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Association between dairy consumption and type 2 diabetes, hypertension and obesity: Results from a nationally representative survey in Chilean adults

Asociación entre consumo de lácteos y diabetes tipo 2, hipertensión y obesidad: resultados de una encuesta representativa a nivel nacional en adultos chilenos

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Abstract

Current evidence suggests an inverse or neutral association between dairy consumption and obesity, type 2 diabetes (T2D), and hypertension (HT) prevalence. However, there are no studies investigating this relationship in the adult Chilean population. Therefore, we aimed to determine the association between dairy product consumption and the prevalence of these diseases in Chilean adults. This cross-sectional study includes data from the latest Chilean National Health Survey (2016-2017), a nationally representative sample of the Chilean population. The outcomes were the prevalence of obesity, T2D, and HT. Dairy consumption was assessed by frequency (categorized as "low", "medium, " and "high", according to frequency of consumption), and types of dairy products consumed (i.e., "skimmed" and "whole-fat") all of which were self-reported. Adjusted Poisson regression models were performed to determine the prevalence ratio (PR) and 95% confidence intervals (CI). There was no association between the frequency of dairy consumption and the prevalence of obesity, T2D or HT. The preference for whole-fat dairy products was associated with a 47% lower prevalence of T2D in women (PR: 0.53; 95% CI: 0.35-0.80), 29% lower prevalence of abdominal obesity in men (PR: 0.71; 95% CI: 0.52-0.97), and 27% lower prevalence of HT in men (PR: 0.73; 95% CI: 0.57-0.92), after adjusting for potential covariates. Our study suggests that the frequency of dairy consumption is not associated with the prevalence of obesity, T2D, or HT in Chilean adults.

Keywords: Dairy. Obesity. Hypertension. Type 2 diabetes. Diet. Noncommunicable diseases.

Resumen

La evidencia actual sugiere una asociación inversa o neutra entre el consumo de lácteos y la prevalencia de obesidad, diabetes tipo 2 (T2D) e hipertensión (HT). Sin embargo, no existen estudios que investiguen esta relación en la población adulta chilena. Por lo tanto, nuestro objetivo fue determinar la asociación entre el consumo de productos lácteos y la prevalencia de estas enfermedades en adultos chilenos. Este estudio transversal incluye datos de la última Encuesta Nacional de Salud de Chile (2016-2017), una muestra representativa a nivel nacional de la población chilena. Los resultados fueron la prevalencia de obesidad, T2D y HT. El consumo de lácteos se midió según la frecuencia (categorías de "bajo", "medio" y "alto" basadas en la frecuencia de consumo) y los tipos de productos lácteos consumidos (es decir, "descremados" y "enteros") fueron autoinformados. Se realizaron modelos de regresión de Poisson ajustados para determinar la razón de prevalencia (RP) y los intervalos de confianza del 95% (IC). No se encontró ninguna asociación entre la frecuencia de consumo de lácteos y la prevalencia de obesidad, T2D o HT. La preferencia por productos lácteos enteros se asoció con una prevalencia un 47% menor de T2D en mujeres (RP: 0,53; IC 95%: 0,35-0,80), un 29% menor de obesidad abdominal en hombres (RP: 0,71; IC 95%: 0,52-0,97) y un 27% menor de HT en hombres (RP: 0,73; IC 95%: 0,57-0,92), después de ajustar por posibles covariables. Nuestro estudio sugiere que la frecuencia de consumo de lácteos no está asociada con la prevalencia de obesidad, T2D o HT en adultos chilenos.

Palabras clave: Lácteos. Obesidad. Hipertensión arterial. Diabetes tipo 2. Alimentación. Enfermedades no transmisibles.

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Introduction

Noncommunicable diseases (NCDs) represent a significant public health issue at a global level[1], being responsible for 73% of deaths, with cardiovascular disease (CVD) as the leading cause. Hypertension (HT), smoking, high blood glucose, and high body mass index (BMI) were the risk factors attributable to more than half of deaths (28.8 million)[2]. According to the World Health Organization (WHO), the current global prevalence of adult obesity and overweight is 13% and 39%, respectively[3,4]. The global prevalence of HT and diabetes in adults is around 22%[5] and 10.5%[6], respectively.

The WHO considers healthy eating habits as part of the strategies that countries should implement to reduce premature mortality from NCDs[5]. Along with sugar and sodium, saturated fats are considered critical nutrients that must be reduced to achieve a healthier, more energy-balanced diet[7]. The American College of Cardiology and the American Heart Association guidelines recommend 5% to 6% of the daily calorie intake from saturated fats to reduce cardiovascular risk[8]. Accordingly, 43% of countries with dietary guidelines indicate that saturated fats should be limited[7]. However, evidence indicates that the intake of saturated fats and the incidence of CVD depend on the dietary origin of these nutrients. A cohort study involving 6,814 adults between 45 and 84 years old showed that the intake of saturated fats coming from dairy is inversely related to the risk of CVD, while the intake of saturated fats coming from meat (beef, pork, chicken, and lamb, processed and unprocessed) is positively related[9]. Recent meta-analyses suggest an inverse association between dairy intake and the risk of type 2 diabetes (T2D)[10-15], HT[14], obesity[16], and insulin resistance[11]. Additionally, yogurt consumption has been linked to a lower incidence of T2D[13]. Concerning full-fat dairy and saturated fat from dairy, based on recent observational and clinical evidence, it has been suggested that cheese does not have a negative effect on blood pressure despite its high sodium content[17] and that whole milk products are not associated with an increased risk of obesity[18], as it has traditionally been thought. However, there is also epidemiological evidence for the adverse effects of dairy on health.

Overall, dietary guidelines recommend consuming dairy on a daily basis[8]. However, despite the varied and complete nutritional contribution of dairy to the human diet, there are concerns regarding possible harmful effects on health associated with its consumption[19], mainly due to its saturated fats[20]. Nevertheless, recent evidence suggests that total dairy intake is associated with a low risk of overweight or obesity, HT, and T2D[21].

