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Associations between dietary patterns and serum lipids, apo and C-reactive protein in an adult population: evidence from a multi-city cohort in South America

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Abstract

Several previous epidemiological studies from developed countries have shown that an unhealthy dietary pattern affects plasma lipid levels and inflammation biomarkers. We assessed the cross-sectional associations between dietary patterns and cardiovascular risk factors among 961 adults from a multi-city cohort in South America. We conducted a principal component analysis to derive dietary patterns. As outcomes, we examined plasma levels of apo A-I, apo B, high-sensitivity C-reactive protein (hs-CRP), LDL-, HDL- and serum total cholesterol and TAG. The crude and adjusted changes in each outcome were estimated for quartiles of dietary patterns using multivariable linear regression models. The prudent pattern (PP) characterised by higher intake of fruits, vegetables, fish, seafood, whole cereal and low-fat dairy products was associated with reduced plasma concentrations of apo B (−8·5 mg/l), total cholesterol (−18·8 mg/dl) and LDL-cholesterol (−16·5 mg/dl) and hs-CRP (−1·6 mg/l) in men. In women also reduced plasma concentrations of apo B (−6·6 mg/l), total (−12·0 mg/dl) and LDL (−9·3 mg/dl). The 'Western-like' pattern characterised by higher intake of eggs, pastry and cakes, pizza, snacks, refined grains, red meat, vegetable oils and poultry was not significantly associated with any of the selected serum lipid or inflammatory biomarkers. The explained variances were 10·3 and 7·4 %, respectively. The PP was associated with better lipid profile, mainly lower atherogenic particles (apo B) and LDL-cholesterol and serum total cholesterol. This study provides possible evidence of a prudent diet in South American populations to help reduce the burden of CVD.

Key words: Dietary patterns: Apolipoproteins: Principal component analysis: C-reactive protein

Unhealthy diet is the most important cause of burden of disease globally[1] and in many developing regions[2]. In South America, unhealthy diet caused 10·5 % of total burden of disease (1 670 656 disability-adjusted life years (DALY)), 72 % of the burden from CHD (1 214 996 DALY) and 23 % of the burden from diabetes (252 259 DALY) in 2015[3]. The global prevalence of diabetes reported by The Study of Detection and Follow-up of Cardiovascular Disease and Risk Factors in the Southern Cone of Latin America (CESCAS I) was 12·4 % and the self-reported prevalence of CHD was 6·9 %[4].

The impact of unhealthy diet on chronic disease in this region is expected to increase – as trends in diet show increasing total energy intake, particularly from sugars and fats[5] and lower consumption of fruits and vegetables than recommended[6]. In last decade, there was a significant increase in the availability of energy content in Latin America and this pattern was observed in seventeen of the twenty countries analysed. Countries in South America tended to have a greater increment than those in the Andean region, Central America or the Caribbean. In Argentina, the available energy (daily energy per capita) increased from 2090 in 1990 to 3070 kcal (12 845 kJ) in 1999, in Chile from 2610 kcal (10 920 kJ) to 2850 kcal (11 924 kJ) and in Uruguay from 2600 kcal (10 878 kJ) to 2910 kcal (12 175 kJ)[7,8]. Total fat and SFA intake has also dramatically increased in South America from 25 % in 1964 to 30 % in 1996. Sugar intake also increased from 15·9 % in 1970 to 16·9 % of energy in 1997[9].

Traditional nutrient studies often evaluate single nutrients or food items and are therefore unable to examine the impact of interactions between different nutrients or foods[10]. In contrast, dietary patterns allow assessment of the relationship between overall diet and disease, and often provide associations that are stronger and more consistent than those found by analysing single nutrients or foods[11,12].

Several previous epidemiological studies from developed countries have shown that an unhealthy dietary pattern affects

Abbreviation: hs-CRP, high-sensitivity C-reactive protein.

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plasma lipid levels, inflammation biomarkers and other cardiovascular risk factors[13,14]. As there is no published data describing the impact of diet on biological risk factors in populations of the Southern Cone of Latin America, our aim was to identify the major dietary patterns in four cities in Argentina, Chile and Uruguay and examine whether those dietary patterns are associated with plasma levels of apo A-I, apo B, C-reactive protein, cholesterol and TAG.

