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Nutrients intake, and serum calcium and phosphorus levels: An evidence-based study

Zahra Jafari Giv[1] | Amir Avan[2,3] | Farshid Hamidi[4] | Maryam Tayefi[2] | Sayyed Saeid Khayyatzadeh[3] | Ali Javandoost[3,5] | Mohsen Nematy[3] | Gordon A. Ferns[6] | Majid Ghayour Mobarhan[3,7]

[1]Department of Veterinary Medicine, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, Mashhad, Iran

[2]Department of Modern Sciences and Technologies, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

[3]Metabolic syndrome Research center, Mashhad University of Medical Sciences, Mashhad, Iran

[4]Section of Physiology, Department of Basic Sciences, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, Mashhad, Iran

[5]Department of Biochemistry, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

[6]Division of Medical Education, Brighton & Sussex Medical School, Brighton, Sussex, UK

[7]Cardiovascular Research Center, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

Correspondence
Majid Ghayour-Mobarhan, Biochemistry of Nutrition Research Center, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.
Email: ghayourm@mums.ac.ir
and
Farshid Hamidi, Section of Physiology, Department of Basic Sciences, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, Mashhad, Iran.
Email: Farshidhamidi@um.ac.ir

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Introduction: Dietary calcium and phosphorus appear to be important determinants of dyslipidemia and hypertension. We have investigated (1) the prevalence of hypocalcemia and hypophosphatemia in an Iranian population, and (2) the association between nutrient's intake and serum levels of calcium and phosphorus.

Methods: A total of 908 individuals were enrolled using a stratified-cluster sampling method from the Mashhad stroke and heart atherosclerosis disorder (MASHHAD) study. Dietplan6 software was used for 24-hour recalls and food frequency questionnaire to investigate macro- and micronutrient intakes of our population, followed by univariate analysis for evaluation of the association of dairy consumption with serum calcium and phosphorus.

Results: We observed that the mean dietary Ca intake was 862.4 mg/d (672.7-1052) for men and 864.2 mg/d (604.5-1123) for women in our population, which is lower than the dietary reference intake for Ca. Moreover, a significant relationship was detected between serum calcium level and dietary intakes of saturated fatty acids, copper, iodine, sucrose, potato, and juices. Of note, we observed a negative association between copper intake, and serum Ca ($P<.01$). Also, a significant association was found between serum phosphorus levels and dietary intakes of chicken meat and fresh fruits. Interestingly, we observed an inverse relationship between tea and Ca/P ratio (eg, $-r=.098$; $P=.02$).

Conclusion: We found that the dietary intake of Ca was not sufficient in our population and was associated with the dietary intake of some macro- and micronutrient, supporting further investigation on clinical impact of this condition on calcium/phosphorus deficiency related diseases.

KEYWORDS
calcium, dairy consumption, phosphorus, population

1 | INTRODUCTION

Calcium, the most plentiful mineral in the body, is found in some foods and is available as a dietary supplement; calcium must be absorbed from the foods in digestive system. The health of bones relies on a balanced diet and a constant stream of nutrients. Serum calcium is tightly regulated and does not fluctuate with changes in food intake; the body uses bone tissue as a storage source of calcium, to maintain calcium homeostasis in plasma, and extracellular fluids.[1] The important role of calcium intake and its metabolism are related to incidence and pathology of cardiovascular diseases (CAD) and dyslipidemia.[2-4] Several studies have shown that calcium intake is inversely related with hypertension.[5-7] Moreover, it has been shown that a combination of calcium and dietary fat with bile acids could prevent fat absorption[8,9] and reduce cholesterol absorption.[10] Calcium plays different roles in the body such as the body skeleton, increasing the strength of the heart and smooth muscle contraction, maintaining certain nervous and muscular equilibria.[11,12] Phosphorus is another important element in the body and with serum calcium influences bone health. Half of it is in the form of free ions $H_2PO_4^-$ and HPO_4^{2-}; 10% bounded to protein and 40% associated with other components. The free ions have different functional roles, such as: (1) controlling the extremes of acidity or alkalinity and help to maintain a normal pH, (2) temporary storage transport and energy transfer due to fuel metabolism, and (3) activation of many catalytic proteins by phosphorylation. Unlike calcium, phosphorus deficiency is a rare phenomenon, but it must be recognized that the severe deficiencies of this element cause neurological, muscle, blood, and renal disorders.

