during the first hour after each stage (1.1 $g \cdot kg^{-1}$), which usually consisted of a mixture of cereals, dairy products, and fruits.

Besides all of them received the same treatment in terms of ergogenic aids or pharmacological supplementation, including concentrated multivitamin/mineral supplements.

The cyclists were tested at three specific points around the "Vuelta a Mallorca": a)Baseline at rest just before start the race (T0), b) In the middle of the race (T1 - before start 3^{rd} stage) and c) At the end of race (T2 – the day after finishing the race).

Ca and Mg Assessment

Team dietitian weighed each food that cyclist consumed in their diet at T0, T1 and T2 and then wrote 24-hour dietary recall. Food values were converted into Ca and Mg by the online version of the validated food software package, Easy diet©, which is based on the tables of food composition comprised by the Centre for Higher Studies in Nutrition and Dietetics (CESNID)[24]. Likewise, Ca/Mg ratio was calculated.

Anthropometric measurements

Anthropometric measurements were taken by an ISAK (*International Society for Advancement in Kinanthropometry*) level 3 anthropometrist, following the standard procedures in T0. The height and body mass technical error of measurement (TEM) was less than 0.02 %. The girths TEM was all less than 0.45% and the skinfolds TEM was all less than2.6%.The height (cm) was measured with a SECA® measuring rod, with a precision of 1 mm (range: 130-210 cm), while body mass (BM) (kg) was assessed by a SECA®model scale, with a precision of 0.1 kg (range: 2-130 kg).All skinfolds (triceps, biceps, abdominal, supraspinale, subscapular, chest, front thigh and medial calf) were taken by Harpenden skinfold calliper (CMS instruments, London, UK), with a precision of 0.2 mm. A sum of 8 skinfolds (mm) and 6 skinfolds (triceps, abdominal, supraspinale, subscapular, front thigh and medial calf) was calculated. Bone diameters (wrist and femur, cm) were measured using a Holtain® bicondylar calliper with 0.1 cm precision.

Blood Collection and Analysis

Antecubital venous blood samples were collected from all cyclists at T0, T1 and T2. All samples were collected in basal conditions after an overnight fast. At the 3rd time points the blood sample was taken at 8:30am and then rested comfortably in a seated position. Blood samples were collected by antecubital venipuncture with Vacutainer system (10 mL to serum tubes, 5-mL and 3-mL tubes with EDTA) from all subjects to assess biochemical study parameters. Serum was separated from blood cells and stored at -20º C until analyzed.

Creatine kinase (CK) and total proteins (TP) were measured before start the "vuelta" (T0) in the last day (T2). Creatinkinasse (CK) and total proteins (TP were measured using a classic enzymatic method, with the aid of a Hitachi autoanalizer (Hitachi 917, Japan).Serum Ca and Mg were determined with a Perkin Elmer 272 "Flame atomic absorption spectrometry (FAAS)" device in flame emission mode. Erythrocytic Mg was determined: whole blood was hemolyzed by dilution with deionized water, mixed with a vortex, and then frozen. After Mg determination in whole blood and plasma, erythrocytic Mg concentration was calculated as: [whole blood Mg - plasma Mg)x(1 - Hct)]/Hct. Red blood cell counts, hemoglobin (Hb), and hematocrit (Hct) were determined on a Coulter Counter (model MAX-M). The percentage in plasma volume variation (%PV) was calculated using pre- and post Hct and pre- and post TP[25].

Statistical Data Analyses

Statistical analyses were performed by IBM Statistical Package (SPSS Version 22]. Data were expressed as mean ± standard error of the mean. The Shapiro-Wilk test was used. After check the normal distribution, a one-way repeated measures ANOVA was carried out for Ca and Mg by Greenhouse-Geisser test to check if there were significant variations among mineral parameters along the different phases of the study. To determinate differences among period of study post hoc Bonferroni test was applied. Bivariate correlations between changes in Ca and Mg during season Δ(T0–T2) were tested using Pearson rank order correlation test after calculate Δ(T0–T2) = ((T2-T0)/T0)x100. A value of $p < 0.05$ was regarded as significant.