Methods

Study population

The CESCAS I study is an observational prospective cohort study with a representative sample of 7524 participants aged 35–74 years from four mid-sized cities (50 000–240 000 inhabitants) representing the Southern Cone of Latin America: Bariloche and Marcos Paz in Argentina, Temuco in Chile and Pando-Barros Blancos in Uruguay.

The sampling design included four stages to obtain a representative sample from the general population in each city. The eligibility criteria were: being a permanent resident at the location for at least 6 months per year, willing to sign a consent form to participate, not intending to relocate within the next 2 years and able to respond autonomously to the questionnaire (i.e. not having cognitive impairment or language problems). We did not replace participants if they refused to participate or were not located. More details of the study are published elsewhere[15].

For this analysis, we excluded 182 participants without baseline information on date of birth, body weight, height, smoking status, diabetes, educational level or physical activity; 173 who did not provide a blood sample; 307 that were receiving lipid-lowering drugs; and 368 who had a history of cancer or CVD. In addition, we excluded 1466 participants who did not provide information on diet or had more than seventy items blank on the FFQ or reported a total daily energy intake outside the range of 600–4000 kcal (2510–16 740 kJ) (Fig. 1). After all these exclusions, we considered 5028 participants eligible for this analysis. Out of this eligible subset, 961 participants (312 from Chile, 310 from Uruguay and 339 from Argentina) were randomly selected to determine apo A-I, apo B and high-sensitivity C-reactive protein (hs-CRP) from the frozen serum samples collected at baseline. All participants provided an informed consent and the study was approved by the Institutional Review Boards in Argentina, Chile and Uruguay.

Data collection

Baseline data were collected in two stages: (1) in homes and (2) in health centres. Information on medical history, socio-demographic characteristics and alcohol consumption was collected in participants' homes using the same validated questionnaires used in the Hispanic Community Health Study/Study of Latinos[16]. Smoking status was assessed using a locally-validated version of the Global Adult Tobacco Survey[17] and physical activity using the International Physical Activity Questionnaire[18]. In health centres, anthropometric measurements were carried out, blood pressure was measured and a fasting blood sample was collected. Participants were asked to fast for at least 12 h before the blood withdrawal. Plasma samples were processed and temporarily stored at −20°C for a maximum of a week at the extraction site, then sent to the central laboratory in Hospital Italiano of Buenos Aires and stored in a blood sample repository at −80°C. Diet was assessed using a previously validated 126-item

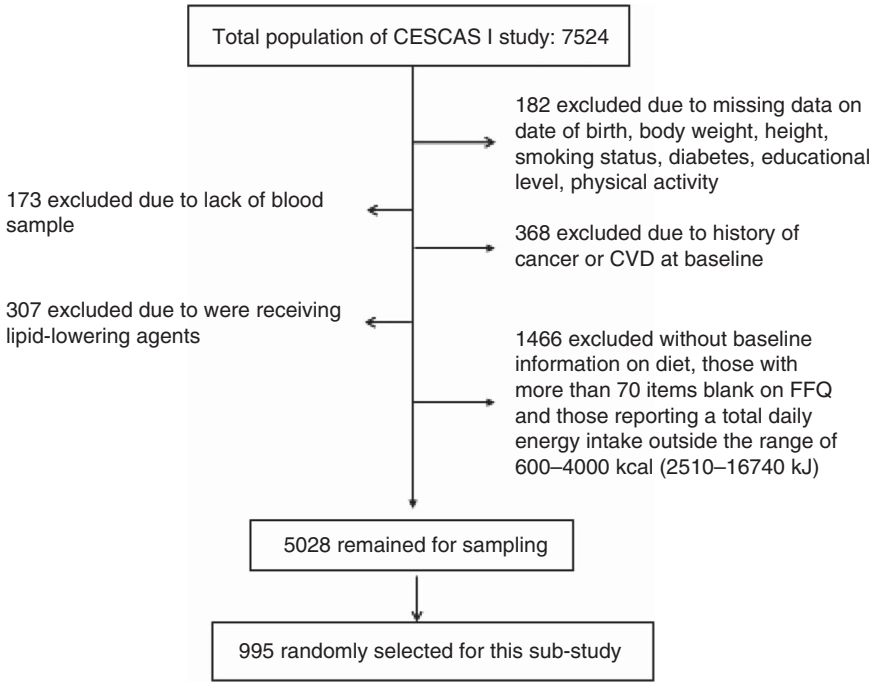

Fig. 1. Flow chart for selection of participants (The Study of Detection and Follow-up of Cardiovascular Disease and Risk Factors in the Southern Cone of Latin America (CESCAS I) study)