Many foods contain phosphorus and calcium, but dairy products such as yogurt, milk, and cheeses are the best source, although various studies showed a high prevalence of hypocalcemia and hypophosphatemia in both men and women in Iran as well as other countries.[12-14] On the other hand, dietary intake evaluation have reported that people do not receive adequate amounts of calcium in their usual diet and lower consumption of dairy products than dietary reference intakes.

The effect of orally administered calcium salts on the blood calcium level has been investigated in many studies; however, there is no relationship between nutrition and consumption of a diet rich in calcium and phosphorus, and also the increased levels of serum calcium and phosphorus.

In our previous studies, we explored the correlation of dietary intake and copper/zinc in 445 CAD patients.[15] We showed the important role of the nutrient intake as an independent risk factor for CAD. Similar results were also found in our healthy population.[16] Moreover, we found the effect of high dairy diet on body mass index and body fat in overweight and obese children.[17] Therefore, in the current study, we further investigated the relationship between dietary intakes of macro- and micronutrients and serum levels of calcium and phosphorus.

2 | SUBJECTS AND METHODS

2.1 | Population

A total of 908 subjects were recruited using a stratified-cluster sampling method from the Mashhad stroke and heart atherosclerosis disorder (MASHHAD) study. Exclusion criteria were pregnancy and lactation, established cardiovascular disease or diabetes, consumption of dietary supplements, thyroid disorders, and cancers. The protocol was approved by the Ethics Committee of MUMS, and all the subject gave informed written consent to participate in the study.

2.2 | Assessment of dietary intake

In order to assess nutritional status of the subjects, 24-hour recalls and food frequency questionnaire (FFQ) was used, and trained interviewers were involved during a face-to-face interview. The analyses were performed in Dietplan6 software (Forestfield Software Ltd., Horsham, UK) for evaluation of macro- and micronutrient intakes.

2.3 | Statistical analysis

Statistical analyzes were performed using SPSS V.20 software (SPSS® Inc., Chicago, IL, USA). Nutritional findings from a 24-hour recall questionnaire entered to Dietplan6 and then the information was added to our database. Descriptive statistics, including mean and standard deviation, was used for normal distributions, or median and interquartile range for non-normal distributions. Data were expressed as mean±SD for normally distributed or median (IQR) for non-normally distributed variables. Student *t* test was used for normally distributed variables, while Mann-Whitney *U* test was used for continuous variables. Chi-square test was used for categorical parameters. Logistic regression analysis was used to calculate association of micro/macro nutrients with clinical data. All the data were analyses two-sided and statistical significance was set at $P<.05$.

3 | RESULTS

3.1 | Characteristics of the population

The characteristics of the population with respect to dietary intake are shown in Table 1. We observed that energy intake from diet was significantly ($P<.001$) different between men and women. Serum calcium and phosphorus levels were 9.3±1.0 mg/dL and 4.2±0.8 mg/dL, respectively, which is within the normal range. Serum magnesium was significantly different between genders, and was higher in women than men. Similar results were found for dietary potassium, magnesium, folate, thiamine, lactose, and fiber. Also, dietary niacin was higher in men than women ($P<.05$). Additionally, we found that the consumption of meat, egg, nuts, seeds, and fruit were significantly different between genders ($P<.05$). Conversely, no statistically significant differences were detected for other macro- and micronutrients between gender groups.

