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ORIGINAL CONTRIBUTION

José Mataix
Pilar Aranda
María López-Jurado
Cristina Sánchez
Elena Planells
Juan Llopis

Factors influencing the intake and plasma levels of calcium, phosphorus and magnesium in southern Spain

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J. Mataix · P. Aranda
M. López-Jurado · C. Sánchez
E. Planells · J. Llopis
Institute of Nutrition and Food Technology
Dept. of Physiology
Campus Cartuja
University of Granada
Granada, Spain

J. Llopis (✉)
Depto. de Fisiologia
Facultad de Farmacia
Campus Cartuja
Universidad de Granada
18071 Granada, Spain
Tel: +34-958/24-3885
Fax: +34-958/24-8959
E-Mail: jllopis@ugr.es

Abstract *Objective* The aim of the study was to assess factors influencing the intake and plasma levels of calcium (Ca), phosphorus (P) and magnesium (Mg) in an adult population from southern Spain, in order to identify patterns of intake and groups at risk for deficiency. *Methods* A cross-sectional survey was carried out in Andalusia, a western Mediterranean region in southern Spain. Nutrient intakes were studied in a random sample of 3,421 subjects (1,747 men, 1,674 women) between 25 and 60 years of age. Blood samples were obtained for biochemical assays in a random subsample of 354 subjects (170 men, 184 women). Food consumption was assessed by a 48-h recall. Concentrations of Ca, P and Mg were measured in plasma. Information about level of education, smoking habit, alcohol consumption and physical exercise was collected with a structured questionnaire. *Results* Intakes were below two-thirds of the RDA in 39.52% of the sample for Ca, and in 32.31% for Mg. Gender, age, educational level, obesity, smoking, alcohol use and physical activity were associated with differences in nutrient intakes. Plasma concentrations were below the reference value in 14.81% of the sample for Ca, and in 8.82% for Mg. Obese persons [body mass index (BMI) ≥ 30 kg/m^2] consumed less Ca, P and Mg, and had lower plasma Ca concentrations ($P < 0.05$) than non-obese persons. BMI showed an inverse correlation with plasma concentrations of Ca ($r = -0.21$, $P < 0.05$). *Conclusion* Our results provide an estimate of the intake of Ca, P and Mg in the adult population of southern Spain. Of the factors that affected the intake of these nutrients, logistic regression analysis showed that only female gender and older age were associated with the risk of low plasma Ca concentrations.

Key words minerals – adult – intake – plasma levels – southern Spain

Introduction

Economic development in Spain during recent decades has favored the appearance of social, cultural and dietary changes in this typically Mediterranean country. Although much information is available on dietary habits of the Spanish population and on the intakes of different foods and nutrients [1], information on the influence of physical exercise, obesity, smoking and drinking on mineral intakes in the adult Spanish population is generally scarce [2, 3].

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The aims of this study were to evaluate the influence of demographic characteristics, educational level, obesity, smoking habit, alcohol consumption and physical exercise on nutritional intake and plasma concentrations of Ca, P and Mg in the adult population in Andalusia, a western Mediterranean region in southern Spain. Food intakes in this geographical region departs somewhat from the mean national figures for certain groups such as cereals, fruit and dairy products [1]. Our findings document the patterns of nutrient intake, identify groups at risk for dietary deficiency, and suggest factors that may influence the intakes of these nutrients. It is hoped that this information will be useful in developing future health interventions aimed at modifying dietary habits.

Methods

Participants

The data reported here were obtained within the framework of a large-scale study in the region of Andalusia [4]. A cross-sectional epidemiological survey was conducted with a representative random sample of adults between 25 and 60 years old living in the region of Andalusia, an 87,597-km^2 area with 2,946,228 inhabitants between the ages of 25 and 60 years at the time of the study [5]. The theoretical sample size was 3,680 subjects for a sampling error of less than 5% and estimates at the 95% confidence level. The actual sample consisted of 3,421 individuals (1,747 men, 1,674 women), for a participation rate of 92.9% with valid observations. Participants were asked whether they had any acute or chronic illness, and were included if they were (or appeared to be) in good health; pregnant and lactating women were excluded. The population of participants who consumed mineral or vitamin–mineral supplements (3.9%) was also excluded. The demographic characteristics of the sample, the sampling system, methods of food consumption assessment (48-h recall) and blood sample collection for biochemical analysis, and how level of education, smoking and drinking habits, and physical exercise was recorded, are described in detail elsewhere [4]. The study protocol was approved by the Medical-Ethical Committee of the Health Council of the Andalusian Regional Government, and informed consent was obtained from each subject.