Current Chilean Dietary Guidelines (valid until December 2022) recommend consuming low-fat and low-sugar dairy products 3 times per day to strengthen bones[22]. These guidelines were recently updated, and they no longer mention dairy fat as a critical nutrient that must be avoided[23]. At the national level, the Chilean population shows a high and growing prevalence of risk factors for NCDs, with 34.4% for obesity, 27.6% for HT, and 12.3% for T2D[24]. CVD is one of the leading causes of death, and high blood pressure, high blood glucose, and obesity are the three main risk factors associated with mortality[3]. According to this background, our study aimed to determine the association between dairy consumption and the prevalence of obesity, T2D, and HT in the Chilean adult population. We hypothesized that dairy product consumption differs by sex, age, educational level and urban/rural setting. In addition, it is essential to estimate the association between dairy consumption and risk factors related to cardiovascular diseases in Chilean adults controlled for sociodemographic variables to provide more accurate dietary recommendations for prevention of cardiovascular diseases.

Material and methods

Data source and study sample

This study was conducted using data from the Chilean National Health Survey 2016-2017 (Encuesta Nacional de Salud, ENS 2016-2017). Data were obtained from the publicly available online version of the Department of Epidemiology of the Ministry of Health of the Government of Chile[25]. The ENS 2016-2017 employed a stratified multistage sampling method and includes non-institutionalized participants over 14 years old from urban and rural regions in Chile. Detailed information about the survey has been described elsewhere[26]. A total of 6,233 subjects participated in the ENS 2016-2017. For this study, we restricted our analysis to 4,231 participants older than 20 who had complete data on food assessment, cardiovascular risk factors, and covariates (**Figure 1**). Participants who had been diagnosed with diabetes during pregnancy or who reported fasting for less than 8 hours at the time of blood sample collection were excluded from the analysis. All participants signed the written consent form. The Ethics Committee from the Pontificia Universidad Católica de Chile approved the study protocol (Number: 16–019).

Dairy consumption assessment

The assessment of dairy consumption was conducted by trained interviewers who gathered information on the self-reported frequency of dairy product consumption, preferences for other food groups, and the type of dairy products preferred. These questions were designed by experts, drawing from the food-based dietary guidelines for the Chilean population, as outlined in the ENS 2016-2017.

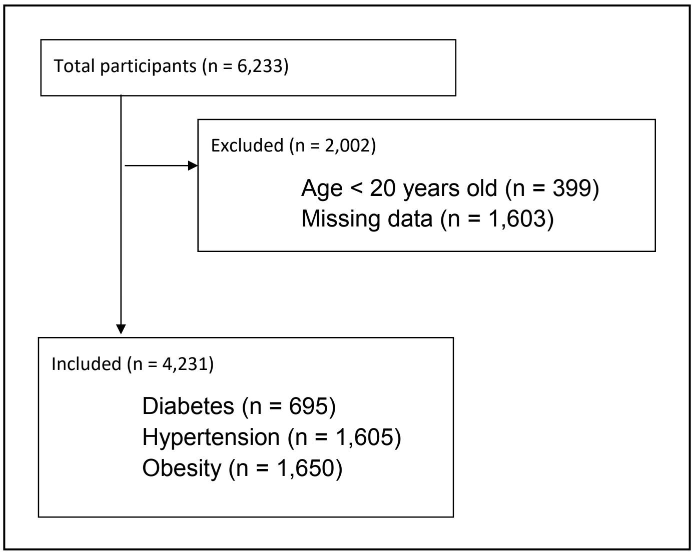

Figure 1. Flowchart of study participants.

The frequency of total dairy consumption was categorized as follows: low (occasional intake; including 'never' and 'at least once a month'); medium (regular intake, though less than recommended; including 'at least once a week' and 'once a day'); high (regular intake close to the recommended levels; including 'less than three times a day' and 'three or more times a day'). Dairy product preferences based on fat content were categorized as skimmed (including semi-skimmed, non-fat, or low-fat) and whole-fat. According to the dietary guidelines for the Chilean population in 2016-2017, the recommended dairy intake for adults was 3 servings of skimmed dairy products per day[22].

Assessment of anthropometric measurements and cardiovascular risk factors

Weight and height were measured using a digital scale (OMRON HN289, Omron Corporation, Kyoto, Japan) and a metal measuring tape, respectively. BMI was calculated based on those measurements (Kg/m^2). Waist circumference (WC) was measured at the midpoint between the lower edge of the costal margin and the iliac crest at the level of the axillary line using a plastic tape[27]. Systolic and diastolic blood pressure (SBP and DBP, respectively) measurements were the average of three measurements for each participant, using an automatic pressure apparatus (OMRON HEM 7200, Omron Corporation, Kyoto, Japan). Fasting blood glucose concentration (with at least 8 hours fasting) was measured from blood samples collected[26].

Outcomes

General obesity (based on BMI) was defined according to the WHO definition of obesity[28]. The categories used were non-obese (BMI ≥ 18.5 kg/m^2 and < 30 kg/m^2) and general obesity (BMI ≥ 30 kg/m^2). For abdominal obesity, we used the cut-off point according to NCEP ATP III[29]. WC was classified as within the normal range (WC <102 cm and <88 cm in men and women, respectively) and abdominal obesity (WC ≥ 102 cm and ≥ 88 cm in men and women, respectively). HT was defined based on the self-report of blood pressure treatment and the average of the three measurements of SBP (≥ 140 mm Hg) and DBP (≥ 90 mmHg). T2D was defined based on the self-report of diabetes diagnosis and glycemia levels (≥ 126 mg/dl) with at least 8 hours of fasting. For both HT and T2D presence, we used cut-off point definitions according to the ENS (2016-2017)[24]. The percentage of participants preferring whole-fat or skimmed dairy products calculated for healthy individuals and those with obesity, T2D, and HT.

