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Are There Any Correlations between Vitamin D, Calcium, and Magnesium Intake and Coronary and Obesity Indices?

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ABSTRACT

Objective: The association between nutrient intake and obesity and coronary problems has received great attention. So, this study aimed to examine the association between vitamin D, calcium, and magnesium intake and obesity and coronary indices.

Methods: A total of 491 male and female university employees (18–64 years) were randomly included in a cross-sectional study. Blood samples were drawn, and the lipid profile was analyzed. Different anthropometrics were measured. Obesity and coronary indices were calculated based on standard formulas. A 24-h recall was used to measure the average dietary intake of vitamin D, calcium, and magnesium.

Results: For the total sample, vitamin D had a significantly weak correlation with the abdominal volume index (AVI) and weight-adjusted waist index (WWI). However, calcium intake had a significant moderate correlation with the AVI and a weak correlation with the conicity index (CI), body roundness index (BRI), body adiposity index (BAI), WWI, lipid accumulation product (LAP), and atherogenic index of plasma (AIP). In males, there was a significant weak correlation between calcium and magnesium intake and the CI, BAI, AVI, WWI, and BRI. Additionally, magnesium intake had a weak correlation with the LAP. In female participants, calcium and magnesium intake had a weak correlation with CI, BAI, AIP, and WWI. Additionally, calcium intake showed a moderate correlation with the AVI and BRI and a weak correlation with the LAP.

Conclusion: Magnesium intake had the greatest impact on coronary indices. Calcium intake had the greatest impact on obesity indices. Vitamin D intake had minimal effects on obesity and coronary indices.

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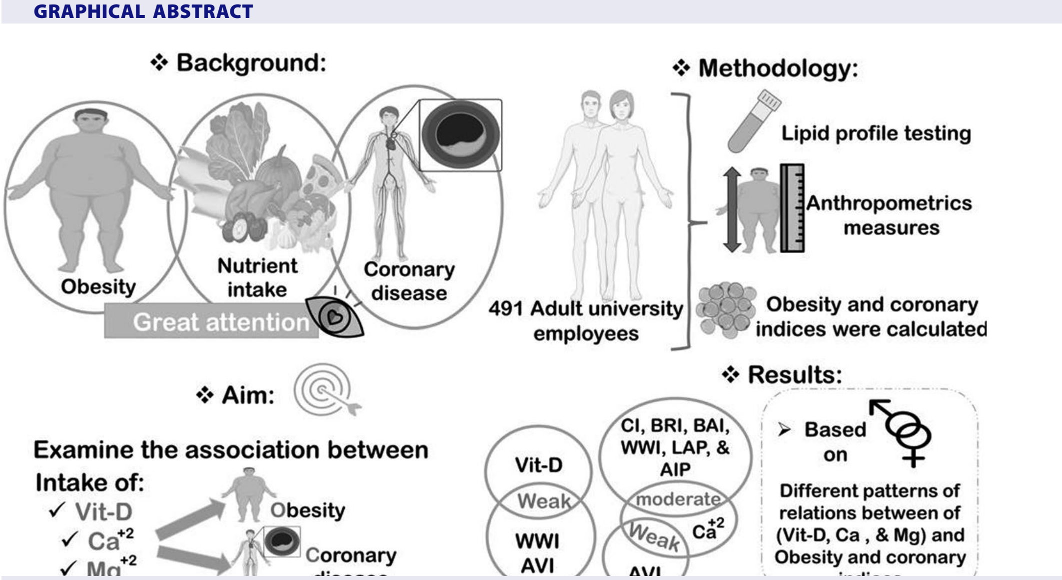
Vitamin D; calcium; magnesium; obesity indices; coronary indices

GRAPHICAL ABSTRACT



The association between nutrient intake and obesity and coronary problems has received great attention. Vitamin D, calcium, and magnesium are micronutrients that may affect body fat and body shape. Magnesium intake had the highest impact on coronary indices. While calcium intake had the highest impact on obesity indices. Vitamin D intake had minimal effect on obesity and coronary indices.

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Introduction

Obesity is characterized as an abnormal or excessive buildup of body fat as a result of an imbalance between energy intake and expenditure (1). It has been shown that the obesity epidemic is influenced by a combination of genetic and environmental variables, including dietary factors (2). Obesity-modifiable dietary risks factors such as calcium intake, dairy intake, vitamin D intake, and antioxidant nutrients such as magnesium, vitamin C, and vitamin E have attracted great attention (3–5).