TABLE 1 Dietary nutrient and food group intakes

	Total	Male	Female	*P* value
Macronutrients				
Protein (g)	67.27 (57.01-77.53)	70.30 (26.59-84.00)	69.85(57.67-82.02)	.693
Carbohydrate (g)	225.7 (189.88-261.52)	213.3 (176.7-249.8)	224.9 (96.70-353.1)	.904
Fat (g)	74.60 (60.28-88.91)	78.20 (50.96-105.4)	75.87 (61.82-89.91)	.841
Saturated fatty acid (g)	18.99 (14.60-23.38)	19.33 (13.75-24.90)	19.40 (15.73-23.06)	.723
Monounsaturated fatty acid (g)	20.41 (11.21-29.60)	20.86 (16.58-25.14)	20.88 (16.70-25.05)	.784
Polyunsaturated fatty acid (g)	24.54 (15.34-11.73)	25.04 (15.52-34.56)	24.94 (15.33-34.54)	.672
Cholesterol (mg)	201.8 (109.1-294.5)	208.9 (80.60-337.2)	204.1 (37.80-370.4)	.664
Lactose (g)	9.050 (3.530-14.570)	10.75 (4.29-17.21)	10.91 (3.485-18.33)	.091
Sucrose (g)	26.38 (11.37-41.39)	25.58 (10.20-40.95)	25.45 (8.795-42.10)	.436
Fiber (g)	15.51(9.695-21.32)	14.70(7.440-21.96)	17.33(12.35-22.31)	.001
Micronutrients				
Calcium (mg)	864.7 (653.8-1075)	862.4 (672.7-1052)	864.2 (604.5-1123)	.231
Phosphorus (mg)	1282 (1079-1484)	1297 (1110-1483)	1307 (1089-1524)	.128
Iron (mg)	9.635 (6.225-13.04)	9.026 (5.711-12.34)	9.618 (6.593-12.64)	.005
Magnesium (mg)	238.8 (176.9-300.6)	239.1 (177.1-301.1)	250.7 (199.2-302.2)	.001
Zinc (mg)	8.983 (7.248-10.71)	9.052 (6.992-11.11)	9.048 (7.553-10.54)	.164
Sodium (mg)	2571 (1452-3689)	2457 (1075-3838)	3000 (1008-4992)	.001
Potassium (mg)	2962 (2331-3592)	2914 (2175-3653)	3065 (1608-4522)	.005
Copper (μg)	1.710(0.855-2.565)	1.674 (1.459-1.889)	1.785 (1.505-1.032)	.006
Iodine (μg)	122.1 (52.55-191.65)	131.0 (55.55-206.4)	122.1 (48.65-195.5)	.789
Selenium (μg)	31.63 (17.91-45.34)	31.46 (17.43-45.49)	32.42 (17.90-46.93)	.831
Retinol (mg)	170.6 (83.4-257.8)	161.7 (47.4-276.0)	187.0 (109.8-264.1)	.311
Folate (μg)	224.1 (169.4-278.8)	232.3 (178.4-286.2)	227.4 (171.4-283.4)	.010
Vitamin D (μg)	1.638 (1.048-2.228)	1.694 (0.924-2.464)	1.597 (1.137-2.057)	.442
Vitamin E (mg)	18.08 (10.47-25.69)	18.37 (10.09-26.64)	18.34 (11.14-25.53)	.393
Vitamin C (mg)	73.78 (19.13-128.43)	65.49 (7/09-123/8)	79.54 (30.72-128.3)	.009
Food groups				
Dairy Products (g)	321.3 (181.8-460.8)	387.0 (104.3-669.7)	363.00 (217.9-508.1)	.046
Cereals (g)	203.9 (85.35-322.45)	366.8 (205.2-528.3)	344.4 (211.2-477.6)	.128
Meat, egg, bean (g)	98.62 (59.03-138.2)	103.1 (69.73-136.4)	91.72 (62.38-121.0)	.012
Fruits (g)	189.4 (70.20-308.6)	194.3 (78.25-310.3)	162.6 (29.00-296.2)	.010
Vegetables (g)	144.4 (46.95-241.6)	223.9 (101/0-346/8)	204.9 (65.10-344.7)	.441
Oils and fats (g)	16.63 (152.1-175.4)	24.65 (4.735-44.56)	21.75 (4.710-38.79)	.728
Sugars (g)	33.28 (0.945-65.61)	41.80 (4.595-79.00)	30.82 (1.21-62.85)	.787

P value: male vs female; Median (IQ).