Covariates

Trained interviewers collected socio-demographic data from all participants, including geographical area (urban vs. rural); age (years); sex (male, female); education level (<8, 8–12, >13 years of education); physical activity using the Global Physical Activity Questionnaire (categorized as low, moderate, and high); tobacco use (current smokers vs. non-smokers and former smokers); and risky alcohol consumption using the AUDIT-C questionnaire (score < 8 indicating no risky alcohol consumption, and score ≥ 8 points indicating risky alcohol consumption)[30].

Statistical analyses

Categorical data are presented as percentages, and continuous variables are shown as mean with standard error of the mean (SEM). We included the Chi-square test for comparisons of categorical variables and Student t test for comparison of mean values of BMI, weight, WC, SBP, DBP, and fasting glycemia according to the frequency of total dairy consumption and type of dairy products of preference. The association between the frequency of total dairy consumption and type of dairy products of preference and continuous outcome variables (BMI, weight, WC, SBP, DBP, and fasting glycemia) was tested using a multivariable linear regression adjusted for sex, age (categorized as 20-33, 34-47, 48-59, ≥60 years), geographical area, and educational level. Results were reported as adjusted means with SEM. The association between the frequency of total dairy consumption and the type of dairy products of preference and general obesity, abdominal obesity, HT, and T2D was tested using Poisson regression. Comparisons were made between high versus low frequency of dairy consumption (with low frequency as the reference category) and between preference for whole fat versus skimmed dairy (with skimmed dairy as the reference category).

The Prevalence Ratio (PR) and 95% confidence intervals (CI) were calculated using the following modeling strategy. Model 1 was unadjusted. Model 2 was adjusted for socio-demographic variables: sex, age, educational level, and geographical area. Model 3 was additionally adjusted for tobacco use, risky alcohol consumption, and physical activity. Model 4 included additional adjustments for dairy consumption frequency or dairy preference, as appropriate. Interaction terms were not included as covariates in the models, as no significant interactions were observed between dairy consumption and sex for any of the response variables. However, because previous studies have observed differences between men and women in the association between dairy consumption and the presence of some diseases[14], and because our analysis also shows relevant differences between sexes, the The association results are presented separately for all participants, men, and women. A P-value < 0.05 was considered for statistical significance. We used the "svy" and "subpop" commands in Stata/MP 16.0 software (Stata Corporation, College Station, TX) to apply survey weights to allow a sample to be representative of the Chilean population and account for the complex design of the ENS 2016-2017.

Results

General characteristics of the population according to the frequency and preference of dairy consumption

Table 1 shows the general characteristics of the studied sample. Participants were less than 33 years old, who live in urban areas and have higher education levels and had a higher frequency of dairy consumption. Men showed a higher preference for whole-fat dairy, while women preferred skimmed products. Older participants chose to consume skimmed dairy products. In rural areas, people showed a preference for whole-fat dairy products, while in urban areas, they showed a preference for skimmed dairy

Table 1. General characteristics of participants according to the frequency and preference of dairy consumption.

			Frequency of dairy consumption							Type of preferred dairy product				
	Total		Low		Medium		High			Skimmed		Whole fat		
	N	%	N	%	n	%	N	%	*P*-value	n	%	N	%	*P*-value
Total	4,231	100.0	273	6.5%	3,322	78.5%	635	15.0%		1,896	44.8%	2,335	55.2%	
Sex														
Men	2,077	49.1%	124	6.0%	1,639	78.9%	313	15.1%	0.8004	802	38.6%	1,275	61.4%	0.0000*
Women	2,154	50.9%	149	6.9%	1,683	78.1%	322	15.0%		1,094	50.8%	1,061	49.2%	
Age														
20-33	1,215	28.7%	70	5.7%	866	71.2%	279	23.0%	0.0000*	482	39.7%	732	60.3%	0.0246*
34-47	1,141	27.0%	92	8.1%	925	81.1%	123	10.8%		501	44.0%	640	56.1%	
48-59	910	21.5%	63	6.9%	749	82.3%	98	10.8%		415	45.6%	495	54.4%	
60+	966	22.8%	49	5.0%	783	81.1%	135	13.9%		497	51.5%	469	48.6%	
Area														
Urban	3,785	89.5%	232	6.1%	2,966	78.3%	588	15.5%	0.0157*	1761	46.5%	2,024	53.5%	0.0000*
Rural	446	10.5%	41	9.3%	357	80.1%	48	10.7%		135	30.2%	311	69.8%	
Education level														
Low	713	16.8%	54	7.5%	554	77.7%	105	14.8%	0.0022*	263	36.9%	449	63.1%	0.0000*
Medium	2,233	52.8%	167	7.5%	1,797	80.5%	269	12.1%		921	41.2%	1.312	58.8%	
High	1,285	30.4%	53	4.1%	971	75.6%	261	20.3%		712	55.4%	574	44.6%	

The frequency of dairy consumption was categorized as low ('never' and 'at least once a month'), medium ('at least once a week' and 'once a day'), and high ('less than 3 times a day' and '3 or more times a day'). The dairy product of preference corresponds to the question: what type of dairy products (milk, yogurt, cheese, or fresh cheese) do you prefer? Whole or skimmed, semi-skimmed or low-fat. The educational level was categorized as low (less than 8 years of study), medium (between 8 and 12 years of study), and high (more than 12 years of study). P-values were calculated from the Chi-square test for categorical variables by a complex sample (*$P < 0.05$).

products. Participants with higher education preferred to consume skimmed dairy, while lower education categories preferred whole-fat dairy.

Prevalence of obesity, hypertension, and type 2 diabetes according to the frequency and preference of dairy consumption.