FFQ[19]. Nutrient intakes were estimated by summing the nutrients of all food items using the Argenfoods[20] and Latinfood Databases[21,22]. For fatty acid types (SFA, MUFA and PUFA), we used data from the 21st release of the US Department of Agriculture's National Nutrient Database for Standard Reference[23]. Apo were measured using kinetic immunonephelometry (IMMAGE® Immunochemistry System). The reagents materials are those accepted for the WHO/IFCC International Reference Reagent[24]. Total cholesterol, HDL, TAG and glucose plasma concentrations were processed by Synchron LX System. The LDL levels was calculated using the Friedewald equation for the participants who had TAG < 400 mg/dl. hs-CRP was measured by a sensitive latex turbidimetric immunoassay method.

Statistical analyses

Food items were collapsed into thirty-five predefined groups to minimise within-person variation in consumption of individual foods. Food groups were defined based on food groups used in other studies[25–28] and collapsing food items according to their habitual culinary use or nutrient composition. Some items (e.g. coffee, tea and mate, a local brew) were kept separate because they were considered to represent distinctive food choices. This classification, a summary of the available food products, was developed by a nutritionist with experience in nutritional epidemiology in the region.

We conducted a principal component factor analysis to derive major dietary patterns. The number of factors retained was based on the following criteria: components with an eigenvalue >1, scree plot test and the interpretability of the factors. The factors identified were rotated by an orthogonal transformation, which maintains uncorrelated factors and achieves a simpler structure with greater interpretability[29]. The factor score for each pattern was constructed by summing observed intakes of the component food items weighted by factor loadings.

All analyses were performed separately for women and men and for each dietary pattern. To examine the univariate associations between dietary patterns, general characteristics and CVD risk factors, we used univariate linear regression models for continuous variables and χ^2 extended Mantel–Haenszel for linear trend for categorical variables. Multivariable linear regression models were used to examine the associations between dietary pattern scores and apo A-I, apo B, hs-CRP, total cholesterol, HDL-cholesterol, LDL-cholesterol and TAG. The models included age, education, energy intake, physical activity, diabetes, smoking status and BMI as potential confounders based on results of previous studies[10,30,31]. We examined statistical interactions between dietary patterns and BMI (categorical) and age (continuous) by adding product terms to the multivariable models. Total cholesterol, LDL and hs-CRP were log-transformed to reduce the skewness in the distribution of the data.

In a sensitivity analysis, we dropped BMI from the multivariable model because it may be an intermediate factor in the causal pathway between dietary patterns and the selected outcomes. All calculations were weighted to represent the general adult population aged between 35 and 74 years in the study sites. Weights were calculated on the basis of data from the 2010 Population Census and the CESCAS I study sampling scheme, and took into account several features of the survey[15]. All tests were two sided. Statistical analyses were performed using STATA version 11.0 (StataCorp LP) and took into account the complex sampling strategy using survey commands ('svy').

Results

Food consumption patterns

Two major dietary patterns were identified in this population which together accounted for 18% of the total variance in food items (Table 1). We labelled the first pattern 'prudent diet' as it was mainly characterised by higher intake of fruits, vegetables, seafood, whole cereal and low-fat dairy products being similar to other prudent patterns described elsewhere[26,32,33], but also showed a smaller load of potatoes and tubers. We called the second pattern 'Western diet' (WL) but it may well represent a combination of the Western pattern described in the United States of America and Canada[26,32,34] with foods like eggs, pastry and cakes, pizza, snacks and refined grains as well as traditional Argentine foods such as red meat, vegetable oils and poultry (Table 1).