3.2 | Association of dietary macronutrients and micronutrients with serum calcium and phosphor

As shown in Table 2, we observed a significant correlation between saturated fat/dietary Cu/dietary iodine/sucrose/potato and juices and the serum levels of calcium (Table 2). In particular, there was a negative correlation between copper intake and serum Ca ($P<.01$), Moreover, a relationship between dietary K, meat, egg, bean, chicken meat and vegetarian food was found. Of note, no association was detected between dietary Ca and P with serum Ca or P (Table 2). Moreover, we did not observe an association between fruits and serum Ca and P levels. Furthermore, we observed a significant association between P level and meat, egg, bean, combined course, and vegetarian food, while this association was seen for saturated fat, Cu, dietary I, potato, sucrose, combined course, and juices with respect to the serum Ca (Table 3).

TABLE 2 Correlation between dietary nutrient and food groups and serum calcium and phosphorus levels

	Serum Ca		Serum P		Ca/P	
	r	*P* value	*r*	*P* value	*r*	*P* value
Macronutrients						
Protein	−.028	.44	.030	.41	−.031	.41
Carbohydrate	−.027	.46	−.010	.79	−.015	.68
Fat	.040	.29	−.006	.87	.032	.39
Saturated fatty acid	.116	.003	.006	.87	.068	.08
Monounsaturated fatty acid	.044	.26	−.019	.63	.054	.17
Polyunsaturated fatty acid	−.030	.44	.017	.66	−.037	.34
Cholesterol	.002	.95	.016	.66	−.014	.71
Fiber	.045	.25	−.004	.91	.020	.62
Lactose	.052	.17	.009	.80	.027	.48
Sucrose	.084	.03	.042	.28	−.029	.45
Micronutrients						
Calcium	.055	.16	.047	.23	−.013	.74
Phosphorus	−.009	.81	−.017	.67	.018	.65
Iron	−.003	.94	.018	.64	−.010	.80
Magnesium	.066	.09	.036	.36	−.017	.66
Zinc	.001	.98	.001	.99	.023	.56
Sodium	.039	.30	.063	.09	−.059	.12
Potassium	.057	.13	.074	.05	−.052	.17
Copper	−.107	.00	−.018	.64	−.055	.15
Iodine	.092	.02	.077	.05	−.016	.69
Selenium	.018	.66	.029	.46	−.009	.82
Retinol	−.023	.54	−.019	.62	−.008	.83
Folate	.054	.25	.019	.69	.011	.81
Vitamin D	−.010	.79	−.006	.86	−.004	.90
Vitamin E	−.034	.57	.015	.81	−.039	.51
Vitamin C	.042	.26	.070	.06	−.020	.60
Food groups						
Low-fat dairy	.008	.84	.074	.08	−.084	.05
High-fat dairy	−.003	.95	−.057	.24	.072	.14
Whole cereals	−.041	.34	−.053	.22	.013	.77
Refined grains	.040	.35	.004	.92	.048	.27
Potato	.107	.01	.079	.06	−.023	.59
Meat	.055	.20	−.008	.85	.038	.37
Processed meat	.044	.30	.008	.85	−.001	.97
Bean	.027	.53	.044	.31	−.030	.48
Fish and shrimp	.059	.22	.082	.09	−.051	.29
Chicken meat	.043	.31	.110	.01	−.084	.05
Visceral meat	.099	.05	.008	.87	.039	.44
Egg	−.023	.59	.028	.52	−.023	.59
Juices	.087	.04	.068	.11	−.023	.59
Fresh fruits	−.024	.58	−.086	.04	.086	.04
Dried fruits	.046	.37	−.046	.37	.071	.16
Vegetables	.036	.40	.011	.79	.028	.52
Mayonnaise	.013	.79	−.020	.70	.075	.14

(Continues)

TABLE 2 (Continued)