Several studies have shown an inverse association between dairy consumption, dietary calcium intake, and obesity risk (4, 6, 7). Calcium and dairy consumption were negatively correlated with central obesity based on the waist-to-height ratio (WHtR) (8). Moreover, an adverse relationship between low-dairy low-calcium dietary patterns and body mass index (BMI) (9), waist circumference (WC), and WHtR has been confirmed (10). Low consumption of dairy products and calcium was not only associated with obesity but was associated with an increased risk of hypertension, heart disease (11), metabolic syndrome (12), dyslipidemia, low bone mineral density, and osteoporosis (13).

Low serum vitamin D levels as a metabolic abnormality are also connected to obesity (14). Currently, vitamin D deficiency and obesity are both major global epidemiological issues; moreover, obese people frequently have vitamin D deficiency (15, 16). In Jordan, the overall prevalence of vitamin D deficiency was 89.7%, with a higher prevalence in males (92.4%) than in females (88.6%) (17), while the age-standardized prevalence of obesity was 60.4% and 75.6% among males and females, respectively (18). Some authors have linked vitamin D deficiency to various pathologies, including its involvement in the secretion of hormones such as insulin, the regulation of body weight, and a role in the immune system, in addition to its role in the maintenance of bone tissue and the maintenance of calcium and phosphorus homeostasis (19). Additionally, it is involved in cardiovascular pathophysiology (20, 21). A strong correlation between serum vitamin D and BMI has been found (3). Additionally, vitamin D deficiency was significantly correlated with hyperglycemia, HbA1c, total cholesterol (TC), low-density lipoprotein cholesterol (LDL-c), triglycerides (TGs), BMI, WC, body roundness index (BRI), and body shape index (ABSI) (3, 16, 22, 23). While many anthropometric indices have been used to predict vitamin D deficiency, WC, BMI, WHtR, BRI, and visceral adiposity index (VAI) are most useful for prediction in males (21).

Magnesium is regarded as an antioxidant nutrient and is important in energy metabolism since it is a cofactor of various antioxidant enzymes, including superoxide dismutase and intracellular adenosine triphosphate (ATP) (24). Nevertheless, consuming more magnesium is linked to decreased BMI, WC, and serum glucose levels (5), and uncertainty exists regarding the mechanism behind this connection. Magnesium deficiency has been associated with more severe or fatal coronary heart disease through atherosclerotic progression (25). The dietary intake of magnesium was noted to be inversely associated with incident coronary heart disease risk and total cardiovascular disease (26, 27). Furthermore, lower magnesium concentrations are associated with changes in lipid profiles and cardiovascular risk factors such as obesity, hypertension, and hypercholesterolemia (28).

In addition, there are no adequate studies linking vitamin D, calcium, and magnesium intake to coronary indices such as the cardiometabolic index (CMI), lipid accumulation product (LAP), and atherogenic index of plasma (AIP). Moreover, there is little evidence connecting reduced calcium and magnesium intake with novel anthropometric obesity indices such as the BRI, weight-adjusted waist index (WWI), abdominal volume index (AVI), conicity index (CI), and body adiposity index (BAI). Therefore, the present study aims to investigate the association between vitamin D, calcium, and magnesium intake and obesity and coronary indices.

Material and methodology

A total of 491 male and female university employees were randomly included in a cross-sectional study. They were aged 18–64 years old, and pregnant or lactating women as well as subjects with incomplete anthropometric measurements and/or biochemical data were excluded. Written informed consent was obtained from each participant. The Hashemite University Ethics Committee authorized the protocols, tools, and procedures for obtaining informed consent for this project. All procedures were carried out by the Helsinki Declaration and the Institutional Board Review (IRB) No. 7/13/2020/2021.

Sociodemographic data (age, sex, marital status, and education status), lifestyle (such as smoking status and physical activity), and medical history data were collected through a questionnaire in a face-to-face interview by professional staff. A biochemical autoanalyzer was used to evaluate TG, TC, LDL-c, and high-density lipoprotein cholesterol (HDL-c) levels in blood samples collected from each participant after 8–12 h of fasting.