RESULTS

In table 2 are showed the calcium, magnesium and Ca/Mg ratio mean consumption per 1000 kcal of professional cyclists during, same in all competition as in each moment studied. It can be observed that whereas the Mg consumption was maintained with light changes, the intakes of Ca decreased significantly along of the competition ($p<0.01$). In the same way was the behavior of ratio Ca/Mg.

Table 2shows the serum Mg, erythrocytic Mgand Ca levels in the 3 points of study. Serum Mg and erythrocytic Mg levels have showed a non-significant decrease tendency during the race. However, serum Ca levels at the end of race was significant lower than at begin of these ($p<0.01$).

The table 3 shows haematological and muscle damage parameters at T0 and T2. Although no significant differences were shown in WBC, RBC, Hb and TP, it has observed an increase tendency of them at the end of "*La Vuelta a Mallorca*". However, it has observed significant higher values at the end of study than baseline of CK ($p<0.05$) and Hct ($p<0.001$).

Figure 1 shows a significant high positive correlations ($p<0.001$, R^2=0.7572) between Ca and Mg behaviour during stage race. This indicates the cyclists who have higher decrease of Ca level also have high decrease on Mg level and vice versa.

DISCUSSION

Professional road cycling in a 1-week stage race is a little brother of the most extraneous demanding sport[26]. However, constitutes also an ideal situation of long, strenuous daily exercise [27]. This race is an adequate model for evaluating the effects of continuous high workload on athletes. To our knowledge the present study was the first to examine the effects of cycling stage race during 5 days on serum Ca and Mg levels in sportsmen very well trained (professional cyclists).

Mg may be considered a potentially limiting element for human performance. Although Mg status does not appear to be compromised in athletes, there are several studies showing that Mg may be lost from the body after performing strenuous exercise.

First of all, our data shown that average dietary calcium to magnesium ratios (Ca:Mg) was 1,91. However this relation was decreasing along of the competition due fundamentally to the decrease in the Ca intakes. Similar observations have published recently [28]. They have found that calcium intake was low in soccer players and in cyclists, but especially in the cyclists, whose ingestion is about half of what recommended. Durlach [29], warned against excessive calcium relative to magnesium intake, and recommended that total dietary calcium to magnesium ratios (Ca:Mg) remain close to 2.0. Recent studies reinforce these data [30]. In this way Nielsen and Lukaski [6] in their review communicated that the magnesium content of the self-selected diets of nine men aged 20-35 years ranged from 190 to 595 mg/day and intakes ranging from 204 to 595 mg/day were sufficient to maintain balance in four men. The cyclists studied in this work maintain a level of Mg intake more than this levels (around 200 mg/1000Kcal), because the total average Kcal ingested by the cyclist in competition is around 5000 Kcal.

On the other hand, in our work there were no significant differences in postrace serum magnesium, however we found a light decrease. In general, short-term, high-intensity exercise has been shown to be associated with increased serum or plasma magnesium concentrations, while long term endurance exercise results in decreased concentrations[10, 21,22]. We can considerate that a race of 5 consecutive days of competition is more than a short-term, high-intensity exercise, and is more appear to a long term endurance. Each race is around 180 km with a speed average 38-41 km^{-1}. We think that the hypomagnesemia may reflect a redistribution of magnesium in the body compartments, perhaps indicating a release from one storage area to be used at an active site (e.g., exercising muscle, erythrocytes, adipose tissue), as previously have been communicated [10, 13, 21, 22, 23, 31, 32, 33]. We think that this redistribution can be a good explanation because, in the cases with increased serum Mg found after exercise is suggested that is concomitant with small increase in serum CK activity [23].Other authors [16, 17]as have proposed a mechanism for Mg uptake into adipocytes. In this same line there are several papers as shown the review of Bohl and Volpe [10]or Nielsen and Lukaski[6]. However, if the decrease in serum Mg is not transient, it may indicate that exercise increases the magnesium requirement to a point where intake is inadequate and thus results in a sub clinical or deficient status. In our case, the decreased of Mg is small and it cannot induce to think this theory[17, 19].Other theory to justified the decreased serum Mg is the transient shift of magnesium to myocytes from the extracellular fluid occurs during prolonged strenuous exercise includes reports that Mg apparently slowly increases in exercising muscle in parallel to decreases in plasma Mg[34], and that prolonged exhaustive exercise increased muscle Mg[35].On the other hand, strenuous exercise is associated to muscle cramps, caused mainly by dehydration and imbalances in serum electrolyte concentrations as Mg. In our study we it can consider that serum Mg was within the normal range, also the changes in plasmatic volume was low (3%), and no cyclists said cramps throughout the study period.