Table 1. Food-group rotated loadings for two dietary patterns identified from FFQ data*

Food groups	Prudent diet	Western-like diet
Other vegetables	0·78	
Green, leafy vegetables	0·65	
Fruits	0·62	−0·19
Cruciferous vegetables	0·60	−0·10
Dark-yellow vegetables	0·59	
Tomato	0·52	
Fish and other seafood	0·44	0·13
Potatoes and tubers	0·39	0·36
Whole grains and legumes	0·27	
Tea	0·25	−0·13
Low-fat dairy products	0·25	
Nuts	0·16	0·15
Cold breakfast cereal and cereal bars	0·15	
Bovine meat/beef (fatty cuts)		0·60
Processed meat		0·56
Bovine meat/beef (lean cuts)	0·12	0·51
Vegetable oils	0·21	0·48
Pastry and cakes		0·46
Mayonnaise and other dressings		0·44
Pizza and 'empanadas'		0·44
Snacks		0·43
Poultry	0·17	0·42
Refined grains		0·41
Eggs	0·21	0·36
Sweets and desserts		0·29
Sugar, jam, marmalade and 'Dulce de leche'		0·29
High-fat dairy products	0·12	0·27
Organ meat		0·24
Animal fats and margarine		0·22
Pork and other meats		0·21
High-energy drinks		0·19
Coffee		0·14
Beer		0·13
Wine		0·11
Other alcoholic beverages		0·10
Proportion of total variance explained	10·3%	7·4%

* Loadings <0·10 are not shown.

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General characteristics and nutrient intake

The eligible study population included 429 men and 542 women. Men in the highest quartile of the prudent diet were more educated (10·1 *v.* 8·7 years), had higher prevalence overweight/obesity (85 *v.* 72 %), a lower prevalence of current smoking (30 *v.* 42 %) and a non-significant trend to higher prevalence of hypertension (53 *v.* 39 %) and older ages (51·9 *v.* 55·2 years) compared with the lowest quartiles. Women, in the highest quartile of the prudent diet had higher prevalence overweight/obesity (75 *v.* 62 %) and a lower prevalence of current smoking (22 *v.* 38 %) compared with the lowest quartile.

Men in the highest quartile of the WL pattern were younger (51·4 *v.* 54·8 years), more likely to smoke (40 *v.* 30 %), with a lower prevalence of diabetes (8 *v.* 15 %) compared with the lowest quartile. Women in the highest quartile of the WL pattern were also younger (51·0 *v.* 54·4 years), more likely to smoke (35 *v.* 21 %), with a lower prevalence of diabetes (5 *v.* 11 %) and overweight/obesity (64 *v.* 74 %) compared with the lowest quartile (Table 2).

In relation to nutrient intake, participants in the highest quartile of the prudent diet had lower intake of SFA, similar intake of unsaturated fats and higher intake of fibre and proteins compared with the lowest quartile. Participants in the highest quartile of the Western diet had a substantially higher intake of SFA, MUFA, PUFA and dietary cholesterol with a lower intake of fibre and carbohydrates compared with the lowest quartile. These differences resulted in a substantially higher energy intake in the highest quartile of the Western diet *v.* those in the highest quartile of the prudent diet (2805 *v.* 2167 kcal (11 736 *v.* 699 kJ) in women and 2903 *v.* 2305 kcal (12 146 *v.* 9644 kJ) in men). Participants in the two highest quartiles of the prudent and Western diets had lower intake of alcohol/2000 kcal (8368 kJ) compared with the lowest quartiles, except for women in the analysis of the prudent diet (Table 3).

CVD risk factors

Men in highest quartile of prudent diet had significantly lower apo B (mean adjusted difference −8·5 mg/l; 95 % CI −15·8, −1·4), total cholesterol (−18·8 mg/dl; 95 % CI −31·7, −5·9), LDL (−16·5 mg/dl; 95 % CI −27·7, −5·3) and hs-CRP (−1·6 mg/l; 95 % CI −2·3, −1·0) (Table 4) compared with men in the lowest quartile. Similar results were observed in women: those at highest quartile of prudent diet had lower apo B (−6·6 mg/l; 95 % CI −13·0, −0·3), total cholesterol (−12·0 mg/dl; 95 % CI −22·5, −5·3) and LDL (−9·3 mg/dl; 95 % CI −18·2, −0·5) (Table 5) compared with the lowest quartile. However, there was no association between prudent diet and hs-CRP in women. Prudent diet was not associated with plasma levels of HDL or apo A-I in either women or men.