Body weight, height, WC, and hip circumference (HC) were measured. Moreover, obesity and coronary indices were calculated based on the standard formulas for the CI (29), BAI (30), AVI (29), BRI (31), WWI (32), AIP, LAP, and CMI (33). Two nonconsecutive 24-h dietary recalls were used to measure dietary intake (including weekdays and weekends) and analyzed using ESHA's Food Processor®, Nutrition Analysis Software (version 11:0; ESHA Research). The average intake of vitamin D, calcium, and magnesium was calculated. Based on the intakes of vitamin D, calcium, and magnesium, subjects were further divided into tertiles (T1: the lowest intake, and T3: the highest intake) using percentiles (33% and 66%). Statistical Package for the Social Sciences (SPSS) version 25 (IBM, Chicago, IL, USA) was used for analysis. The continuous variables are presented as the means and standard deviations and were analyzed using independent t-tests. Frequencies and percentages are used to present the categorical variables, which were calculated using chi-square tests. Pearson correlation was performed to determine the correlation between obesity indices and macronutrient intake. The percent change in the indices explained by nutrient intake is presented by r-square calculated using linear regression analysis. The statistical significance was set at $p < 0.05$.

Results

A total of 491 participants were included in this study. Based on age, there were 198 participants aged between 20–34 y, 169 aged between 35–44 y, and 124 aged between 45–65 y. The mean weight was 74.04 ± 15.72, 79.48 ± 15.32, and 84.40 ± 15.51 kg for the participants aged 20–34 y, 35–44 y, and 45–65 y, respectively. The WC and HC were 89.69 ± 13.15 cm and 102.98 ± 10.09 cm for participants aged 20–34 y, respectively; 97.18 ± 12.65 cm and 106.26 ± 9.62 cm for participants aged 35–44 y, respectively; and 105.18 ± 15.59 cm and 108.22 ± 12.02 cm for participants aged 45–65 y, respectively. The mean BMI values were 25.68 ± 4.96 kg/m^2, 28.00 ± 4.58 kg/m^2, and 30.21 ± 5.94 kg/m^2 for participants aged 20–34 y, 35–44 y, and 45–65 y, respectively.

Male participants represented 66.2% of the 20–34-y age group, 68.0% of the 35–44-y age group and 79.0% of the 45–65-y age group. Additionally, 51.5%, 42.6%, and 49.2% of participants aged 20–34 years, 35–44 years, and 45–65 years had a school education level, respectively, whereas 48.5%, 57.4%, and 50.8% of them had a university education level, respectively. A total of 55.6% of participants aged 20–34 y were single, and 43.9% of them were married. According to marital status, 87.6% and 95.2% of the single participants were aged 35–44 years and 45–65 years, respectively. More than half of the participants in all age categories had an income between 200–499 JDs. A total of 40.2% and 32.0% of participants aged 35–44 y and 45–65 y were overweight, and 42.7% and 41.1% of them were obese, respectively. Participants aged 20–34 y were either normal or overweight (49.5% and 30.3%, respectively). Furthermore, a larger proportion of the participants of all ages were physically active (65.6% of 20–34 y, 53.3% of 35–44 y and 50.8% 45–65 y) and smokers (41.4% of 20–34 y, 36.1% of 35–44 y and 46.0% of 45–65 y). Almost all the participants of different ages were disease free.

In most cases, increasing vitamin D intake had little to no effect on the scores of various obesity and coronary indices. Notably, all the index scores—aside from the BAI—rose with higher calcium and magnesium intakes (Table 1).

Table 2 illustrates the correlation between vitamin D, calcium, and magnesium intake and obesity and coronary indices. For the total sample, there was a significant weak correlation between the AVI and vitamin D ($r = 0.114$, $p = 0.011$) and a significant weak correlation between all the studied indices and magnesium intake, with values ranging from $r = 0.123$ ($p = 0.006$) for WWI to $r = 0.238$ ($p < 0.001$) for the AVI. While calcium intake had a significant moderate correlation with the AVI ($r = 0.338$, $p < 0.001$), it had a significant weak correlation with the CI ($r = 0.250$, $p < 0.001$), BAI ($r = 0.133$, $p = 0.003$), BRI ($r = 0.294$, $p < 0.001$), WWI ($r = 0.215$, $p < 0.001$), LAP ($r = 0.093$, $p = 0.040$), and AIP ($r = 0.160$, $p < 0.001$). Male participants exhibited no correlation between vitamin D, obesity, and coronary indices. For calcium and magnesium intake, there was a significant weak correlation with the CI ($r = 0.153$, $p = 0.004$, and $r = 0.107$, $p = 0.047$, respectively), BAI ($r = 0.287$, $p < 0.001$ and $r = 0.210$, $p < 0.001$, respectively), AVI ($r = 0.276$, $p < 0.001$

Table 1. The mean obesity and coronary indices score among the vitamin D, calcium, and magnesium tertials.

