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Dietary Acid Load and Breast Cancer Risk: A Case-Control Study in Uruguay

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Abstract

Background and purpose: If the endogenous acid-base balance is not well regulated, dietary acid load contributes to metabolic acidosis, leading to inflammation and cell transformation, which can contribute to the development of cancer. Nevertheless, there is still limited epidemiologic evidence on the association between diet-dependent acid load and cancer risk, particularly for breast cancer (BC), although an increased risk of recurrence among BC survivors was reported for a high acid load. Therefore, we have explored in the present study its role in BC risk.

Methods: A case-control study was performed on 572 BC cases and 889 age-frequency matched controls, using a specific multi-topic questionnaire, including a food frequency questionnaire. Food-derived nutrients were calculated from available databases. We assessed dietary acid load based on existing measures as potential renal acid load (PRAL) score and net endogenous acid production (NEAP) score. Odds Ratios (ORs) were estimated by logistic regression, adjusting for potential confounders.

Results: We found direct associations between dietary acid load and BC risk. The highest quartiles of PRAL and NEAP were significantly associated (OR = 2.46 and OR = 1.78, respectively). Besides, BC's positive family history led to even higher risks (OR = 6.14 and OR = 3.38 for highest PRAL and NEAP, respectively).

Conclusions: PRAL and NEAP scores are directly associated with meat intake and inversely associated with plant- based foods intake. Therefore, results suggest that a low acid load dietary style may reduce BC risk, in agreement with studies focused on food groups and dietary patterns. Further studies are needed to confirm these findings.

Key words

Acid Load, Breast Cancer, Diet, Epidemiology, Nutrition

Introduction

Breast cancer (BC) is the leading malignancy among Uruguayan women [1], with the highest incidence rate in South America and close to North American pictures [2,3]. An independent effect of modifiable risk factors as dietary patterns, lifestyle factors, macro- and micronutrient intake, physical activity, tobacco smoking, and weight gain on the BC risk was highlighted in several studies [4]. Among the nutritional items that may reduce the BC risk, particularly those that tend to be aggressive tumors, are fruits and vegetables, specifically cruciferous and yellow/orange vegetables [5]. Conversely, Western-like dietary patterns have gained some relevance linked to its risk association [6]. The quoted patterns usually involve a high meat intake, which is considered a potential risk factor for BC [7,8]. Uruguay is a developing country; nevertheless, its human development index is high [9], and its average diet is meat-based, with the world's highest per capita beef intake [10]. In this respect, the associations between meat and BC in Uruguay were initially explored more than two decades ago [11,12].

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Blood pH is maintained within the range of 7.35 - 7.45 and tends to be rapidly controlled by the body's buffer systems to avoid acidosis (pH < 7.35) or alkalosis (pH > 7.45). Minimal changes are expected in the value of plasma bicarbonate, and blood pH within the range considered normal [13]. When the pH is balanced at values close to the lower limit (7.35), this condition is called low-grade metabolic acidosis. Some factors can lead to low-grade metabolic acidosis, and diet is one of the main factors that may influence the occurrence of this condition [14]. In particular, a long-term high protein consumption (e.g., from Western-like dietary patterns) can induce it [15,16].

Metabolic acidosis can be calculated through the potential renal acid load (PRAL) [15] and net endogenous acid production (NEAP) [16] formulas, which are validated and straightforward methods to estimate the dietary acid load from diet-composition data. A prolonged diet-induced low-grade metabolic acidosis over the years may predispose to metabolic abnormalities, in particular, insulin resistance, diabetes, high serum triglycerides, and obesity [17,18]. Consequently, the production of insulin-like growth factor-1 (IGF-I) probably increases [19], which, in turn, is associated with an increased BC risk [20].