Analytical methods

The content of Ca and Mg in plasma was determined by atomic absorption spectroscopy (Perkin Elmer AAnalyst 300 spectrometer, Norwalk, CT, USA).

Table 1 Percentage contribution of the different food groups to Ca, P and Mg intakes

Food group	Ca	P	Mg
Total grain products	9.84	14.94	18.27
Potatoes	0.58	2.96	4.95
Vegetables	3.83	4.24	6.16
Fruits	7.58	5.17	12.85
Pulses	3.75	8.38	12.71
Nuts	0.19	0.81	2.61
Meat	4.03	20.73	10.91
Fish	3.44	8.61	6.65
Eggs	1.84	4.80	1.21
Dairy products	59.37	22.57	16.55
Pastries	3.56	4.22	3.58
Others	1.98	2.57	3.54

Phosphorus was measured with a commercial colorimetric kit from QCA (Amposta, Spain). Seronorm^{TM} Trace Elements (ref 201405) (SERO AS, Billingstad, Norway) was used for Ca and Mg quality control measures. Randox human-assayed serum level 3 (ref. HE1532, Laboratorios Randox, Barcelona, Spain) was used for P quality control measures.

Statistical analysis

Crude experimental data were subjected to Student's *t* test for independent samples. Linear regression analysis was used to find bivariate correlations; Pearson's correlation coefficient was calculated for 95% confidence levels. Multiple logistic regression analysis was used to estimate the degree of association between intake or plasma values (dependent variable) and energy, gender, age, educational level, smoking, drinking and physical exercise. All analyses were done with version 11.0 of the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA). Differences were considered significant at the 5% probability level.

Results

Table 1 shows the contribution of the different food groups to Ca, P and Mg intake. The bivariate analysis for food intake and mineral intake showed that Ca intake appeared to correlate with the consumption of dairy products ($r = 0.67$, $P < 0.01$), P intake with the consumption of dairy products and grain products ($r = 0.54$, $P < 0.01$ and $r = 0.35$, $P < 0.01$, respectively), and Mg intake with the consumption of grain products and dairy products ($r = 0.46$, $P < 0.01$, $r = 0.29$, $P < 0.01$, respectively).

Table 2 shows mean intakes of energy, Ca, P and Mg and mean plasma levels of these minerals, to-

Table 2 Mean intakes and plasma concentration of Ca, P and Mg

	Total (*n* 3,421)		Men (*n* 1,747)					Women (*n* 1,674)				
	Mean	SD	Mean	SD	P25	P50	P75	Mean	SD	P25	P50	P75
Intake												
Energy (MJ/d)	9.23	3.47	10.48	3.72	7.97	10.04	12.45	7.92	2.62[a]	6.01	7.67	9.42
Ca (mmol/d)	20.81	10.69	21.58	11.36	13.84	19.43	27.02	19.99	9.86[a]	13.41	18.40	24.64
			19.55	9.64[b]				22.11	9.64[a,b]			
P (mmol/d)	38.42	14.40	40.99	14.99	30.75	38.80	48.79	35.66	12.96[a]	26.67	34.40	42.45
			37.45	11.09[b]				39.36	11.11[a,b]			
Mg (mmol/d)	11.73	4.36	12.87	4.65	9.66	12.23	15.29	10.54	3.61[a]	8.08	10.17	12.64
			11.70	3.02[b]				11.76	3.02[b]			
Plasma level	(*n* 354)				(*n* 170)					(*n* 184)		
Ca (mmol/l)	2.49	0.29	2.58	0.20	2.50	2.56	2.69	2.43	0.31[a]	2.12	2.50	2.63
P (mmol/l)	1.65	0.89	1.56	0.81	1.08	1.30	1.51	1.72	0.94	1.14	1.39	1.77
Mg (mmol/l)	0.92	0.18	0.93	0.20	0.74	0.86	1.11	2.24	0.17	0.74	0.86	0.99

SD = Standard deviation; P = Percentile
[a]Mean values significantly different from those for the men ($P < 0.05$)
[b]Mean values adjusted for energy intake

gether with their percentile distributions. Energy intake appeared to correlate significantly with the intakes of Ca ($r = 0.48$, $P < 0.01$), P ($r = 0.66$, $P < 0.01$) and Mg ($r = 0.74$, $P < 0.01$).