Other important findings of this study were a small decreased in serum Ca after 5 consecutive stage races in the professional cyclists. Moreover, was observed a significant and positive relationship between behaviour in serum Ca and Mg during this race.This relation is well described and given the role of both, as divalent cations, in constitution of bone seems normal the similar behaviour. This results are contrary that observed by Lombardi et al. during Giro d'Italia after correction for changes in plasma volume[36].These authors [37]previously have reported that bone resorption is stimulated in these athletes. Activation of osteoclasts seems to be a peculiarity of heavy exercise, even in professional athletes, despite the fact that they are usually well trained and closely controlled for diet and beverages. Single bouts of bicycle exercises (1–5 h) raised serum PTH and calcium, and lowered ionized calcium, demonstrating that the increase in PTH with exercise was independent from hypocalcemia. Besides, even serum P rose, probably as a result of leakage from the working muscle[38]. The calcium-independent rise in PTH seems to be an adaptive response to endurance activities[39].

Lombardi et al. [36,37] during 3 weeks of competition have observed absence of changes in PTH, accompanied by constant serum Ca and P (along the entire race), might be the result of adaptation to the strenuous activity not only throughout the first phase, but right up to the end of the competition.

Table 1.Physical characteristics and anthropometric and body composition in the cyclists at the start the study (T0).

	Mean ± SEM
Age (ys)	26.13±0.99
Weight (kg)	71.66±2.43
Height (cm)	180.38±2.14
Skinfolds (mm)	
Bicipitale	3.79±0.30
Tricipitale	6.45±0.67
Subscapulare	7.14±0.51
Chest	5.50±0.70
Supraespinale	5.43±0.27
Abdominale	9.01±1.41
Thigh (front)	8.70±0.87
Calf	5.38±0.52
Sum of 6 skinfolds	42.10±2.56
Sum of 8 skinfolds	51.39±3.35
Body composition (%)	
Fat mass	7.69±0.25
Bone mass	16.41±0.49

Table 2. Calcium and magnesium mean consumption of professional cyclists during La "vuelta a Mallorca".

		Mean ± SEM	*95% confidence interval of ICC*		p
Ca (mg/1000kcal)	T0	440.75±27.81	377.84	503.66	0.01
	T1	385.60±21.24	337.55	433.65	
	T2	345.95±14.95[a,b]	312.14	379.77	
Mg (mg/1000kcal)	T0	211.09±9.33	189.99	232.19	NS
	T1	203.51±2.88	196.98	210.03	
	T2	201.88±4.62	191.44	212.32	
Ca/Mg	T0	2.11±0.14	1.79	2.43	0.01
	T1	1.89±0.10	1.67	2.12	
	T2	1.72±0.07[a]	1.56	1.87	

Significant differences among period of study by Bonferroni´s test:
[a]: Vs. T0.
[b]: Vs. T1.