Nutrient	Mean ± SEM			
	T1 ($n = 165$)	T2 ($n = 165$)	T3 ($n = 161$)	p-value*
Vitamin D				
Conicity index (CI)	1.29 ± 0.01	1.30 ± 0.01	1.30 ± 0.01	0.578
Body adiposity index (BAI)	−17.50 ± 0.01	−17.50 ± 0.02	−17.50 ± 0.03	0.921
Abdominal volume index (AVI)	18.19 ± 0.50	19.35 ± 0.42	19.76 ± 0.47	**0.047**
Body roundness index (BRI)	1.69 ± 0.08	1.86 ± 0.08	1.87 ± 0.08	0.184
Weight-adjusted-waist index (WWI)	10.85 ± 0.08	10.90 ± 0.07	10.88 ± 0.07	0.862
Cardiometabolic index (CMI)	2.34 ± 0.24	2.91 ± 0.30	2.43 ± 0.16	0.208
Lipid accumulation product (LAP)	53.75 ± 3.95	68.81 ± 8.57	57.33 ± 3.52	0.162
Atherogenic index of plasma (AIP)	0.46 ± 0.03	0.52 ± 0.03	0.50 ± 0.03	0.251
Calcium				
Conicity index (CI)	1.26 ± 0.01	1.29 ± 0.01	1.33 ± 0.01	**<0.001**
Body adiposity index (BAI)	−17.51 ± 0.01	−17.51 ± 0.02	−17.49 ± 0.03	0.107
Abdominal volume index (AVI)	17.01 ± 0.40	18.68 ± 0.47	21.61 ± 0.45	**<0.001**
Body roundness index (BRI)	1.52 ± 0.07	1.75 ± 0.08	2.16 ± 0.08	**<0.001**
Weight-adjusted-waist index (WWI)	10.64 ± 0.07	10.87 ± 0.08	11.12 ± 0.07	**<0.001**
Cardiometabolic index (CMI)	2.00 ± 0.25	2.89 ± 0.29	2.79 ± 0.17	**0.018**
Lipid accumulation product (LAP)	49.93 ± 8.21	60.93 ± 4.35	69.13 ± 3.93	0.067
Atherogenic index of plasma (AIP)	0.39 ± 0.02	0.53 ± 0.03	0.56 ± 0.02	**<0.001**
Magnesium				
Conicity index (CI)	1.27 ± 0.01	1.29 ± 0.01	1.32 ± 0.01	**0.001**
Body adiposity index (BAI)	−17.51 ± 0.01	−17.50 ± 0.01	−17.49 ± 0.01	**0.039**
Abdominal volume index (AVI)	17.44 ± 0.38	18.65 ± 0.43	21.21 ± 0.53	**<0.001**
Body roundness index (BRI)	1.58 ± 0.07	1.75 ± 0.07	2.09 ± 0.09	**<0.001**
Weight-adjusted-waist index (WWI)	10.75 ± 0.07	10.85 ± 0.07	11.03 ± 0.08	**0.022**
Cardiometabolic index (CMI)	2.49 ± 0.21	1.96 ± 0.11	3.24 ± 0.34	**0.001**
Lipid accumulation product (LAP)	51.54 ± 3.81	48.70 ± 2.83	79.83 ± 8.81	**<0.001**
Atherogenic index of plasma (AIP)	0.47 ± 0.03	0.43 ± 0.02	0.57 ± 0.03	**<0.001**

*p value < 0.05 considered statistically significant (2-tailed).

Table 2. The correlation between vitamin D, calcium, and magnesium intake with obesity and coronary indices.