Calcium intake was equal to or higher than the RDA for the Spanish population [6] in only 23.3% of the population. However, mean P intake was higher than the RDA [7]. (No RDA has been established yet for this element in the Spanish population.) The Ca/P ratio was 0.70:1 in men and 0.75:1 in women. Mean Mg intakes were lower in both genders than the amounts recommended for the Spanish population [6].

Plasma levels of Ca, P and Mg are reported here for a sub-sample of approximately 10% of the population (354 subjects for a sampling error of less than 5% and estimates at the 95% confidence level). Mean intakes (mean ± SD, mmol/day) of Ca (21.61 ± 10.78), P (38.82 ± 14.29) and Mg (11.78 ± 4.49) in this subsample did not differ significantly from the values found for the entire sample (Table 2). Despite the limited sensitivity and specificity of this measure, it is used widely in nutritional research [7]. The results of the analyses showed that mean plasma concentrations of all minerals were within normal limits in both genders. We found no significant correlations between Ca, P or Mg intakes and plasma levels. However, we found a significant correlation between protein intake and plasma Ca concentration ($r = 0.13$, $P < 0.05$).

Intakes were below two-thirds of the RDA [6] for Ca in 38.10% of the men and 41.00% of the woman, and were below this level for Mg in 26.33% of the men and 38.53% of the woman. Phosphorus intake was below two-thirds of the RDA in only 1.03% of the men and 2.15% of the women in our sample [7].

The results for Ca were below the reference value (2.18 m mol/l) [8] in 2.30% of the men and 25.10% of the women. Compared to the reference value for Mg (0.70 mmol/l) [11], plasma concentration was lower in 7.30% of the men and 10.40% of the women. However, concentrations of P were below the reference value (> 0.80 mmol/l) [8] in only 1.14% of the men and 3.13% of the women.

Table 3 shows how age, education level, obesity, smoking, drinking and physical exercise, and crude intakes were associated with plasma levels of minerals. In obese persons (BMI ≥ 30 kg/m^2; 18.85% of the population) we noted an inverse linear correlation between BMI and plasma Ca levels ($r = -0.21$, $P < 0.01$).

Table 4 shows the associations for Ca, P and Mg intake with energy intake, demographic characteristics, educational level, obesity, smoking habits, alcohol consumption and physical exercise.

In addition to the results shown in Table 4, we estimated the degree of association between plasma level of minerals and energy intake, demographic characteristics, educational level, obesity, smoking habits, alcohol consumption and physical exercise. The model adjusted for all variables showed that only plasma Ca concentration was associated with gender (OR = 13.13, 95% CI = 3.47–49.72; $P < 0.001$, with male gender used as the reference value) and with age (OR = 5.34, 95% CI = 1.27–22.50; $P < 0.05$; 40-to-49 year old subgroup; and OR = 11.91, 95% CI = 2.92–48.55; $P < 0.001$; 50-to-59 year old subgroup, when the 25-to-39 year old subgroup was used as the reference).