	Serum Ca		Serum P		Ca/P	
	r	*P* value	*r*	*P* value	*r*	*P* value
Nuts	.013	.79	−.013	.78	−.004	.93
Honey	.078	.12	.001	.97	.036	.48
Cakes and pastries	.038	.44	−.012	.81	.024	.63
Sugar	.013	.79	.035	.48	−.011	.83
Beverages and soft beer	−.004	.92	−.052	.23	.080	.05
Pizza	−.010	.84	−.028	.58	.022	.66
Snack	.009	.84	.018	.67	−.032	.46
Tea	−.008	.85	.078	.05	−.098	.02
Coffee and espresso	−.016	.71	−.006	.89	−.004	.93
Pickle	.037	.39	.015	.72	−.001	.98

TABLE 3 Association of dietary constituents with serum P and Ca

	B	*P* value
Serum P		
Dietary K	.005	.054
Dietary I	.001	.053
Vit C	.001	.065
Potato	.004	.068
Meat, egg, bean	.001	.009
Chicken meat	.001	.011
Vegetarian food	.003	.002
Serum Ca		
Saturated fat	.015	.003
Dietary Cu	−.074	.006
Dietary I	.001	.021
Sucrose	.003	.030
Potato	.006	.014
Visceral meat	.015	.055
Juices	.003	.045

4 | DISCUSSION

To the best of our knowledge, this is the first study evaluating the impact of macronutrients and micronutrients on serum calcium and phosphate levels in an Iranian population. Our findings demonstrated an association of meat, egg, bean, and vegetarian food with serum phosphate. Additionally, there was an association between serum calcium and dietary saturated fat, copper, dietary I, potato, sucrose, and juices. Moreover, dietary Ca intake in our population was 862.4 mg/d (672.7-1052) for men and 864.2 mg/d (604.5-1123) for women, while the dietary reference intake for Ca in men is 1000 mg/d and 1000-2000 mg/d in women, suggesting that dietary intake of Ca is not adequate in Mashhad population. Also, dietary phosphorus intake of our population was 1282 mg/d (1079-1484), which is higher than dietary reference range of phosphorus for adults (700 mg/d).[18]

There is a growing body of evidence showing the association of Ca and P with dietary intake. Bell and colleagues showed that a diet rich in P, can increase serum P level, while it decreased serum Ca level.[19] Similar results were also found by other studies. Another study by Abbasian et al.,[20] showed that a low Ca intake could reduce serum Ca level in plasma. Avioli et al.,[21] concluded that dietary Ca intake increased the serum Ca level in one hour after consumption, however, this level was decreased after 3 h, indicating the importance of consumption's time from diet. However, several other studies showed no correlation between serum Ca or P level with consumption of these from diet, suggesting the important role of homeostatic control of these elements in the body.[22,23] These observations could be explained at least in part by its time dependent on the measurement of these parameters. Moreover, in the present study, a positive correlation was found between dietary meat, egg, and bean consumption and serum P, which is in agreement with previous studies.[24] In addition, we did not show find any significant relationship between serum Ca and dietary protein and meat intake, which is consistent with several other studies.[25] Increasing data has shown a correlation between sucrose intake and higher concentrations of serum Ca,[26,27] which is consistent with our data. Furthermore, several studies have reported that dietary fat is positively correlated with serum Ca and lower dietary fat intakes.[28] We also observed a similar result for the correlation of fat intake and serum Ca. Moreover, no relationship was found between serum Ca and dietary fiber or vitamin C, which is agreement with the study of Kone et al.[29] Sebastian et al.[30] showed that dietary potassium can influence the level of serum P. We also found a positive correlation between dietary potassium and serum P. Calcitonin and parathyroid hormone have the important role in regulating Ca metabolism and maintain serum Ca level in normal ranges. On the other hand, homeostatic system in the body regulates serum P level in order to maintain Ca/P ratio in a normal amount, so the relation between dietary iodine intake and serum Ca and serum P can be logical.

In conclusion, we have demonstrated an association between macro- and micronutrients on serum calcium and phosphate levels. Finally, we observed that dietary Ca intake in our population was

not adequate; however, their levels in serum was in a normal range. Therefore, further studies are needed to explore the clinical impact of dietary intake of Ca and P in our population with respect to osteoporosis.

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