The prevalence of general and abdominal obesity, hypertension, and T2D according to dairy consumption is presented in **figure 2**. It was observed that those who consume dairy more frequently have a significantly lower prevalence of hypertension (high: 22%; low: 28%; p = 0.0236). At the same time, no significant differences were observed for obesity (general and abdominal) and T2D (**Figure 2A**). On the other hand, those who preferred whole-fat dairy had a lower prevalence of abdominal obesity (whole-fat 45%; skimmed: 51%; p = 0.0016), hypertension (whole-fat: 26%; skimmed: 33%; p = 0.0031) and T2D (whole-fat: 10%; skimmed: 16%; p = 0.0002) (**Figure 2B**). The prevalence of obesity, HT, and T2D according to participants' characteristics are presented in **table 2**.

BMI, weight, WC, SBP, DBP, and glycemia levels according to frequency and type of dairy consumption

BMI, DBP, and glycemia showed a significant inverse association with high versus low frequency of dairy consumption (BMI: 28.0 vs. 29.8 kg/m^2; DBP: 72.9 vs. 75.9 mm Hg; glycemia: 92.8 versus 96.5 mg/dl, p < 0.05, respectively). No significant differences were observed between preference for whole fat versus skimmed dairy (**Table 3**). Results from multiple linear regression models showed a significant inverse association between BMI, weight, and DBP, and high versus low frequency of dairy intake (BMI: 28.0 versus 29.8 kg/m^2; weight: 75.2 versus 78.7 kg, DBP: 72.9 versus 75.9 mm Hg, p<0.05, respectively), after adjusting for gender, age, geographical area, and educational level. No significant differences were observed between preference for whole fat versus skimmed dairy (**Table 3**).

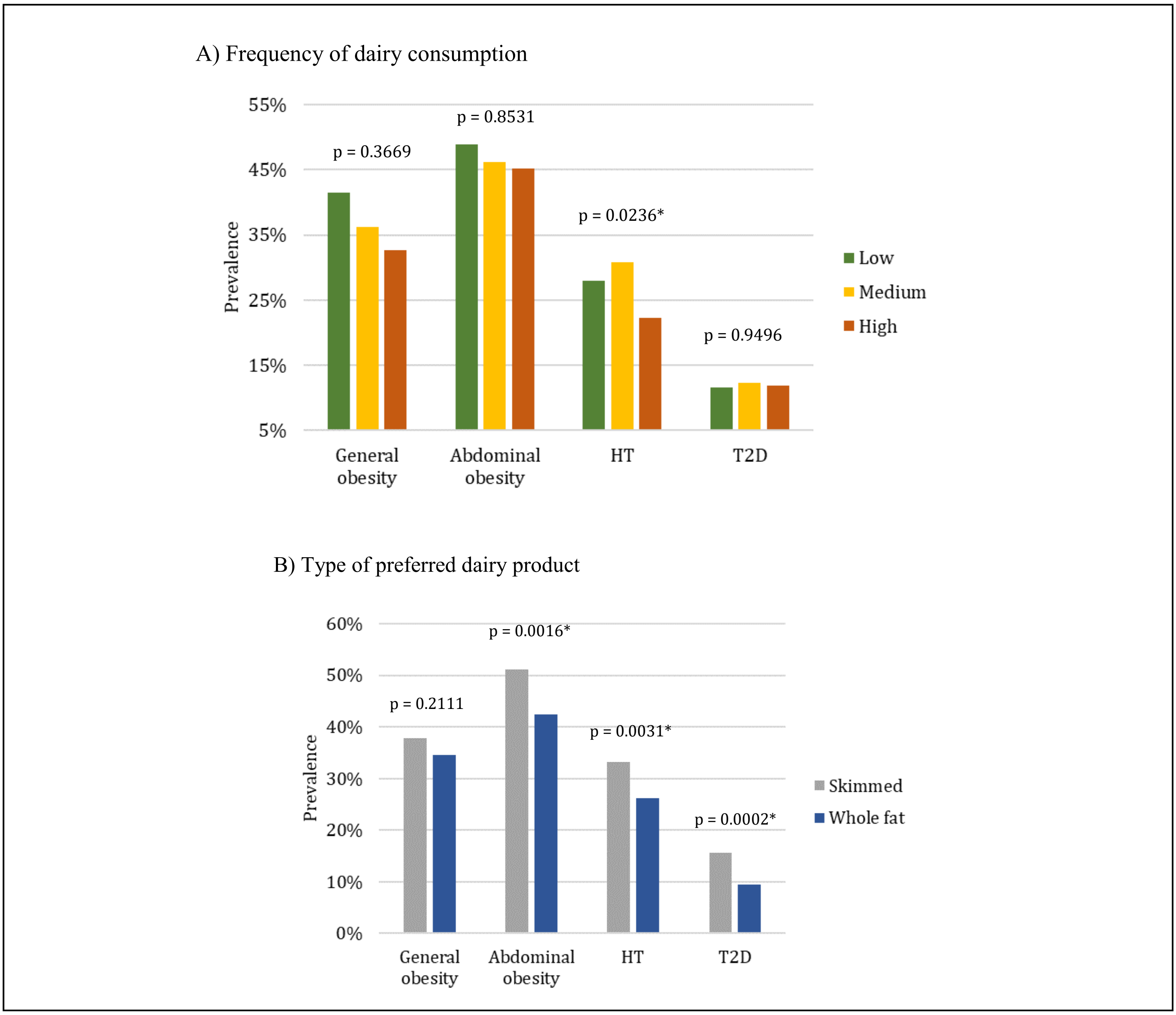

Figure 2. Prevalence of general obesity, abdominal obesity, HTA, and T2D according to the frequency (A) and preference (B) of dairy consumption in Chilean adults.
P-values were calculated from the Chi-square test for categorical variables (*P < 0.05). HT: hypertension; T2D: type-2 diabetes.

Table 2. Prevalence of general and abdominal obesity, HT, and T2D according to the participant's characteristics.