Table 3. Serum Ca and Mg levels of professional cyclists during *La vuelta a Mallorca.*

		Mean ± SEM	*95% confidence interval of ICC*		p
Ca (mg/L)	T0	107.79±3.43	100.37	115.20	0.05
	T1	105.79±2.08	101.30	110.28	
	T2	96.88±1.80[a]	92.63	101.12	
Mg (mg/L)	T0	22.93±0.96	20.86	25.00	NS
	T1	22.93±0.68	21.45	24.40	
	T2	20.25±0.49	19.09	21.41	
Mg-e (mg/L)	T0	6.11±0.25	5.55	6.67	NS
	T1	6.25±0.20	5.80	6.70	
	T2	5.68±0.17	5.30	6.06	

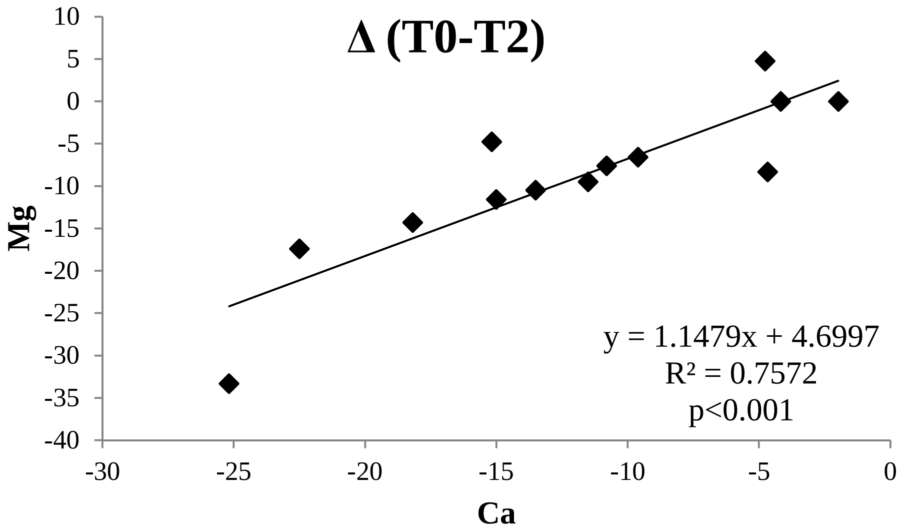
Mg-e: eritrocytic magnesium.
[a]: Vs. T0: Significant differences among period of study by Bonferroni´s test

Table 4.Hematological and muscle damage of professional cyclists during the"vuelta a Mallorca".

		Mean±SEM	***95% confidence interval of ICC***		**p**
Leucocytes (WBC)	T0	6.03±0.38	5.15	6.90	0.05
	T2	6.40±0.41	5.47	7.33	
Red blood cells (RBC)	T0	4.82±0.10	4.59	5.05	NS
	T2	4.85±0.13	4.55	5.15	
Hb (g/dl)	T0	14.87±0.16	14.50	15.23	NS
	T2	15.10±0.19	14.66	15.54	
Hct (%)	T0	45.88±0.71	44.24	47.51	0.01
	T2	47.34±0.74	45.64	49.05	
CK (U/L)	T0	136.22±17.91	94.93	177.52	0.03
	T2	165.00±13.94	132.86	197.14	
Total proteins (g/dl)	T0	7.16±0.14	6.83	7.48	NS
	T2	7.38±0.10	7.15	7.64	
%PV	T0-T2	3.11			

Hb: Hemoglobin; Hto: Hematocrit; CK: Creatin Kinase; %PV: Change of plasmatic volume

Figure 1. Bivariate correlations between Ca and Mg behavior during *La Vuelta a Mallorca* (Δ T0-T2).



In summary, long term exercise along a race from 5 days was accompanied by small decrease in serum Mg concentration seemed to be related to the redistribution of Mg between the extra- and intracellular compartment. We consider that serum magnesium was within the normal range and the decrease was transient. Our main findings support the hypothesis that serum Mg levels decrease during daily strenuous endurance stages of cycling stages race although the cyclists follow a recommendations intake of it. We think that with an adequate diet, it the content in magnesium is correct, can help to the recovery of the athletes.

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