A recent prospective study suggested that a higher diet-dependent acid load is associated with an increased risk of invasive BC. Conversely, alkaline diets or diets lower in diet-dependent acid load may be protective, especially for Estrogen Receptor-negative BC [21]. Nevertheless, there is limited and inconsistent epidemiologic evidence on the association between diet-dependent acid load and cancer risk [22], currently restricted to BC incidence and recurrence risk [21,23-25]. Therefore, we decided to explore possible associations of diet-dependent acid load and the risk of BC among Uruguayan women. To our knowledge, the present study is the first Latin American case-control study that analyzes dietary acid load and BC risk.

Material and Methods

We combined two databases previously used in epidemiologic studies on BC in the Uruguayan population [26-29]. Those studies were carried out in Uruguay during 1996-2004 in Montevideo's principal public hospitals (Pasteur, Maciel, Clinicas, Oncology Institute) and one private hospital. Formal consents were not required for this type of study at that time. The studies were conducted after being authorized by Directors receiving ethical approval in each participant institution. With a similar structure, both databases enabled us to study a total sample of 1461 participants (572 BC cases, 889 controls). Each one is briefly described as follows.

Public hospitals

As part of multi-site epidemiologic research, 480 incident BC cases were eligible for the study period. Nineteen patients rejected an interview, leaving 461 cases to be included (response rate 96.0%). In the same period and hospitals, 685 admitted patients afflicted with diseases unrelated to smoking and drinking were eligible for the study. Twenty-five patients rejected the interview, leaving 667 controls (response rate 97.4%). Trained social workers interviewed patients in the hospitals shortly after admittance. No proxy interviews were conducted. According to Uruguayan law, patients admitted to public hospitals were people with low incomes, from the whole country, and free access to medical services. Considering the population's features, they were good representatives of a third world country, different from the community admitted at the private health institution.

Private hospital

An epidemiologic study on BC conducted in 1999-2001 at a pre-paid medical institution in Montevideo (IMPASA) derived 116 incident BC cases and 223 controls women having normal mammography (BI-RADS 1) [30] ≤ 1 year before the interview. One control and two cases refused the interview, and three cases were excluded for medical reasons, finally achieving 111 cases and 222 controls (response rates: 95.7% and 99.6% respectively). They were age-matched (± five years). All participants, inhabitants of Montevideo (the capital city), did not remain at the hospital during the interviews. Women were < 85 years old and belonged to mid-to-high socioeconomic strata. After appointments made by phone, interviews were face-to-face conducted in a hospital's office by a trained nurse blinded by major risk factors.

Each hospital Director has authorized the project after receiving the approval from the respective Ethical Committee. In past years, only oral consent was required from the patients, assuming the confidentiality about their data. An auto-generated number was built based on initials (first and last name + ID number) to preserve anonymity.

Interviews and questionnaire

Participants answered a structured questionnaire which included: socio-demographic variables; occupation; BC history in 1º-2º degree relatives; self-reported height and weight five years before the interview; smoking and alcohol; a history of "mate," tea and coffee drinking; menstrual-reproductive events; and a food frequency questionnaire (FFQ) of 64 items, representative of Uruguayan diet, focused on food consumption five years before the interview. Proxy interviews were not accepted. The FFQ was not validated; however, it was tested for reproducibility [31], allowing individual energy estimation. All dietary questions were open-ended. Local tables of food composition were used for estimating energy and nutrients [32].

Estimation of dietary acid load

We calculated the diet-dependent acid load using previously defined formulas [15,16] and applied in other epidemiologic studies on BC risk [21, 25] as well as on recurrence [23,24]: potential renal acid load (PRAL) and net endogenous acid production (NEAP). These measurements were calculated as follows:

PRAL (mEq/day) = (0.49 × total protein [g/day]) + (0.037 × phosphorus[mg/day]) – (0.021 × potassium[mg/day]) – (0.026 × magnesium[mg/day]) – (0.013 × calcium[mg/day]);

NEAP (mEq/day) = (54.5 × protein[g/day]) / (0.0256 × potassium[mg/day]) – 10.2;

An analysis program was compiled to calculate energy, which made the sum of all individual values. Each one was obtained after multiplying the number of servings/year by the ratio calories of the serving/100g of each, divided by 365 days. Most typical or average servings of solid foods are within the range of 100-150g. Since iron intake showed a high correlation with energy, we calculated an iron density expressed as daily mg of the mineral/kcal*1000.