		Total		General obesity			Abdominal obesity			HT			T2D		
		n	%	n	%	p-value	N	%	p-value	n	%	p-value	n	%	p-value
Total		4,231	100.0%	1,650	36.0%		2,264	46.2%		1,605	29.3%		695	12.2%	
Sex															
	Men	2,077	49.1%	649	31.3%	0.0005*	557	26.8%	0.0000*	611	29.4%	0.9547	217	10.5%	0.0354*
	Women	2,154	50.9%	875	40.6%		1,399	64.9%		630	29.3%		301	14.0%	
Age															
	20-33	1,215	28.7%	352	29.0%	0.0049*	399	32.9%	0.0000*	43	3.5%	0.0000*	31	2.5%	0.0000*
	34-47	1,141	27.0%	465	40.8%		525	46.0%		157	13.7%		86	7.5%	
	48-59	910	21.5%	353	38.8%		504	55.4%		395	43.4%		144	15.9%	
	60+	966	22.8%	353	36.5%		528	54.7%		647	67.0%		258	26.7%	
Zone															
	Urban	3,785	89.5%	1,324	35.0%	0.0023*	1,718	45.4%	0.0172*	1,083	28.6%	0.0160*	458	12.1%	0.4098
	Rural	446	10.5%	199	44.8%		238	53.5%		158	35.5%		61	13.6%	
Education level															
	Low	713	16.8%	317	44.5%	0.0005*	431	60.5%	0.0000*	420	59.0%	0.0000*	166	23.4%	0.0000*
	Medium	2,233	52.8%	830	37.2%		1,080	48.4%		617	27.6%		261	11.7%	
	High	1,285	30.4%	376	29.3%		446	34.7%		204	15.9%		91	7.0%	

Data extracted from the Chilean National Health Survey 2016-2017 database. All the data, except for the sample sizes, were calculated using the expansion factors according to the sample design of the survey. General obesity is defined as those participants with a BMI ≥ 30. Cut-off point according to WHO. Abdominal obesity is defined as waist circumference in men ≥ 102 cm and women ≥ 88 cm. Cut-off point according to NCEP ATP III. HT is suspected arterial hypertension and is constructed from the self-report of blood pressure treatment and the average of the three systolic blood pressure measurements (greater than or equal to 140 mm Hg) and diastolic blood pressure (greater than or equal to 90 mm Hg. T2D is suspected of diabetes mellitus and is constructed from the self-report of diabetes and blood glucose levels (greater than or equal to 126 mg/dl) with fasting of 8 hours or more. In addition, people who declare having had gestational diabetes are excluded.). HT and T2D cut-off points according to the Chilean National Health Survey 2016-2017. The educational level was categorized as 'low' (less than 8 years of study), 'medium' (between 8 and 12 years of study), and 'high' (more than 12 years of study). P-values were calculated from the Chi-square test for categorical variables (*$p < 0.05$).

Association between dairy consumption and obesity, HT and T2D

Regarding the frequency of dairy consumption, no significant associations were observed with obesity, HT, and T2D (**Table 4**). However, significant associations were observed between dairy preference and abdominal obesity and HT in men, and T2D in women after adjusting for age, geographical area, educational level, smoking, alcohol consumption, physical activity level, and dairy consumption frequency (**Table 5**). No significant associations were observed between a preference for dairy consumption and general obesity. In the comparison of the preferential consumption of whole-fat dairy with skimmed dairy, a PR of 0.53 (95% CI: 0.35-0.80) was observed for T2D in women, a PR of 0.71 (95% CI: 0.52-0.97) observed for abdominal obesity in men, and a PR of 0.73 (95% CI: 0.57-0.92) observed for HT in men (**Table 5**).

Discussion

Our study results revealed no association was observed between the frequency of dairy consumption and the prevalence of obesity, T2D, or HT in this nationally representative sample of Chilean adults. In contrast, a significant association between the preference for whole-fat dairy products and a lower prevalence of abdominal obesity and HT in men and T2D in women was found.

Diabetes

The preference for whole-fat dairy products was significantly associated with a 47% lower prevalence of T2D in women (PR = 0.53; 95% CI: 0.35-0.80), after adjusting for age, area, educational level, smoking, risky alcohol consumption, level of physical activity and frequency of dairy consumption. Previous observational studies show that high consumption of total dairy, particularly low-fat dairy and yogurt, compared to low consumption, is mainly associated with a lower risk of T2D[10,13]. Meanwhile, systematic reviews and meta-analyses of observational studies indicate no association, particularly between high-fat dairy products and the risk of T2D[10,13]. However, a meta-analysis that included 16 prospective cohort studies found that higher levels of pentadecanoic acid (15:0), heptadecanoic acid (17:0), and *trans*-palmitoleic acid (t16:1n-7) (biomarkers of consumption of milk fat) were associated with a lower risk of T2D[31]. Randomized controlled trial (RCT) studies, although suggesting a null or slight inverse effect of dairy intake on the risk of T2D, have not shown very consistent results concerning total dairy consumption and its fat content[15]. A recent RCT study designed to compare high-fat versus low-fat dairy-rich diets' effect on glucose tolerance in people with metabolic syndrome found that neither diet improved glucose tolerance, with both diets showing a modest reduction of insulin resistance. Although the authors raise possible mechanisms that could explain the unexpected results, they also conclude that it is not clear how exposure to dairy may impact the development of T2D in the long term[32].

Although the results of our study showed a strong association between the consumption of full-fat dairy products and a lower prevalence of T2D in adult Chilean women, due to the nature of the study, it is not possible to indicate that

Table 3. BMI, waist circumference (WC), diastolic and systolic blood pressure (DBP and SBP, respectively), and glycemia levels according to frequency and type of preferred dairy product consumption in Chilean adults.