In contrast, having a Western diet was not associated with a significant change in any of our outcomes in men or women, except for a non-significant trend (*P* value of trend 0·07–0·09) toward higher TAG, lower apo A-I and HDL in women.

In sensitivity analysis, when BMI was excluded from the models the results did not change, except for the association between prudent diet and apo B and hs-CRP, which lost statistical significance potentially indicating that BMI acted in this relationship more as a confounder than as a mediator. There was no significant interaction between BMI and age.

Table 2. General characteristics of the study population according to quartiles (Q) of dietary pattern scores

	Prudent diet					Western-like diet				
	Q1	Q2	Q3	Q4	*P**	Q1	Q2	Q3	Q4	*P**
Men (*n* 429)										
Age† (years)	51·9	53·4	52·6	55·2	0·057	54·8	54·7	51·8	51·4	0·004
Educational level† (years)	8·7	10·3	10·7	10·1	0·004	10·0	10·3	10·0	9·8	0·715
Physical inactivity (%)	44	57	58	49	0·154	51	53	54	50	0·923
Current smokers (%)	42	41	28	30	0·025	30	29	42	40	0·041
Alcohol use (%)	66	50	58	61	0·150	56	66	51	62	0·130
Overweight/obese (%)	72	78	78	85	0·019	85	74	74	80	0·411
Diabetes (%)	10	8	7	14	0·459	15	12	6	8	0·022
Hypertension (%)	39	40	41	53	0·052	44	46	38	46	0·597
Women (*n* 542)										
Age† (years)	52·6	51·1	52·6	53·5	0·333	54·4	52·5	51·8	51·0	0·008
Educational level† (years)	9·5	10·1	9·7	10·1	0·434	9·6	9·9	10·0	9·5	0·905
Physical inactivity (%)	70	65	69	70	0·764	68	71	69	67	0·874
Current smokers (%)	38	29	23	22	0·000	21	26	29	35	0·009
Alcohol use (%)	27	35	34	37	0·145	32	37	30	33	0·761
Overweight/obese (%)	62	74	70	75	0·037	74	76	68	64	0·041
Diabetes (%)	7	8	9	7	0·877	11	9	5	5	0·026
Hypertension (%)	38	36	45	36	0·384	38	47	35	34	0·185

* *P*-value for linear trend for continuous variables and χ^2 for categorical variables.

† Mean values. Alcohol intake includes moderate and heavy drinkers. Moderate drinker was defined as ≤14 drinks in men or ≤7 drinks in women per week. Heavy drinker was defined as ≥15 drinks/week in men and ≥8 drinks/week in women. Physical inactivity was defined as energy expenditure <600 MET-min/week. Diabetes: fasting glucose ≥126 mg/dl or self-reported history of diabetes. Current smokers are those who are currently smoking or quit smoking for <12 months. Educational level was defined by years of schooling. BMI was calculated by dividing weight in kilograms by height in metres squared (kg/m^2), participants were categorised into normal weight (18·5–24·9 kg/m^2), overweight (25·0–29·9 kg/m^2) and obese (≥30·0 kg/m^2). Hypertension: systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg and/or use of antihypertensive medication.