Statistical analysis

The questionnaire variables were initially continuous. When necessary, they were categorized for analysis purposes. Aside from primary descriptive analyses (frequencies, mean values), we calculated Odds Ratios (ORs) and 95% confidence intervals (95% CI) by unconditional logistic regression [33]. Terms for potential confounders were included in the multivariate analyses. The equations included terms for: age (categorical), residence (binary), education (categorical), age at menarche (categorical), menopausal status (binary), age at first live birth (categorical), number of live births (categorical), age at menopause (categorical), family history of BC (binary), BMI (continuous), smoking intensity in pack-years (continuous), alcohol status (categorical) and energy intake (categorical) as independent variables, and cancer (yes/no) as the dependent one. Possible heterogeneities in the stratified analyses were explored through likelihood-ratio tests. The STATA software was used to make all calculations (Release 10, StataCorp LP, College Station, TX, 2007).

Results

Table 1 shows the distribution of cases and controls according to selected socio-demographic variables. Although participants were not completely matched, an adequate age distribution was achieved (p = 0.87). There were more rural cases than controls (12.9% vs. 9.4%, resp.). Most traditional BC risk factors (family history of cancer, reproductive variables) displayed significant or marginal differences between cases and controls. On the other hand, educational level and BMI did not.

Some selected lifestyle variables were analyzed and presented in **Table 2**. Energy, red meat, and alcohol intake were directly and significantly associated with BC risk. On the other hand, fruits, vegetables, and the three infusions (coffee, tea, and 'mate') were inversely and significantly associated with the risk.

Table 3 displays the mean values of PRAL and NEAP scores and their components comparing cases and controls. Both mean scores were higher among BC cases. Regarding the details, differences in protein and Phosphorus intakes

Table 1: Distribution of sociodemographic and selected reproductive variables in cases and controls.

Variables	Categories	Controls % (n = 889)	Cases % (n = 572)	Global p - Value
Age groups	≤ 49	200 22.5	123 21.5	
	50 - 59	223 25.1	143 25.0	
	60 - 69	243 27.3	155 27.1	
	≥ 70	223 25.1	151 26.4	0.94
Health system	Public	667 75.0	461 80.6	
	Private	222 25.0	111 19.4	0.01
Education years	≤ 6	551 62.0	359 62.8	
	7 - 12	223 25.1	142 24.8	
	≥ 13	115 12.9	71 12.4	0.94
Residence	Urban	805 90.5	498 87.1	
	Rural	84 9.4	74 12.9	0.03
Body Mass Index	≤ 24.99	389 43.8	238 41.6	
(kg/m^2)	25.0 - 29.99	327 36.8	210 36.7	
	≥ 30.0	173 19.5	124 21.7	0.54
Fam.History of BC	No	811 91.2	450 78.7	
	Yes	78 8.8	122 21.3	< 0.001
Menopausal status	Pre	182 20.5	97 17.0	
	Post	707 79.5	475 83.0	0.09
Age of menarche	≤ 11	207 23.3	138 24.1	
	12	273 30.7	145 25.3	
	13	175 19.7	136 23.8	
	≥ 14	234 26.3	153 26.7	0.09
Nº of live births	Nulliparous	111 12.5	104 18.2	
	1 - 2	394 44.3	252 44.1	
	≥ 3	384 43.2	216 37.8	0.006
Age at 1st live birth	≤ 20	281 36.1	150 32.0	
	21 - 26	304 39.1	173 37.0	
	≥ 27	193 24.8	145 31.0	0.054
Breastfeeding time	≤ 3	283 31.8	218 38.1	
(total months)	4 - 15	307 34.5	168 29.4	
	≥ 16	299 33.6	186 32.5	0.03

Table 2: Crude Odds Ratios (OR) of selected consumptions linked to lifestyle. Comparisons between highest vs. lowest categories.