		CI	BAI	AVI	BRI	WWI	CMI	LAP	AIP
Total									
Vitamin D (µg)	Pearson r	0.044	0.048	**0.114***	0.085	0.019	−0.027	0.001	0.009
	p-value	0.327	0.292	**0.011**	0.061	0.676	0.546	0.978	0.846
Calcium (mg)	Pearson r	**0.250****	**0.133****	**0.338****	**0.294****	**0.215****	0.059	**0.093***	**0.160****
	p-value	**<0.001**	**0.003**	**<0.001**	**<0.001**	**<0.001**	0.194	**0.040**	**<0.001**
Magnesium (mg)	Pearson r	**0.152****	**0.150****	**0.238****	**0.215****	**0.134****	**0.123****	**0.151****	**0.141****
	p-value	**0.001**	**0.001**	**<0.001**	**<0.001**	**0.003**	**0.006**	**0.001**	**0.002**
Male									
Vitamin D (µg)	Pearson r	−0.003	0.093	0.072	0.051	−0.016	−0.022	−0.003	0.021
	p-value	0.954	0.084	0.181	0.344	0.765	0.688	0.955	0.698
Calcium (mg)	Pearson r	**0.153****	**0.287****	**0.276****	**0.273****	**0.156****	−0.001	0.032	0.078
	p-value	**0.004**	**<0.001**	**<0.001**	**<0.001**	**0.004**	0.981	0.554	0.147
Magnesium (mg)	Pearson r	**0.107***	**0.210****	**0.224****	**0.197****	0.093	0.102	**0.146****	0.098
	p-value	**0.047**	**<0.001**	**<0.001**	**<0.001**	0.086	0.059	**0.007**	0.070
Female									
Vitamin D (µg)	Pearson r	0.104	0.060	**0.190***	0.160	0.080	−0.088	−0.035	−0.105
	p-value	0.209	0.469	**0.021**	0.053	0.338	0.290	0.671	0.208
Calcium (mg)	Pearson r	**0.220****	**0.232****	**0.324****	**0.335****	**0.226****	0.105	**0.186***	0.143
	p-value	**0.007**	**0.005**	**<0.001**	**<0.001**	**0.006**	0.206	**0.024**	0.084
Magnesium (mg)	Pearson r	**0.196***	**0.175***	**0.234****	**0.233****	**0.185***	0.144	0.161	**0.182***
	p-value	**0.017**	**0.034**	**0.004**	**0.005**	**0.025**	0.083	0.051	**0.028**

Abbreviations: CI: Conicity Index; BAI: Body adiposity index; AVI: Abdominal volume index; BRI: Body Roundness Index; WWI: Weight-adjusted-waist index; CMI: Cardiometabolic index; LAP: Lipid accumulation product; AIP: Atherogenic index of plasma.
**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

and $r = 0.224$, $p < 0.001$, respectively), and BRI ($r = 0.273$, $p < 0.001$ and $r = 0.197$, $p < 0.001$, respectively). In addition, calcium intake had a significantly weak correlation with WWI ($r = 0.156$, $p = 0.004$), and magnesium intake had a significantly weak correlation with the LAP ($r = 0.146$, $p = 0.007$). In female participants, vitamin D intake had a significantly weak correlation with the AVI only ($r = 0.190$, $p = 0.021$). Calcium and magnesium intake had a significant weak correlation with the CI ($r = 0.220$, $p = 0.007$ and $r = 0.196$, $p = 0.017$, respectively), BAI ($r = 0.232$, $p = 0.005$ and $r = 0.175$, $p = 0.034$, respectively) and WWI ($r = 0.226$, $p = 0.006$ and $r = 0.185$, $p = 0.025$, respectively). Additionally, calcium intake showed a significant moderate correlation with the AVI and BRI ($r = 0.324$, $p < 0.001$ and $r = 0.335$, $p < 0.001$, respectively) and a significant weak correlation with the LAP ($r = 0.186$, $p = 0.024$). Magnesium intake also had a significantly weak correlation with the AIP ($r = 0.182$, $p = 0.028$).

The changes in obesity and coronary indices based on vitamin D, calcium, and magnesium intake using the linear regression model are shown in Table 3. Among vitamin D, calcium, and magnesium intakes, the highest percentage of change was noted for calcium with respect to most of the obesity indices and magnesium for most of the coronary indices. Vitamin D intake resulted in minimal changes in the scores of the different indices, with percent changes ranging from <0.01% to 1.3%. The calcium intake was found to describe 6.3% of the changes presented in the CI, 1.8% in the BAI, 11.4% in the AVI, 8.7% in the BRI, 4.6% in the WWI, and 2.5% in the AIP. The percentage of changes in indices explained by the magnesium intake ranged from 1.5% for the CMI to 5.6% for the AVI. For the BAI, CMI, and LAP, magnesium intake explained the highest percentage of the changes seen in the indices among the three nutrients.