Table 3. Nutrient intakes according to quartiles (Q) of dietary pattern scores

	Prudent diet					Western-like diet				
	Q1	Q2	Q3	Q4	*P**	Q1	Q2	Q3	Q4	*P**
Men (*n* 429)										
Protein (% energy)	14·1	15·1	15·7	15·8	0·001	14·2	15·2	15·0	16·2	0·001
Carbohydrate (% energy)	52·4	52·1	51·9	53·4	0·563	56·1	51·4	53·5	48·5	0·000
Fibre (g/2000 kcal (8368 kJ))	11·4	13·5	16·7	19·9	0·000	18·5	15·9	14·6	12·3	0·000
Total fat (% energy)	28·2	28·9	28·9	26·9	0·294	24·4	28·4	28·0	32·0	0·000
SFA (% energy)	9·9	10·1	9·7	8·7	0·005	7·8	9·6	9·7	11·3	0·000
MUFA (% energy)	10·3	10·3	10·3	9·5	0·113	8·6	10·2	9·9	11·6	0·000
PUFA (% energy)	5·3	5·4	5·6	5·0	0·408	4·4	5·2	5·5	6·1	0·000
Cholesterol (mg/2000 kcal (8368 kJ))	220·2	231·3	234·8	213·5	0·413	181·4	227·8	232·4	258·6	0·000
Alcohol (g/2000 kcal (8368 kJ))	5·9	3·4	3·0	2·7	0·006	7·4	4·2	1·8	1·4	0·000
Total energy intake	1592	1950	1983	2305	0·000	1138	1617	2177	2903	0·000
Women (*n* 542)										
Protein (% energy)	14·3	15·3	15·2	16·0	0·001	14·5	15·5	16·0	14·8	0·333
Carbohydrate (% energy)	55·7	52·2	55·1	53·6	0·431	57·2	54·3	51·6	53·6	0·001
Fibre (g/2000 kcal (8368 kJ))	12·2	15·8	18·1	23·4	0·000	21·4	18·5	15·9	13·6	0·000
Total fat (% energy)	27·8	29·8	27·1	27·9	0·443	25·4	27·3	30·3	29·6	0·000
SFA (% energy)	9·9	9·8	9·2	8·7	0·001	8·0	9·1	10·2	10·4	0·000
MUFA (% energy)	9·6	10·2	9·3	9·3	0·156	8·5	9·3	10·4	10·3	0·000
PUFA (% energy)	5·3	6·0	4·9	5·3	0·267	4·9	5·0	5·9	5·7	0·000
Cholesterol (mg/2000 kcal (8368 kJ))	220·9	227·7	219·5	211·5	0·380	193·1	217	239·6	229·8	0·002
Alcohol (g/2000 kcal (8368 kJ))	1·2	1·7	1·5	0·9	0·345	2·3	2·0	0·7	0·35	0·000
Total energy intake	1699	1725	1960	2167	0·000	1148	1576	2024	2805	0·000

* *P*-value for linear trend for continuous variables and χ^2 for categorical variables.

Table 4. Mean biomarkers values by quartiles (Q) of dietary pattern scores in men

	Prudent diet					Western-like diet				
	Q1	Q2	Q3	Q4	*P**	Q1	Q2	Q3	Q4	*P**
Apo B										
Mean (mg/l)	90·9	86·9	87·8	84·3		88·4	88·6	85·4	89·1	
Adjusted mean difference	Ref.	−2·2	−3·7	−8·5	0·018	Ref.	1·0	−1·7	1·5	0·907
Apo A-I										
Mean (mg/l)	111·4	106·7	109·9	109·0		111·0	110·5	106·4	110·1	
Adjusted mean difference	Ref.	−2·7	0·0	−2·7	0·212	Ref.	−3·8	−0·7	−3·1	0·356
Total cholesterol‡										
Mean (mg/dl)	209·4	206·4	205·8	193·9		202·7	206·1	201·8	204·9	
Adjusted mean difference	Ref.	−3·0	−5·1	−18·8	0·009	Ref.	3·0	−0·7	2·1	0·959
LDL†‡										
Mean (mg/dl)	137·9	128·3	130·7	120·0		129·7	130·5	126·5	134·3	
Adjusted mean difference	Ref.	−3·7	−6·2	−16·5	0·007	Ref.	2·9	0·9	9·7	0·290
HDL										
Mean (mg/dl)	42·7	40·7	41·4	39·4		42·1	42·5	39·6	41·3	
Adjusted mean difference	Ref.	−0·7	0·2	−2·2	0·244	Ref.	−0·45	−3·6	−2·1	0·266
TAG										
Mean (mg/dl)	158·0	176·8	204·6	177·2		175·1	189·6	170·4	182·2	
Adjusted mean difference	Ref.	19·3	38·4	11·3	0·553	Ref.	25·6	8·9	18·8	0·353
Hs-CRP‡										
Mean (mg/l)	3·8	3·9	3·3	3·7		2·9	3·1	3·9	4·9	
Adjusted mean difference	Ref.	−1·0	−1·3	−1·6	0·018	Ref.	0·07	0·63	1·39	0·311

Ref., referent values; Hs-CRP, high-sensitivity C-reactive protein.