	Frequency of dairy consumption			
	Low	**Medium**	**High**	***P*-value**
Total (n)	273	3322	635	
BMI (kg/m²)	29.79 ± 0.64	28.99 ± 0.14	28.01 ± 0.31[bc]	0.0102*
WC (cm)	95.01 ± 2.07	94.66 ± 0.36	92.81 ± 0.82[c]	0.2990
SBP (mm Hg)	125.93 ± 1.45	125.13 ± 0.53	122.71 ± 1.46	0.7881
DBP (mm Hg)	75.97 ± 0.98	75.19 ± 0.30	72.90 ± 0.68[bc]	0.0068*
Glycaemia (mg/dl)	96.52 ± 1.52	97.01 ± 0.61	92.84 ± 0.87[bc]	0.1014

	Type of preferred dairy products		
	Skimmed	**Whole fat**	***P*-value**
Total (n)	1896	2335	
BMI (kg/m²)	29.15 ± 0.20	28.68 ± 0.17	0.0850
WC (cm)	94.70 ± 0.48	94.17 ± 0.47	0.1924
SBP (mm Hg)	124.95 ± 0.71	124.72 ± 0.65	0.6980
DBP (mm Hg)	74.59 ± 0.39	75.14 ± 0.37	0.5357
Glycaemia (mg/dl)	97.49 ± 0.92	95.43 ± 0.54	0.0733

BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure. Student t-test was conducted to compare group means: significant differences in the frequency of dairy consumption were marked with an (a) for low versus medium, (b) for low versus high, and (c) for medium versus high. All values represent means ± standard error of the mean. P-values obtained from multiple linear regression models adjusted for sex, age, geographical area, and educational level (* P < 0.05).

Table 4. Association between frequency of dairy consumption and general and abdominal obesity, HT and T2D in Chilean adults.

	Association between high and low frequency of dairy consumption								
	All participants			Men			Women		
	PR	(95% CI)	p-value	PR	(95% CI)	p-value	PR	(95% CI)	p-value
General obesity									
Model 1	0.79	(0.57-1.10)	0.158	0.87	(0.48-1.58)	0.795	0.75	(0.52-1.09)	0.133
Model 2	0.84	(0.60-1.17)	0.301	0.88	(0.48-1.59)	0.665	0.82	(0.55-1.22)	0.331
Model 3	0.84	(0.56-1.26)	0.405	0.85	(0.44-1.65)	0.626	0.85	(0.53-1.37)	0.506
Model 4	0.87	(0.57-1.31)	0.494	0.86	(0.44-1.72)	0.677	0.85	(0.53-1.37)	0.512
Abdominal obesity									
Model 1	0.92	(0.70-1.21)	0.571	0.96	(0.49-1.89)	0.900	0.96	(0.77-1.20)	0.715
Model 2	1.00	(0.79-1.26)	0.990	1.03	(0.53-1.97)	0.940	1.00	(0.79-1.26)	0.993
Model 3	1.11	(0.81-1.52)	0.526	1.19	(0.60-2.38)	0.621	1.07	(0.78-1.46)	0.668
Model 4	1.16	(0.82-1.63)	0.409	1.10	(0.55-2.19)	0.787	1.08	(0.79-1.47)	0.640
HT									
Model 1	0.80	(0.54-1.16)	0.239	0.75	(0.43-1.32)	0.321	0.84	(0.50-1.40)	0.501
Model 2	0.83	(0.62-1.11)	0.206	0.82	(0.54-1.23)	0.329	0.84	(0.55-1.26)	0.395
Model 3	0.81	(0.55-1.19)	0.275	0.90	(0.57-1.41)	0.648	0.70	(0.33-1.48)	0.352
Model 4	0.75	(0.51-1.11)	0.480	0.85	(0.54-1.32)	0.463	0.69	(0.33-1.45)	0.323
T2D									
Model 1	1.01	(0.54-1.89)	0.966	1.59	(0.68-3.73)	0.284	0.82	(0.38-1.78)	0.619
Model 2	1.07	(0.62-1.85)	0.810	1.69	(0.77-3.70)	0.189	0.85	(0.42-1.71)	0.649
Model 3	1.28	(0.70-2.33)	0.423	1.52	(0.63-3.67)	0.349	1.14	(0.53-2.45)	0.739
Model 4	1.18	(0.65-2.14)	0.588	1.46	(0.60-3.54)	0.402	1.00	(0.48-2.10)	0.998

Data extracted from the 2016-2017 Chilean National Health Survey database. All data was calculated using the expansion factors according to the survey sample design. PR, prevalence ratios; 95% CI, 95% confidence intervals. HT: hypertension; T2D; Type-2 diabetes. Poisson regression analyses were used to estimate the PRs for general obesity, abdominal obesity, HT and T2D in the participants surveyed in the 2016-2017 Chilean National Health Survey, in four models: Model 1, unadjusted; Model 2 was adjusted for sociodemographic variables: sex, age, educational level, and geographical area; Model 3 was additionally adjusted for tobacco use, risky alcohol consumption, and physical activity; Model 4 was additionally adjusted for dairy preference variable (whole-fat dairy or skimmed dairy). P values were obtained from Poisson regression models with general obesity, abdominal obesity, HT and T2D as out-comes.

Table 5. Prevalence Ratios (PR) and 95% confidence intervals (CI) for general and abdominal obesity, HT, and T2D according to preference of dairy products (whole-fat or skimmed) in Chilean adults.