Discussion

The present study aimed to assess the association between vitamin D, calcium, and magnesium intake and obesity and coronary indices. To our knowledge, the selected indices for the present study have not been studied altogether before. We found that although increasing vitamin D intake had little to no effect on the scores of all the studied obesity and coronary indices, there was a significant weak correlation with the AVI for the total sample ($r = 0.114$, $p = 0.011$). Additionally, this was reflected in female participants only, as vitamin D intake had a significantly weak correlation with the AVI score ($r = 0.190$, $p = 0.021$). Vitamin D intake resulted in minimal changes in the scores of the different indices, with percent changes ranging from <0.01% to 1.3%. This may differ slightly from earlier research findings since previous studies looked at serum vitamin D levels, vitamin D supplements, and traditional indices rather than vitamin D dietary intake. However, we hypothesized that vitamin D intake may affect indices similarly to vitamin D tested in serum or as a supplement. In São Paulo, Brazil, adults and older adults with altered levels of vitamin D presented significantly higher values of glycemia, HbA1c, TC, LDL-c, TG, BMI, and WC. Additionally, vitamin D correlated negatively with atherogenic indices, BMI, and blood pressure (22). In a meta-analysis of the effect of vitamin D supplementation, Duan and colleagues found that vitamin D supplementation had no significant effect on the BMI, WC, or WHR of healthy adults (BMI, WC, and WHR were used to calculate most of the obesity indices as mentioned in the present methodology) (1). In addition, in a cross-sectional study on Iranian adults, Mansouri et al. (34) found an inverse association between serum vitamin D and abdominal obesity (presented by WC). In addition, a significant positive association was found between vitamin D deficiency and obesity; participants with vitamin D deficiency had an

Table 3. The changes in obesity and coronary indices based on vitamin D, calcium, and magnesium intake using the linear regression model.

Model	R	R square change	% of change	*The p*-value for change*
Conicity index (CI)				
Vitamin D	0.044	0.002	0.2%	0.327
Calcium	0.250	0.063	6.3%	**<0.001**
Magnesium	0.152	0.023	2.3%	**0.001**
Body adiposity index (BAI)				
Vitamin D	0.048	0.002	0.2%	0.292
Calcium	0.133	0.018	1.8%	**0.003**
Magnesium	0.150	0.023	2.3%	**0.001**
Abdominal volume index (AVI)				
Vitamin D	0.114	0.013	1.3%	**0.011**
Calcium	0.338	0.114	11.4%	**<0.001**
Magnesium	0.238	0.056	5.6%	**<0.001**
Body roundness index (BRI)				
Vitamin D	0.085	0.007	0.7%	0.061
Calcium	0.294	0.087	8.7%	**<0.001**
Magnesium	0.215	0.046	4.6%	**<0.001**
Weight-adjusted-waist index (WWI)				
Vitamin D	0.019	<0.001	<0.01%	0.676
Calcium	0.215	0.046	4.6%	**<0.001**
Magnesium	0.134	0.018	1.8%	**0.003**
Cardiometabolic index (CMI)				
Vitamin D	0.027	0.001	0.1%	0.546
Calcium	0.059	0.003	0.3%	0.194
Magnesium	0.123	0.015	1.5%	**0.006**
Lipid accumulation product (LAP)				
Vitamin D	0.001	<0.001	<0.01%	0.978
Calcium	0.093	0.009	0.9%	**0.040**
Magnesium	0.151	0.023	2.3%	**0.001**
Atherogenic index of plasma (AIP)				
Vitamin D	0.009	<0.001	<0.01%	0.846
Calcium	0.160	0.025	2.5%	**<0.001**
Magnesium	0.141	0.020	2.0%	**0.002**

*p value < 0.05 considered statistically significant (2-tailed).