* Linear trends tests were conducted to assess the associations with multivariable regression analysis by assigning the median of the observations in each quartile and computing the *P*-value for each trend. Multivariable model adjusted for: age, BMI, education, energy intake, physical activity, diabetes and smoking status.

† Calculated for participants who fasted >9 h and TAG concentrations ≤400 mg/dl according to Friedwald's equation. Alcohol consumption was not considered as covariate because it was included into the dietary patterns.

‡ Total cholesterol, LDL and Hs-CRP were log-transformed before running the ordinary linear regression models. The log-transformed means were then converted back to their usual scale.

Discussion

We found that a prudent diet, that is high in fruit and vegetables, seafood, whole grains and low-fat dairy products, was associated with lower apo B, total cholesterol and LDL-cholesterol in both sexes and with lower hs-CRP in men. In contrast, a Western diet was not significantly associated with any of the selected serum lipid or inflammatory biomarkers. Our result for the prudent diet could be partially explained by higher dietary fibre intake[35,36] and proteins (mainly from fish and vegetables) and the reduction

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Table 5. Mean biomarkers values by quartiles (Q) of dietary pattern scores in women

	Prudent diet					Western-like diet				
	Q1	Q2	Q3	Q4	*P**	Q1	Q2	Q3	Q4	*P**
Apo B										
Mean (mg/l)	89·1	84·2	83·1	85·2		84·2	87·5	83·5	86·3	
Adjusted mean difference	Ref.	−5·7	−6·8	−6·6	0·043	Ref.	4·5	0·7	5·7	0·372
Apo A-I										
Mean (mg/l)	125·9	122·7	125·5	124·1		125·1	124·3	124·9	123·6	
Adjusted mean difference	Ref.	−3·0	−0·1	−2·7	0·597	Ref.	−2·6	−3·4	−7·0	0·095
Total cholesterol‡										
Mean (mg/dl)	217·6	205·1	204·6	208·9		207·0	212·5	205·8	210·9	
Adjusted mean difference	Ref.	−12·1	−14·4	−12·0	0·018	Ref.	7·9	1·2	9·2	0·476
LDL†‡										
Mean (mg/dl)	138·6	138·6	129·7	131·2		131·1	134·6	128·8	135·1	
Adjusted mean difference	Ref.	−8·2	−9·6	−9·3	0·027	Ref.	0·2	−0·0	0·3	0·488
HDL										
Mean (mg/dl)	50·6	47·5	50·8	51·1		50·6	49·6	49·6	50·5	
Adjusted mean difference	Ref.	−2·6	0·5	0·1	0·419	Ref.	−2·1	−3·1	−4·1	0·093
TAG										
Mean (mg/dl)	144·2	134·1	122·4	134·0		128·9	140·2	138·3	127·4	
Adjusted mean difference	Ref.	−14·2	−23·9	−17·5	0·063	Ref.	19·2	26·1	27·4	0·075
Hs-CRP‡										
Mean (mg/l)	3·9	4·0	3·6	3·4		3·7	3·7	4·2	3·2	
Adjusted mean difference	Ref.	−0·2	−0·5	−0·8	0·263	Ref.	0·2	0·8	0·4	0·472

Ref., referent values; Hs-CRP, high-sensitivity C-reactive protein.

* Linear trends tests were conducted to assess the associations with multivariable regression analysis by assigning the median of the observations in each quartile and computing the *P*-value for each trend. Multivariable model adjusted for: age, BMI, education, energy intake, physical activity, diabetes and smoking status.

† Calculated for participants who fasted >9 h and TAG concentrations ≤400 mg/dl according to Friedwald's equation. Alcohol consumption was not considered as covariate because it was included into the dietary patterns.