	Association between whole-fat and skimmed dairy products								
	All participants			Men			Women		
	PR	(95% CI)	p-value	PR	(95% CI)	p-value	PR	(95% CI)	p-value
General obesity									
Model 1	0,91	(0,79-1,05)	0,210	0,85	(0,67-1,09)	0,212	1,01	(0,85-1,19)	0,913
Model 2	0,90	(0,77-1,04)	0,150	0,85	(0,66-1,10)	0,223	0,94	(0,80-1,11)	0,480
Model 3	0,92	(0,75-1,11)	0,378	0,83	(0,62-1,11)	0,214	1,03	(0,81-1,31)	0,805
Model 4	0,93	(0,76-1,14)	0,471	0,88	(0,65-1,19)	0,390	1,03	(0,81-1,31)	0,815
Abdominal obesity									
Model 1	0,83	(0,74-0,93)	0,002**	0,77	(0,59-1,00)	0,052	0,98	(0,88-1,09)	0,713
Model 2	0,91	(0,82-1,02)	0,096	0,75	(0,57-0,98)	0,034*	0,98	(0,89-1,09)	0,720
Model 3	0,92	(0,80-1,07)	0,284	0,71	(0,52-0,97)	0,032*	1,06	(0,92-1,22)	0,402
Model 4	0,82	(0,70-0,96)	0,015*	0,71	(0,52-0,97)	0,032*	1,06	(0,92-1,22)	0,402
HT									
Model 1	0,79	(0,67-0,92)	0,003**	0,76	(0,60-0,96)	0,024*	0,81	(0,66-1,00)	0,051
Model 2	0,85	(0,74-0,98)	0,028*	0,77	(0,63-0,94)	0,011*	0,97	(0,80-1,17)	0,715
Model 3	0,78	(0,64-0,94)	0,010*	0,73	(0,58-0,92)	0,008**	0,92	(0,68-1,25)	0,588
Model 4	0,79	(0,66-0,95)	0,012*	0,73	(0,57-0,92)	0,007**	0,90	(0,66-1,22)	0,502
T2D									
Model 1	0,61	(0,47-0,79)	0,000**	0,75	(0,49-1,16)	0,191	0,54	(0,40-0,74)	0,000**
Model 2	0,67	(0,52-0,86)	0,002**	0,80	(0,51-1,26)	0,335	0,59	(0,45-0,79)	0,000**
Model 3	0,74	(0,54-1,03)	0,072	0,80	(0,46-1,37)	0,408	0,52	(0,34-0,79)	0,003**
Model 4	0,63	(0,44-0,89)	0,009**	0,80	(0,47-1,38)	0,425	0,53	(0,35-0,80)	0,003**

Data extracted from the 2016-2017 Chilean National Health Survey database. All data was calculated using the expansion factors according to the survey sample design. PR, prevalence ratios; 95% CI, 95% confidence intervals. HT: hypertension; T2D; Type-2 diabetes. Poisson regression analyses were used to estimate the PRs for general obesity, abdominal obesity, HT and T2D in the participants surveyed in the 2016-2017 Chilean National Health Survey, in four models: Model 1, unadjusted; Model 2 was adjusted for sociodemographic variables: sex, age, educational level, and geographical area; Model 3 was additionally adjusted for tobacco use, risky alcohol consumption, and physical activity; Model 4 was additionally adjusted for frequency of dairy consumption variable. P values obtained from the Poisson regression models with general obesity, abdominal obesity, HT, and T2D as outcomes (* $p < 0.05$; ** $p < 0.01$).

there is a causal effect, nor is it clear why an association is observed in women, but not in men. Although most of the observational studies suggest that low-fat dairy products could influence the development of diabetes, as mentioned previously, some milk-specific fatty acids may also play a role in this discussion. One mechanism that could relate to the effect of *trans*-palmitoleic acid, which in previous observational studies has shown a strong association with a lower incidence of diabetes. In a prospective analysis among 2,617 US adults who participated in the Multi-Ethnic Study of Atherosclerosis, higher levels of *trans*-palmitoleic acid were associated with a 48% lower risk of incident diabetes (HR: 0.52; CI 95 % 0.32-0.85). The results were similar for men and women[33].

Obesity

Men who preferred to consume full-fat dairy had a 29% lower prevalence of abdominal obesity (PR = 0.71; 95% CI: 0.52-0.97), after adjusting for covariates. This association was not significant for women. Although, an inverse association trend was observed between the prevalence of general obesity, abdominal obesity, and frequency of dairy consumption. However, these associations were not statistically significant in the Poisson regression models, for both men and women. On the one hand, the results of this study do not differ much from other cross-sectional studies where an inverse[16] and null[34] association has been observed between higher consumption of dairy products and a lower risk of obesity in adults. Moreover, the only two studies conducted in South America (Brazil) in adults included in the meta-analysis by Wang *et al*., reported non-significant associations between total dairy consumption and abdominal obesity and obesity according to BMI[16]. However, a cross-sectional study of 114,682 Dutch adults found that total dairy and reduced-fat dairy consumption was positively associated with overweight and obesity[35], whereas an inverse association was observed between full-fat dairy products and obesity (Q5 OR for obesity: 0.78; 95% CI: 0.73-0.83)[35]. Similarly, the results of our study show that full-fat dairy products were associated with less abdominal obesity. What is not clear from the results of our study is why a preference for full-fat dairy is associated with less abdominal obesity but not general obesity and why there is a significant association with abdominal obesity in men but not women. On the one hand, it is worth mentioning that although the PR when comparing whole-fat dairy to skimmed dairy for general obesity in men was not statistically significant, the values were similar to those of abdominal obesity, suggesting that the lack of association could be explained by the statistical reasons of the sample rather than by differences between types of obesity. Regarding gender differences, previous studies have observed differences between men and women. Although they have been unable to provide a reason, some possible explanations have been proposed[14]. However, it is important to mention that the prevalence of abdominal obesity was markedly different between men and women (27% and 65%, respectively; p < 0.0001). This difference between genders could have influenced the association between dairy consumption and abdominal obesity.

Hypertension

The preference for whole milk products was significantly associated with a 27% lower prevalence of hypertension in men (PR = 0.73; 95% CI 0.57-0.92), but no significant association was observed in women. Previous observational studies have reported an inverse association between dairy consumption, particularly low-fat dairy, and HT[14]. A meta-analysis that included 9 prospective cohort studies, including 57,256 adults from Europe and the United States, observed that total dairy intake was linearly associated with the incidence of hypertension with a relative risk of 0.97 (95% CI 0.95-0.99) for 200 g/d. In addition, the consumption of low-fat dairy products was linearly and inversely associated with the incidence of hypertension (RR 0.96; 95% CI 0.93-0.99), while high-fat dairy products showed no association (RR 0.99; 95% CI 0.95-1.03)[36]. One study comparing blood pressure with consumption of whole or skimmed dairy with data obtained from the 2016-2017 Chilean Health Survey found that consumption of skimmed dairy products was protectively associated with high blood pressure in the unadjusted model but not in the adjusted model[37]. An RCT in 49 older adults with high blood pressure found that 4 servings of low-fat dairy in the diet for 3 weeks significantly reduced SBP and pulse pressure[38]. Another RCT in 76 Canadian adults with mild to moderate HT found that 3 daily servings of dairy (reduced-fat milk, yogurt, and cheese) significantly reduced mean daily ambulatory SBP in men but not women[39].