Variable	Categories	Controls/cases	Global P - value	OR (95% CI)	P - value for trend
Red meat	≤ 112	254/101			
(servings/year)	113 - 183	256/118			
	184 - 290	228/138			
	≥ 291	151/215	< 0.001	3.58 (2.62 - 4.88)	< 0.001
Fruits	≤ 218	207/159			
(units/year)	219 - 365	204/159			
	366 - 844	236/130			
	≥ 845	242/124	0.006	0.67 (0.49 - 0.90)	0.001
Vegetables	≤ 400	190/173			
(servings/year)	401 - 620	226/141			
	621 - 905	245/118			
	≥ 906	228/140	< 0.001	0.67 (0.50 - 0.90)	0.003
Energy	≤ 1625	244/121			
(Kcal/day)	1626 - 1944	225/140			
	1945 - 2288	215/150			
	≥ 2289	205/161	0.02	1.58 (1.17 - 2.14)	0.002
Coffee	Never	607/431			
(Consumption)	Ever	282/141	0.004	0.70 (0.56 - 0.89)	0.004
Tea	Never	503/386			
(Consumption)	Ever	360/212	0.02	0.77 (0.62 - 0.95)	0.02
'Mate' intake	None	146/108			
(ml/day)	≤ 999	308/275			
	≥ 1000	435/189	< 0.001	0.59 (0.43 - 0.79)	< 0.001
Alcohol	Non drinker	759/451			
Status	Ever drinker	130/121	0.001	1.57 (1.19 - 2.06)	0.001
Smoking	Non smoker	659/409			
Status	Ever smoker	230/163	0.27	1.14 (0.90 - 1.45)	0.27

Table 3: Mean daily values ± standard deviation of the acid load scores and their components. Stratification of items according to their animal/plant original source. Comparison between cases and controls.

Variable	Units	CONTROLS	CASES	Diff.(p)
		Mean ± SD	Mean ± SD	
Total Proteins	g	109.6 ± 49.6	118.8 ± 42.3	0.0001
Total proteins/energy	g/10^3 Kcal	56.2 ± 14.1	57.3 ± 12.8	0.14
Animal proteins/energy	g/10^3 Kcal	51.7 ± 14.2	53.2 ± 12.9	0.04
Plant proteins/energy	g/10^3 Kcal	4.6 ± 1.7	4.1 ± 1.6	< 0.0001
Total Phosphorus	mg	759.6 ± 256.9	776.2 ± 265.5	0.23
Total phosphorus/energy	mg/10^3 Kcal	389.9 ± 76.4	374.3 ± 70.9	0.0001
Animal phosphorus/energy	mg/10^3 Kcal	246.3 ± 70.4	241.3 ± 62.0	0.16
Plant phosphorus/energy	mg/10^3 Kcal	143.6 ± 45.1	133.1 ± 45.3	< 0.0001
Total Potassium	mg	2051.5 ± 678.5	2062.5 ± 754.7	0.77
Total potassium/energy	mg/10^3 Kcal	1064.7 ± 258.6	1000.4 ± 247.3	< 0.0001
Animal potassium/energy	mg/10^3 Kcal	379.4 ± 94.4	385.3 ± 91.3	0.24
Plant potassium/energy	mg/10^3 Kcal	685.3 ± 242.9	615.2 ± 242.4	< 0.0001
Total Magnesium	mg	178.8 ± 59.2	179.0 ± 65.8	0.95
Total magnesium/energy	mg/10^3 Kcal	92.5 ± 20.8	86.7 ± 20.9	< 0.0001
Animal magnesium/energy	mg/10^3 Kcal	27.7 ± 6.7	27.7 ± 6.1	0.96
Plant magnesium/energy	mg/10^3 Kcal	64.8 ± 20.2	59.0 ± 20.7	< 0.0001
Total Calcium	mg	854.2 ± 425.0	817.3 ± 466.4	0.12
Total calcium/energy	mg/10^3 Kcal	437.0 ± 192.4	391.6 ± 181.4	< 0.0001
Animal calcium/energy	mg/10^3 Kcal	222.4 ± 165.9	193.7 ± 153.1	0.0009
Plant calcium/energy	mg/10^3 Kcal	214.6 ± 69.9	197.9 ± 74.6	< 0.0001
PRAL	mEq	22.6 ± 21.7	29.7 ± 23.2	< 0.0001
NEAP	mEq	84.9 ± 31.3	90.9 ± 32.3	0.004