‡ Total cholesterol, LDL and Hs-CRP were log-transformed before running the ordinary linear regression models. The log-transformed means were then converted back to their usual scale.

on SFA in those at the highest quartile compared with lowest quartile and by lack of any substantial difference in carbohydrates across these quartiles[37]. Lack of association between the Western diet and the lipid profiles may be due to the combination of nutrients with opposite effects on plasmatic lipoproteins. The increase in LDL-cholesterol as consequence of higher intake of SFA and dietary cholesterol[38] may have been neutralised by the effect of higher intake of unsaturated fats, proteins with high load of lean cuts of red meat and poultry[39], which have demonstrated to reduce VLDL- and LDL- and total cholesterol, apo[40].

On the basis of differences in composition of dietary fat alone, we expected to observe a higher HDL-cholesterol[37] among those at the highest quartile of Western diet, which our data did not show. Other determinants of HDL including physical activity and alcohol use were similar across quartiles of Western diet.

A number of previous studies have examined the relationship between dietary patterns and biomarkers of inflammation and dyslipidemia using principle components analysis[27,32–34,41], however this was the first study to report the reduction of total cholesterol, LDL and apo B with a prudent diet in both sexes. Similar to ours, most previous studies did not find a significant association between prudent diet and apo A-I and HDL-cholesterol[17,18,23,25,29,30].

The results of previous studies on the association between Western diets and lipid and inflammatory profiles are mixed with several studies showing an association with higher LDL- and total cholesterol[27,28,41–43] and others reporting no associations with these lipoproteins[32–34]. All of these studies were from high-income countries. The only previous study from a middle-income country was from Brazil and showed that a 'processed food' pattern was associated with higher LDL-, HDL- and total cholesterol[41].

Our analysis had several strengths. We chose principal component analysis to derive dietary patterns because they can assess the relationship between overall diet, examining the impact of interactions between different nutrients or foods, usually providing associations with greater consistency and strength than they have been possible using analyses of single nutrients or foods. In addition, some important epidemiological studies found significant association among diet, cardiovascular risk factors and cardiovascular events with this approach[25,27,41]. Data on food intake were obtained through a validated FFQ[19].

However, our study had several limitations as well. The reported associations between dietary patterns and CVD risk factors in our cross-sectional study may not be due to causal relationships but rather due to unmeasured confounding and potential reverse causation as high-risk lipid profiles may have encouraged participants to change their diet. However, the potential for reverse causation bias is fairly small in this population as none of the participants were under lipid-lowering treatment and most participants had not checked their serum lipid profile before enrolling in this study. In addition, the reverse causality bias would lead to a positive association between plasma lipids and higher score of prudent diet; however, we observed a negative association. Measurement errors in reporting diet using the FFQ could affect our results by introducing random variation and lowering the significance of

the associations. Because dietary patterns may differ by sex, race, local culture and geographical region, our results may not be generalisable to other populations. Finally, the proportion of variance explained by the two major dietary patterns was <20 % of total variance, suggesting the potential existence of other patterns that were not identified in the present analysis. However, similar results were reported in several previous studies[28,34,41].

Our findings can have important public health implication for CVD prevention in South America. We found that a prudent diet with high intake of fruits and vegetables, seafood, whole grain and low-fat dairy products is associated with a healthier lipid profile that in itself is associated with lower cardiovascular risk[44]. In contrast, a Western diet with higher intake of both lean and fatty red meat did not affect the lipid profile substantially. The effect of red meat consumption on CVD is still a topic of debate. Some studies have reported an increased risk of ischaemic stroke[45–47], diabetes[48–50] and mortality[51,52] with higher intake of red meat, whereas others found no effect[49,53,54]. Our results may point to new avenues of enquiry in this regard. Our findings also indicate that future public health campaigns and programmes in Argentina and the Southern Cone should promote higher intake of fruits and vegetables, seafood and whole grains to reduce the burden of CVD. Follow-up of this cohort study will allow the prospective investigation of the effect of dietary patterns on various CVD and other chronic disease outcomes.

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All authors significantly contributed in the manuscript: R. P. conceived the study aims and design. A. R., V. I. contributed to interpretation of results. R. P., L. G. and N. E. performed the analysis and interpreted the results. R. P., V. E., N. E. and A. R. contributed to the interpretation of results. R. P. drafted the manuscript. A. R. revised the manuscript. R. P. is guarantor.

The authors declare that there are no conflicts of interest to declare.

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