approximately 2 times greater risk of having either general or abdominal obesity (general obesity: OR = 2.16 and abdominal obesity: OR = 2.04) than those with normal levels of vitamin D. Khosravi and colleagues (35) reported that WC and BMI were decreased significantly after six weeks of vitamin D supplementation, while the WHR did not change. In addition, to assess the associations of serum vitamin D status with three obesity-related indices among Chinese adults, Ren and colleagues observed a significant increase in vitamin D deficiency prevalence for higher ABSI, BRI, and higher BMI in men, and a positive association between obesity and lower vitamin D serum concentration was found among Chinese adults (3). In a cohort study of Spanish individuals aged 35–75 years aiming to predict which anthropometric parameter was most strongly associated with vitamin D deficiency, Patino-Alonso and colleagues (21) found that the capacity of anthropometric parameters to predict vitamin D deficiency differed based on sex; thus, WC, BMI, WHtR, and BRI were most useful for prediction in males but not in females (21). Although vitamin D correlates negatively with atherogenic indices (22) and is involved in cardiovascular pathophysiology (20, 22), there are not enough studies to confirm its correlation with coronary indices.

The present study indicated that all the index scores—aside from the BAI—rose with a higher magnesium intake, with a significantly weak correlation between obesity indices and magnesium intake. In Mexican adults, Castellanos-Gutiérrez and colleagues confirmed that higher dietary magnesium intake was correlated with lower markers of adiposity; an increase in 10 mg per 1000 kcal/day of magnesium was associated with an average decrease in BMI of 0.72% (95% CI: −1.36, −0.08) and 0.49 cm (95% CI: −0.92, −0.07) of WC (5). Other studies have also noted an inverse relationship between magnesium consumption and indicators of obesity, which is consistent with our findings. An adverse relationship between magnesium consumption and WC was identified in prospective research that followed 4637 young American adults (36). Additionally, an inverse relationship between dietary magnesium intake and BMI was discovered in a cross-sectional study comprising 11,686 American women (37). However, research linking magnesium consumption to other obesity indicators is still lacking.

Regarding coronary indices, magnesium intake had a significantly weak correlation with the LAP ($r = 0.146$, $p = 0.007$) in males, while in female participants, magnesium intake had a significantly weak correlation with the AIP ($r = 0.182$, $p = 0.028$). The percentage of change in the CMI explained by magnesium was 1.5%. It has been shown that reduced levels of magnesium are linked to alterations in lipid profiles and cardiovascular risk factors such as obesity, hypertension, and hypercholesterolemia (28, 38). Since it activates lipoprotein lipase, lecithin-cholesterol acyl-transferase, and HMG-CoA reductase, it promotes an increase in HDL-c and a decrease in TG, TC, and LDL-c (28). Furthermore, after the evaluation of urine magnesium levels, an inverse association between magnesium and cardiovascular risk factors such as obesity, hypertension, and hypercholesterolemia was found (38).

In a cohort study in Japan, to determine the association between dietary magnesium intake and the risk of stroke and coronary heart disease, Kokubo and colleagues found no decreased risks of incident stroke in men or women with higher dietary magnesium intake, but it did decrease the risk of coronary heart disease (25). On the other hand, in a nested case-control analysis, higher magnesium intake was not associated with a lower risk of total coronary heart disease in women (26). Al-Delaimy et al. (39) found that the intake of magnesium may have a modest inverse association with the risk of coronary heart disease among men. We noted that despite studies confirming the role of lower magnesium intake in increasing the incidence of heart disease, there is still a lack of studies linking magnesium with coronary indices, which may provide an early warning before developing the disease.

Aside from the BAI, the present findings confirmed that all index scores increased with a higher calcium intake. For males, calcium intake had a significantly weak correlation with the CI, BAI, AVI, BRI, and WWI. In female participants, while calcium intake had a significantly weak correlation with the CI, BAI, WWI, and LAP, it showed a significant moderate correlation with the AVI and BRI. Calcium intake was found to describe most of the changes in obesity indices (6.3% of the changes presented in the CI, 1.8% in the BAI, 11.4% in the AVI, 8.7% in the BRI, and 4.6% in the WWI), and 2.5% in the AIP among the coronary indices.