Table 4: Adjusted Odds Ratios (ORs) of BC for acid load scores (PRAL and NEAP), with global estimations and stratified analyses by menopausal status and family history of BC.

SCORE LEVELS					
	I	**II**	**III**	**IV**	
	OR 95% CI	**OR 95% CI**	**OR 95% CI**	**OR 95% CI**	
PRAL (mEq/d)	**≤ 12.1**	**12.2 - 22.7**	**22.8 - 34.9**	**> 34.9**	**Trend (p)**
All	1.00 ---	1.01 0.73-1.40	**1.76** 1.28-2.42	**2.46** 1.76-3.44	< 0.001
Prem	1.00 ---	0.99 0.43-2.27	2.26 0.97-5.25	**3.33** 1.41-7.89	0.002
Postm	1.00 ---	1.02 0.72-1.46	**1.71** 1.21-2.41	**2.31** 1.61-3.33	< 0.001
FH No	1.00 ---	0.88 0.61-1.25	**1.62** 1.15-2.27	**2.12** 1.48-3.04	< 0.001
FH Yes	1.00 ---	2.06 0.93-4.52	**2.97** 1.22-7.23	**6.14** 2.30-16.4	< 0.001
NEAP (mEq/d)	**≤ 68.0**	**68.1 - 82.4**	**82.5 - 99.2**	**> 99.2**	**Trend (p)**
All	1.00 ---	0.98 0.72-1.35	**1.56** 1.15-2.13	**1.78** 1.30-2.42	< 0.001
Prem	1.00 ---	0.76 0.34-1.71	1.39 0.65-2.98	1.49 0.69-3.26	0.14
Postm	1.00 ---	1.00 0.71-1.42	**1.63** 1.16-2.29	**1.82** 1.29-2.56	< 0.001
FH No	1.00 ---	0.97 0.69-1.36	**1.43** 1.03-2.00	**1.58** 1.13-2.22	0.001
FH Yes	1.00 ---	1.05 0.47-2.32	**2.64** 1.12-6.19	**3.38** 1.41-8.11	0.001

The equations included terms for: age (categorical), residence (binary), education (categorical), age at menarche (categorical), menopausal status (binary), age at first live birth (categorical), number of live births (categorical), age at menopause (categorical), family history of BC (binary), BMI (continuous), smoking intensity in pack-years (continuous), alcohol status (categorical) and energy intake (categorical) as independent variables, and cancer (yes/no) was the dependent one.

Likelihood ratio tests for heterogeneity were: non significant for Menopausal status (p = 0.72) and significant for Family history of BC (p = 0.03).

Abbreviations: Prem = premenopausal; Postm = postmenopausal; FH = family history of breast cancer in relatives of 1st and 2nd degree together.

Bold letters indicate statistically significant values.

were significantly higher among cases. However, potassium, magnesium, and calcium intakes were not significantly different between cases and control groups.