Discussion

Mean intakes in the Spanish population we studied were similar to mean values in other western countries (Table 5). The percentage of persons at risk for

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Table 3 Effect of age, education level, obesity, smoking, drinking and physical exercise on mean daily crude intakes and plasma concentrations of Ca, P and Mg

	n	Ca	Intake (mmol/day)		*n*	Ca	Plasma level (mmol/l)	
			P	Mg			P	Mg
Age groups (years)								
25–39	1,720	21.01 ± 10.82	39.01 ± 14.85	11.91 ± 4.47	164	2.56 ± 0.21	1.70 ± 0.96	0.92 ± 0.18
40–49	806	20.28 ± 10.23	37.73 ± 13.40[a]	11.63 ± 4.13	80	2.48 ± 0.31[a]	1.60 ± 0.32	0.93 ± 0.20
50–60	895	20.93 ± 11.08	37.83 ± 14.04	11.59 ± 4.35	110	2.42 ± 0.32[a]	1.63 ± 0.91	0.92 ± 0.18
Educational level								
University	643	22.40 ± 10.49	39.29 ± 13.91	11.82 ± 4.24	49	2.57 ± 0.15	1.94 ± 1.23	0.90 ± 0.21
Secondary	812	22.16 ± 11.50	39.29 ± 15.10	11.81 ± 4.43	75	2.52 ± 0.23	1.57 ± 0.83	0.93 ± 0.19
Primary/no schooling	1,966[#]	19.80 ± 10.30[b,c]	37.85 ± 14.02[b,c]	11.71 ± 4.33	230[§]	2.47 ± 0.31	1.63 ± 0.84	0.93 ± 0.18
Obesity								
Obese*	645	19.91 ± 10.46	37.48 ± 14.71	11.30 ± 4.29	70	2.43 ± 0.34	1.70 ± 0.93	0.98 ± 0.20
Overweight**	1,281	20.76 ± 10.44	38.11 ± 13.64	11.76 ± 4.30[d]	140	2.50 ± 0.27	1.54 ± 0.68	0.97 ± 0.19
Non-obese	1,495	21.32 ± 10.93[d]	39.06 ± 14.50[d]	11.92 ± 4.38[d]	144	2.53 ± 0.26[d]	1.73 ± 1.03	0.95 ± 0.19
Smoking habit								
Current smokers	1,443	20.58 ± 11.17	39.02 ± 14.82	12.04 ± 4.55	141	2.57 ± 0.22	1.75 ± 0.95	0.98 ± 0.18
Former smokers	628	21.93 ± 11.17[e]	38.64 ± 13.96	12.00 ± 4.39	59	2.51 ± 0.38	1.68 ± 1.00	0.92 ± 0.18
Never smokers	1,350	20.52 ± 9.83[f]	37.52 ± 13.70[e]	11.27 ± 4.03[e,f]	164	2.45 ± 0.30[f]	1.59 ± 0.82	0.97 ± 0.20
Alcohol consumption								
Drinkers[$]								
P25	426	21.72 ± 10.95	38.97 ± 13.72	11.64 ± 4.05	44	2.47 ± 0.26	1.68 ± 0.78	0.95 ± 0.18
P50	417	21.22 ± 10.77	38.29 ± 13.42	11.79 ± 4.41	41	2.54 ± 0.23	1.81 ± 1.12	0.93 ± 0.16
P75	841	21.91 ± 11.51	40.75 ± 14.00[g,h]	13.27 ± 4.61[g,h]	84	2.55 ± 0.23	1.60 ± 0.85	0.95 ± 0.21
Non-drinkers[†]	1,737	19.94 ± 10.07[g,h,i]	37.13 ± 14.59[g,i]	11.00 ± 4.04[g,h,i]	185	2.46 ± 0.32[i]	1.63 ± 0.88	0.98 ± 0.19
Physical exercise								
Sedentary[‡]	2,222	20.15 ± 10.52	37.33 ± 13.80	11.46 ± 99.05	225	2.47 ± 0.31	1.72 ± 0.97	0.98 ± 0.20
Active 1–3 h/week	635	21.26 ± 10.00[j]	39.19 ± 14.53[j]	12.02 ± 108.26[j]	69	2.51 ± 0.26	1.47 ± 0.59	0.94 ± 0.17
Active > 3 h/week	564	22.95 ± 11.70[j,k]	41.51 ± 15.09[j,k]	12.48 ± 109.44[j]	60	2.56 ± 0.18[j]	1.57 ± 0.77	0.93 ± 0.19