The previous studies did not cover all the indices we studied, but some corresponded with the results of the current study. Wadolowska et al. (10) supported the evidence of the adverse relationship between low-dairy low-calcium dietary patterns and obesity, which was measured by WC, WHtR, and BMI, and calcium-rich foods could play a vital role in obesity prevention (10). Reinforcing the present findings, Lee et al. (7) found that the consumption of at least one serving of dairy products per day decreased the risk of obesity in Korean women (7). Bendtsen and colleagues (40) showed that consuming many calories from dairy products and getting enough calcium prevents body weight gain (40). A recent meta-analysis by Hong et al. suggested that dairy products significantly changed fat mass and BMI, but calcium supplements did not (9). On the other hand, in a cross-sectional study, Iranian female university students showed no significant association between dairy or calcium intake and weight and WC, as well as the prevalence of obesity, central adiposity, and excess weight (2). Sadeghi and colleagues found that dietary calcium intake was positively associated with general obesity in men but not in women; moreover, no significant association was seen between dairy consumption and general or central adiposity (4).

Additionally, the present findings are logical, as it has been hypothesized that calcium intake and/or deficiency affect obesity by several mechanisms; for example, a decrease in the intracellular calcium concentration of adipose cells prevents the accumulation of fat in these cells by inhibiting lipogenesis and stimulating lipolysis (11). Additionally, calcium is involved in regulating adipogenesis, regulating the proliferation of preadipocytes, enhancing thermogenesis/energy expenditure, suppressing fat absorption and promoting fecal fat excretion, and modifying the gut microbiota composition and diversity (41). Additionally, a systematic review reported that there were positive effects of calcium supplementation alone or with vitamin D on TC, TG, LDL-c, and HDL-c, and three clinical trials demonstrated the favorable effects of calcium supplementation on at least one atherogenic index (42).

Strength and limitations

The present study had certain limitations. First, due to the study's cross-sectional nature, causal relationships between obesity and coronary indices and the dietary intake of vitamin D, calcium, and magnesium could not be adequately confirmed. Second, calcium, magnesium, and vitamin D serum levels were not examined. Third, these results may not be readily generalized to all Jordanians, since our sample represented adult employees from a single university. Fourth, we did not obtain data on the subjects' sun exposure levels or vitamin D supplementation. Additionally, one of the limitations of this study is the small number of female participants. Studies with a larger sample of females are recommended, as female participants show a higher correlation between nutrient intake, obesity, and coronary indices. Last, the study did not evaluate the individuals' body fat percentage by body composition analysis or their abdominal subcutaneous adipose tissue and visceral adipose tissue by MRI or CT; these data can be utilized to investigate the precise contribution of various fat deposits.

Important strengths of our study include the availability of both traditional and novel anthropometric indices and coronary indices. To our knowledge, this is one of the few studies to address the association between vitamin D, calcium, and magnesium with obesity and coronary indices. Moreover, the present data were collected before the COVID-19 pandemic, which helped researchers in the same field conduct comparative studies before and after the pandemic, providing a platform for future studies to investigate the pandemic's effect on these indices and nutrient intakes. The uniqueness of investigating the association between coronary indices and different selected nutrients is another vital strength of the study.

Conclusion

Increasing the vitamin D dietary intake had little to no effect on the scores of various obesity and coronary indices, with a weak correlation with the AVI for the total sample and especially for females. Aside from the BAI, all the index scores (CI, ABSI, BRI, WWI, CMI, LAP, and AIP) increased with higher magnesium and calcium intake. Of the three studied nutrients, magnesium demonstrated the greatest percentage change in the majority of the coronary indices. Calcium demonstrated the highest percentage change in describing most of the obesity indices. Additionally, sex has an impact on the percentage change in several indices that were explained by a particular nutrient. Further studies are recommended to assess the correlations between serum levels of vitamin D and vitamin D supplementation with obesity and coronary indices. Moreover, further studies are required to investigate the association and correlation between obesity indices and coronary indices with magnesium intake.

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Authors' contributions

Buthaina Alkhatib conceived the research idea and the manuscript preparation. Lana M. Agraib conceived the research idea, analysis of data, and manuscript preparation. Anfal M.AL-Dalaeen was involved in the manuscript preparation. Islam Al-Shami conceived the research idea, preparation, overall scientific management, participated in manuscript preparation, and data collection. All authors critically revised the manuscript, approved the final version to be published, and agreed to be accountable for all aspects of the work.

Consent to participate

All participants were informed about the study objectives at the beginning of the questionnaire, then they expressed their informed consent to participate, and their data were anonymous.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethics approval

The study was approved by The Institutional Board Review committee reviewed and approved the survey protocol at The Hashemite University (No.7/13/2020/2021)

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