Table 4 displays the adjusted ORs for both acid load scores. The highest vs. lowest quartile of PRAL derived a significant estimate (OR = 2.46) with a highly significant trend (ptrend < .001). The same applies to the NEAP score: both risk and trend estimates were significant (OR = 1.78, ptrend < .001). The analyses stratified by family history of BC showed higher risks with a positive history: PRAL had an OR = 6.14 (ptrend < .001), and NEAP had an OR = 3.38 (ptrend 0.001).

Discussion

We found direct associations between dietary acid load and BC risk. The ORs for the highest vs. lowest quartile were significant regarding both scores employed and their linear trends: PRAL (OR = 2.54, ptrend < 0.001) and NEAP (OR = 1.78, ptrend < 0.001). Stratified analyses done in a recent prospective study [21] found suggestively stronger associations between PRAL and BC in women who had a sister diagnosed with BC before age 50 years, especially for ER-negative BC. Albeit we had no data on ages of relatives' cancer cases nor hormonal receptors of patients, our stratified analyses by family history also showed a risk increase for PRAL score when this history was present, compared to its absence (OR = 6.14 vs. OR = 2.12, respectively). Besides, the NEAP score displayed similar associations (OR =3.38 vs. OR=1.58, respectively). Having found significant heterogeneity between the absence/presence of BC family history, this might imply gene-dietary interactions to be considered for future studies.

The only existing evidence related to acid load and cancer risk is related to BC. Nevertheless, these research works are not consistent enough [21,23,25]. There were positive associations for acid load with BC risk among American and Puerto Rican women [21,23], but it was not associated among Iranian ones [25]. Some studies reported results about the influence of the acid load on the metabolic condition (hyperinsulinism and/or diabetes) [34,35] and the association with BC recurrence and survival [23,24]. One of these, identified acid load as a novel dietary factor that may lead to inflammation and hyperglycemia [23]. Therefore, a dietary acid load may contribute to inflammation in cancer patients.

It has been claimed that dietary acid load can contribute to metabolic acidosis if the acid-base balance is not correctly adjusted. Metabolic acidosis is a condition characterized by a slight decrease in blood pH [14], and feeding is one of the main factors to produce such a situation. In humans, arterial and venous blood have a pH of 7.35 - 7.4 and 7.20 - 7.35, respectively [36]. Besides, there is growing evidence showing that the fluid pH in the interstitial space around metabolic tissues is easily reduced due to weaker pH buffering capacity than that in the cytosol and blood circulation. Whereas the arterial blood pH is strictly regulated due to strong pH buffers such as albumin and hemoglobin, interstitial fluids have only relatively weak pH buffers, bicarbonate, and phosphate, enabling a pH range of 6.60 - 7.60 [37]. Such interstitial pH reduction might initiate a metabolic dysfunction [38]. In contrast, several nutrients bring benefits in maintaining the interstitial fluid pH within the normal range by improving buffering capacities, suppressing proton production, and activating proton transporters, strengthening the effect of appropriate diet on metabolic health [37].

The excessive consumption of acid precursor foods (such as meat, cheese, and eggs, which are sources of phosphorus

and proteins) leads to acid-base balance volubility. If this situation occurs in a prolonged or chronic way, low-grade metabolic acidosis can become significant and predispose to metabolic imbalances [13,14,39]. Regarding these points, it is well known that metabolic acidosis can cause tissue damage, which can further initiate inflammation [23]. Inflammatory process induces oxidative stress and reduces cellular antioxidant capacity. Overproduction of free radicals reacts with cell membrane fatty acids and proteins, impairing their function permanently. Besides, free radicals can lead to gene mutation and DNA damage that predispose to the development of cancer and age-related disorders [40].

Cancer patients have reduced capabilities for adjusting their acid-base balance [41]. Several metabolic adaptations observed in cancer are recognized as similar to the perturbations observed in diabetic patients [36]. Albeit acidity has more than one source [42], the lactate derived from cancer cells suppresses T cell and NK cell function [43]. Moreover, metformin -an insulin sensitizer- frequently used to reduce hyperglycemia in diabetic patients, has been accepted to reduce cancer incidence [44] and improve survival [45].