1,880 persons with elementary school education only and 86 persons with no formal schooling. [§] 220 persons with elementary school education only and 10 persons with no formal schooling. *Obese: BMI > 30 kg/m^2 ; ** Overweight BMI ≥ 25 < 30; [$] Drinkers divided into quartiles P25 (≤ 5.64 g alcohol/day); P50 (> 5.64 < 12.24 g alcohol/day); P75 (≥ 12.25 g alcohol/day). [†] Never drinks or drinks only on special occasions; [‡] Sedentary: less than 1 h/week spent on leisure-time physical exercise

Mean values were significantly different from [a] 25–39 years, [b] university, [c] secondary, [d] obese, [e] smokers, [f] former smokers, [g] drinkers P25, [h] drinkers P50, [i] drinkers P75, [j] sedentary, [k] active 1–3 h/day, respectively ($P < 0.05$)

inadequate intake (<2/3 R DA) of Ca and Mg in Andalusia (southern Spain) was higher than in Catalonia (north-eastern Spain) [18] and the Canary Islands [3].

The high intakes of P were responsible for the low Ca/P ratio (0.7:1), although this figure was within the range of values that do not affect Ca absorption or balance [7]. Although the differences between men and women in Ca and P intakes were significant, plasma concentration was significantly lower in women only for Ca (Table 2). In our population we found that women consumed smaller amounts of vitamin D ($P < 0.001$). This would account for the lower mean plasma levels of Ca in women.

The high percentages of the population with deficient Ca intake are explainable by the recent increase in the RDA for this mineral in Spain [6], since mean values for Ca intake in our population were similar to those found in other western countries (Table 5). This finding, together with the higher exposure to sunlight in the population we studied, might help to account for the low rate of hypocalcemia despite the high percentage of the population with deficient Ca intake [19]. The Mg intake in our population was similar to the mean values found for other western countries, where intakes 20–30% below the RDA have been found [20].

The lack of correlation between mineral intakes and their plasma levels (see "Results") might reflect the marked homeostatic control of elements such as Ca and Mg, and variability in the data obtained with the method we used to calculate food intakes. Despite its limitations, this methodology is widely used in similar studies.

The steady decrease in plasma Ca concentration with age, especially in women, probably reflects the gradual decrease in Ca absorption with age, especially in post-menopausal women once oestrogen production has declined [7]. An inverse correlation between age and plasma Ca levels was seen only in women ($r = -0.35$, $P < 0.01$), and the logistic regression analysis (OR = 12.06) confirmed this finding.

Educational level is known to influence nutrient intake. The lower intakes of Ca and P among persons

Table 4 Odds ratios and 95% confidence intervals for Ca, P and Mg intakes according energy intake, demographic characteristics, education level, obesity, smoking, drinking and physical exercise

	Ca	P	Mg
Energy intake			
RDA ≥ 100%	0.19 (0.16–0.23)*	0.02 (0.003–0.15)*	0.10 (0.08–0.12)*
Gender			
Female	1.40 (1.16–1.68)*	1.52 (0.99–2.31)	2.18 (1.76–2.70)*
Age (years)			
40–49	1.06 (0.86–1.32)	1.19 (0.75–1.90)	1.09 (0.85–1.39)
50–60	0.83 (0.67–1.04)	0.93 (0.56–1.53)	1.13 (0.88–1.46)
Educational level			
Secondary	1.32 (0.89–1.44)	1.96 (0.99–3.83)	1.05 (0.79–1.40)
Primary/no schooling	1.78 (1.42–2.23)*	2.09 (1.12–3.90)*	0.99 (0.76–1.29)
Obesity			
Overweight BMI ≥ 25 < 30 kg/m^2	1.06 (0.88–1.28)	1.21 (0.73–1.72)	1.15 (0.93–1.43)
Obese BMI ≥ 30 kg/m^2	1.08 (0.84–1.38)	0.83 (0.48–1.45)	1.04 (0.78–1.37)
Smoking habit			
Former smokers	1.12 (0.92–1.36)	1.39 (0.88–2.20)	1.01 (0.81–1.26)
Current smokers	0.89 (0.70–1.12)	1.62 (0.96–2.73)	0.95 (0.73–1.25)
Alcohol consumption			
Drinkers P25 (≤ 5.64 g /day)	0.82 (0.64–1.07)	0.93 (0.51–1.68)	1.12 (0.83–1.52)
Drinkers P50 (> 5.64 < 12.24 g/day	0.96 (0.74–1.25)	0.96 (0.53–1.74)	0.93 (0.69–1.26)
Drinkers P75 (≥ 12.25 g/day)	1.11 (0.90–1.39)	0.81 (0.47–1.40)	0.79 (0.62–0.99)*
Physical exercise			
Active 1–3 h/week	1.03 (0.82–1.28)	0.61 (0.34–1.10)	0.85 (0.66–1.09)
Active > 3 h/week	0.81 (0.64–1.02)	0.81 (0.45–1.47)	0.73 (0.56–0.96)*