Differences between men and women

In the present study, it has been observed that the preference for whole dairy was associated with a lower prevalence of HT and abdominal obesity in men, which does not occur in women. Likewise, the preference for whole-fat dairy products was associated with a lower prevalence of T2D in women, which does not appear in men. Some hypotheses have been proposed to explain a differentiated effect between men and women: i) some studies have reported that sex can be a confounding variable on the impact of dairy consumption over the response variables related to metabolic pathways, such as metabolic syndrome, T2D, and others. The mechanisms involved are not precise, but it has been suggested that sex hormones might be involved[14]; ii) the intake of food groups that may contribute to the development of T2D, HT, and obesity could be different between men and women. In this study, significant differences were observed in both sexes' preference for whole and skimmed dairy products: while 51% of women preferred to consume skimmed dairy products, just 39% of men chose them (p < 0.0001). Data from the National Food Consumption Survey (ENCA in Spanish) in Chile showed similar results, with men consuming proportionally more high-fat dairy while women consuming more low-fat dairy[40]. The ENCA also reported significant differences between men and women regarding the intake of other food groups. Proportionally, men consume more meat, legumes, sugary drinks, and especially alcohol, while women consume more vegetables. No major differences are reported in other food groups. Concerning nutrients, the intake above the acceptable upper limit for sodium was higher in men than in women. For example, between the ages of 51 and 70, 93% of men exceed the acceptable upper limit for sodium, while 67% of women exceed it[40]. On the other hand, although grouping foods may be helpful and necessary for specific analyses, it should be considered that there are important differences between types of dairy products regarding nutrients and nutritional compounds[14]. The differences between men and women could be considered in statistical models that include more covariates related to dietary factors, which were not included in this study. Finally, iii) men and women may have different perceptions of their diseases and might take different measures for their control and treatment[41]. Further studies are needed to determine whether these behaviors may impact dairy consumption's effect on men's and women's health.

Mechanisms involved in beneficial effects

Multiple mechanisms have been described regarding the effect of dairy on human health. To understand them and their impact on metabolism, the complexity of the dairy matrix must be considered. The dairy matrix is made up of various nutrients and bioactive compounds in the different types of dairy products (fermented, non-fermented, whole, skimmed, etc.). Some proposed mechanisms are: i) the effect of calcium on fat absorption (calcium intake was related to the excretion of fat in the feces[42] and on lipid metabolism due to the decrease in intra-adipocyte calcium[43]; ii) the effect that milk proteins have on satiety and the stimulation of insulin secretion through their supply of branched-chain amino acids[44]; iii) the effect of bioactive peptides on the regulation of vasoconstriction through the inhibition of ACE-I[43]. Milk proteins have been shown to significantly lower SBP, DBP, 24-hour ambulatory BP, and other CVD risk markers, including total cholesterol and triglycerides[45,46]; iv) the effect of trans-palmitoleic acid on insulin resistance[33]; and v) the suggested effect of probiotics on metabolic health, by positively modulating host intestinal microbiota[47,48]. On the other hand, although dairy products have been blamed for contributing negatively to CVD because they are an important source of saturated fat, the results of short-term intervention studies have shown that whole milk would increase LDL-C. At the same time, high-density lipoprotein cholesterol (HDL-C) would also increase and thus may not influence or even decrease the ratio of total cholesterol:HDL-C[49]. Likewise, a randomized crossover study found a similar effect of consuming whole milk versus skim milk on total cholesterol, LDL-C, and triglycerides[50]. In this regard, consuming dairy with either regular or low-fat content does not adversely affect the risk of CVD[51,52].

Strengths and limitations of the study

Among the strengths of our study, we would like to mention that we worked with a representative sample of the Chilean adult population. Among limitations, given the type of dietary questions used, we could not separately analyze the frequency of consuming milk, cheese, yogurt, or other dairy products. Also, we did not have information on portion sizes consumed. Importantly, since this was a cross-sectional study, we cannot speak of causality; we can only speak of the association between studied variables. In addition, although our results were adjusted for sociodemographic variables such as gender, age, educational level, geographic area, tobacco use, alcohol consumption, and physical activity level, it is possible that the results could be influenced by additional demographic and dietary factors not accounted in our analysis and that could be related to the presence of obesity, HT and T2D in our sample.

Conclusion

We found no association between the frequency of dairy consumption and obesity, HT, or T2D in Chilean adults. Strong associations were observed between the preference for whole-fat dairy products and a lower prevalence of abdominal obesity and HT in men, as well as a lower prevalence of T2D in women, within this nationally representative sample of the Chilean adult population. The important differences between men and women regarding the association of whole-fat dairy products with the prevalence of obesity, HT, and T2D, should be considered in future research. Future observational and intervention studies must clarify the association between dairy consumption and obesity, HT, and T2D in adults. Studies should be designed for this purpose, including appropriate follow-up over time, differentiating between types of dairy products, and evaluating potential gender differences and confounding variables.

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Conflicts of interest

C. F., and R.V have worked with organizations or companies producing dairy products. R.V., S.D. and RC are members of a scientific advisory committee of the organization that brings together dairy producers in Chile (Consorcio Lechero).

Author contributions

The authors have equally contributed to the conception, design, collection, analysis, and/or interpretation of data, and have contributed to the writing and intellectual content of the article.

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