An adequate intake of phosphorus for adults in the general population is 550 mg/day. However, European countries' mean intake is higher than 2-fold such value (1000 – 1767 mg/day) [46]. By the same token, our study population sample showed a mean intake of 766 mg/day (760 mg/day among controls), which is higher than the adequate consumption, based on the quoted reference numbers. Dietary phosphorus has increased over time [47], mainly due to phosphorus-containing additives in food manufacturing and processing [48]. Furthermore, there is evidence that cellular phosphate burden from phosphate toxicity is a pathophysiological determinant of cancer cell growth [49]. According to these authors, a dysregulated phosphate homeostasis can be associated with the genesis of various human tumors.

Besides, a diet that includes phosphorus-enhanced foods can probably add another 600 - 800 mg to the overall daily intake and non-negligible amounts of sodium chloride (NaCl) [50]. Indeed, its intake is reported to be an independent predictor of plasma bicarbonate concentration. NaCl may exert approximately 50–100% of the acidosis-producing effect of the dietary acidic load and is considered a predictor of diet-induced low-grade metabolic acidosis [51]. Besides, an increasing NaCl dose-dependently decreases blood pH and plasma bicarbonate levels, independent of the partial pressure of CO_2, creatinine clearance, and dietary acid load [13]. On the other hand, potassium, magnesium, and calcium are precursors of bases. Therefore, the main foods that release precursors of acids into the bloodstream are mostly of animal sources, and foods that are precursors of bases are mainly those of plant sources [14]. **Table 3** shows the components of acid load scores, discriminated by animal/plant source, as it has been previously discussed.

In addition to dietary phosphorus, or to the use of phosphorus-containing additives, the picture turns even more complicated when it was taken into account the previous relationships among acid load, chronic inflammation, and oxidative stress: The interaction of free radicals with polyunsaturated fatty acids of cell membrane causes lipid peroxidation and subsequent cell damage, leading to leakage of intracellular phosphorus into serum [52]. Therefore, Western-like dietary patterns may enhance a vicious cycle involving lipoperoxidation, inflammation, and metabolic acidosis.

As for the study's strengths, cases and controls were face-to-face, directly interviewed by the same trained personnel in the same hospital settings, and the studied population included subsets coming from the whole country and belonged to different socio-economic-cultural strata. Besides, times of data collection were coincident.

On the other hand, the present study may share some biases that are common to case-control studies. Within-person variability over the study period may be a source of information bias. Selection bias was limited by the nearly full participation of the identified cases and controls (rates ~ 97%), favored by the interview during the hospital stay. Dietary habits were relatively stable in the Uruguayan population, and patients were asked to report any relevant dietary changes occurring during their life. Furthermore, a recall bias related to dietary habits should be negligible in our study population, as the awareness of BC's dietary hypothesis was very limited. Although the FFQ was not validated, it was satisfactorily reproducible [31]**.** Mineral estimations become one of the limitations of the present study since they were based on average serving sizes rather than actual food sizes. Besides, we could not exclude confounders' role by other dietary factors, such as other constituents of animal foods, the effects of different cooking methods, and the mineral contents in water. For example, highly processed and manufactured foods, which involve the use of phosphorus-containing additives, were not included in the FFQ. Therefore, no estimations of phosphorus and sodium from these potential sources were carried out.

In conclusion, the calculated acid load scores were found directly and significantly associated with BC risk. Since those scores are directly associated with meat intake and inversely associated with plant-based foods intake, results suggest that a low acid load dietary style may reduce BC risk, in agreement with studies focused on food groups and dietary patterns. Further studies are needed to confirm these findings.

Conflict of Interest

The authors declare no conflict of interest.

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