* $P < 0.05$
** Odds ratios and 95% CI are adjusted for all variables in the table
Reference categories: Energy intake < 100; Male; 25–39 years old; University level; BMI < 30 kg/m^2; Non-smokers; never drinks or drinks only on special occasions; Sedentary: less than 1 h/week spent on leisure-time physical exercise = 1
Dependent variables (Ca, P and Mg intake) were categorized in two levels: <RDA = 1, ≥RDA = 0

Table 5 Mean intakes of Ca, P and Mg (mmol/day) in different countries or regions

Country	Ca	P	Mg
Ireland [9]	18.55	37.61	10.71
Austria [10]	14.03	–	–
Austria [11]	19.18		
Belgian [12]	20.1		14.95
France [13]	16.05	–	8.06
UK [14]	19.38	–	–
UK [15]	22.20	41.99	11.21
USA [16]	19.18	38.86	11.87
USA [17]	–	–	13.69
Spain			
Overall [1]	21.22	–	12.98
Andalusia (Table 2)	20.80	38.39	11.72
Catalonia [18]	19.05	42.28	12.26
Canary Islands [3]	23.85	45.06	11.84

with the lowest levels of education (Table 3) may reflect the lower mean consumption of dairy products in this group ($P < 0.05$). Logistic regression analysis confirmed this result (Table 4).

A diet deficient in micronutrients is considered a risk factor for obesity [21]. It was recently suggested that high-Ca diets attenuate lipid deposition in adipocytes and thus forestall weight gain, which may suggest a role for dairy products in the prevention and treatment of obesity [22]. A negative association was recently reported between vitamin D intake and BMI [23]. In the population we studied, we found that obese persons (18.85%) consumed smaller amounts of Ca (Table 3) and vitamin D than non-obese persons ($P < 0.05$).

The lower intakes of Ca and vitamin D in obese persons would account for the lower mean plasma levels of Ca in this population subgroup (Table 3). The inverse linear correlation between BMI and calcemia (see "Results") supports this hypothesis.

In persons who drank, the greater crude intakes (Table 3) for all three elements paralleled the greater energy intake in this population subgroup [4]. The linear correlations between crude energy intake and crude intakes of each of the three ions (see "Results") support this explanation.

The higher intakes of Ca, P and Mg (Table 3) in the active population mainly reflected the higher consumption of dairy products in this groups ($P < 0.001$). A similar situation has been observed in adult Germans [24].

Although the interpretation of data from survey studies can be complex, our results provide an initial estimate of the nutritional status for Ca, P and Mg in the adult population of southern Spain. Although gender, educational level, obesity, smoking habits, alcohol consumption and physical exercise are known to affect the intake of these nutrients, logistic regression analysis of the data for our study population showed that the risk of hypocalcemia (14.81% for the whole sample) was associated only with female gender and older age. The risk of hypomagnesemia (8.82% of the population we studied) and hypophosphatemia (2.17%) was not associated with any of the other factors we investigated.

The percentages of persons found to be at risk for inadequate Ca and Mg intake were worrisome. Low intakes of these minerals are related with the prevalence of certain diseases such as osteoporosis, bone fractures [25] and, to a lesser degree, cardiovascular disease [19, 20, 26]. We therefore feel that the intake of these minerals should be increased in both genders, and that recommendations to increase physical activity are also in order. These measures should be aimed particularly at women, in whom endocrine changes associated with menopause and decreased physical activity can increase the risk of bone disorders.

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