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Total Fermented Dairy Food Intake Is Inversely Associated with Cardiovascular Disease Risk in Women

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ABSTRACT

Background: The relation between fermented dairy consumption and type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) in an Australian population remains to be established.

Objectives: The aim of this study was to investigate the association between fermented dairy consumption and T2DM and CVD risk.

Methods: The Australian Longitudinal Study on Women's Health included Australian women (aged 45–50 y) at baseline in 2001, who were followed up through 5 surveys until 2016. Dietary intake was assessed through the use of a validated 101-item FFQ at baseline. Main study outcomes were self-reported physician-diagnosed T2DM and CVD. Logistic regression models adjusted for sociodemographic and lifestyle factors were used to estimate the association between dairy intake and T2DM and CVD risk.

Results: Of 7633 women free of diabetes at baseline, 701 (9.2%) developed T2DM during a maximum 15-y follow-up period. Women in the highest tertile of yogurt intake had lower adjusted odds of T2DM than those in the lowest tertile (OR: 0.81; 95% CI: 0.67, 0.99; P = 0.041). This relation became nonsignificant after adjustment for dietary variables and total energy intake (OR: 0.88; 95% CI: 0.71, 1.08; P = 0.21). Of 7679 women free of CVD at baseline, 835 (10.9%) cases of CVD were reported during follow-up. High intake of yogurt and total fermented dairy was associated with lower CVD risk (OR: 0.84; 95% CI: 0.70, 1.00; P = 0.05, 0.80; 0.67, 0.96; 0.017, respectively) than observed in the lowest tertile of dairy product intake. Additional adjustment attenuated the relation (OR: 0.87; 95% CI: 0.72, 1.04; P = 0.13, 0.83; 0.69, 1.00; 0.048, for yogurt and total fermented dairy, respectively). No associations were found with other dairy groups.

Conclusion: The findings from this population-based study of Australian women suggest an inverse association between total fermented dairy intake and CVD risk, which may partly be accounted for by other dietary components.

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Keywords: dairy, fermented dairy, yogurt, cheese, type 2 diabetes mellitus, coronary heart disease, stroke, cardiovascular disease, women's health, Australia

Introduction

Type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) are a considerable health burden in Australia (1, 2). In recent years, there has been increasing interest in the relation between dairy consumption—particularly the health-promoting potential of fermented dairy products (3)—and T2DM and CVD risk (4, 5).

As for T2DM risk, recent meta-analyses including prospective cohort studies found a nonlinear inverse association for yogurt intake and incident T2DM (6, 7). In agreement with these findings, a recent systematic review including meta-analyses of prospective cohort studies supports with high-quality evidence a favorable relation between yogurt consumption and T2DM risk (8). Although the overall evidence indicates that yogurt intake is associated with a lower T2DM risk (6, 8), this was not confirmed in Australian populations per se (9, 10). Nevertheless, the latter is based on an insufficient number of studies, and these studies did not report detailed analyses for all dairy products (9, 10). In addition, the overall association between other dairy groups (i.e., total cheese, total milk, and total dairy) and T2DM risk was either inverse or neutral, whereas in the subgroup analyses stronger inverse associations were found for Australia than for America and Europe (6).

As for CVD risk, a recent dose-response meta-analysis of 29 prospective cohort studies observed an inverse association...
for intake of total fermented dairy (i.e., sour milk products, cheese, and yogurt) with CVD risk (11). The inverse association for total fermented dairy, as well as other dairy groups, including total cheese, total milk, and total dairy, was more pronounced for Australia than for Europe. However, these observations are restricted to 2 prospective cohort studies in Australian populations only (12, 13), of which 1 study reported a null association for yogurt intake and CVD mortality (12), and the other did not include fermented dairy products as an exposure variable (13).

Given the limited data and discrepancies regarding the relation between fermented dairy products and T2DM and CVD, further research is warranted in Australian populations, and particularly in a middle-aged cohort given their high risk of developing these diseases. Hence, the aim of the present study was to examine the association of fermented and nonfermented dairy consumption in relation to T2DM and CVD risk in a population-based study of adult Australian women.

**Methods**

**Study design and population**

The Australian Longitudinal Study on Women’s Health (ALSWH) is an ongoing population-based prospective cohort study examining the health and well-being of >58,000 Australian women. Full details on the study design, recruitment methods, and response have been published previously (14, 15). Briefly, women were selected from the national Medicare health insurance database, including all Australian citizens and permanent residents. Four age cohorts were sampled, namely, women born in 1989–1995, 1973–1978, 1946–1951, and 1921–1926. Women from rural and remote areas were intentionally oversampled. Informed consent was obtained from all participants at each survey with ethical clearance obtained from the Human Research Ethics Committees of the University of Newcastle and the University of Queensland, Australia.

The present study included data from the 1946–1951 age cohort. This cohort of women has been surveyed every 2–3 years since the start of the ALSWH in 1996. Based on the initial response of 13,715 to survey 1, response rates for surveys 2–8 were \( n = 12,338 \) (90.0%), \( n = 11,226 \) (81.8%), \( n = 10,905 \) (79.5%), \( n = 10,638 \) (77.6%), \( n = 10,011 \) (73.0%), \( n = 9151 \) (66.7%), and \( n = 8622 \) (62.9%), respectively (16). Dietary intake was first collected at survey 3 in 2001 and used as baseline for the present study. Dietary intake was also collected at surveys 5–7. However, at surveys 5 and 6, dietary intake was assessed as frequencies and was not expressed as grams per day.

Data were excluded for women who had missing data on dietary intake \((n = 597)\), reported implausible energy intake according to fixed cut-off values of \(<2093 \text{kJ}\) or \(>14,654 \text{kJ}\) \((n = 117)\) (17), or had missing values for confounders \((n = 1764)\), resulting in a total sample of \(n = 8748\) in the complete case cohort (Supplemental Table 1).

**Assessment of health outcomes**

Physician-diagnosed T2DM and CVD was self-reported. At each survey, women were asked whether they had been diagnosed or treated for diabetes in the past 3 years, which corresponds to the interval since the previous survey. In survey 3, diabetes was differentiated into type 1 diabetes mellitus (T1DM) and T2DM, whereas in surveys 4–8 diabetes was not differentiated. However, T1DM was unlikely to occur during surveys 4–8, given that all prevalent cases of T1DM and T2DM were excluded at baseline (survey 3). Furthermore, at each survey, women were asked whether they had been diagnosed or treated for coronary heart disease (CHD) or stroke in the past 3 years. For the present study, CVD was defined as the sum of CHD and stroke because the number of stroke cases was insufficient (i.e., prevalence \( n = 76; \) incidence \( n = 178)\). Incidence was defined as new onset of T2DM or CVD at surveys 4–8 (2004–2016). The exact date of disease diagnosis was missing for the main events.

**Dietary assessment**

Dietary intake was derived with the use of a validated FFQ, the Dietary Questionnaire for Epidemiological Studies version 2. Further details on the development of this 101-item FFQ have been described previously (18). Briefly, the FFQ was validated for 63 women against 7-d weighed food records, showing for calcium intake an energy-adjusted Pearson correlation coefficient of 0.59 (19).

Information on dietary consumption was collected for yogurt, cheese (hard cheese, firm cheese, soft cheese, ricotta or cottage cheese, cream cheese, and low-fat cheese), and milk (full-cream milk, reduced-fat milk, skim milk, soya milk, and flavored milk). Participants were asked to report their frequency of dairy consumption over the previous 12 months through the use of a 10-point scale (from never to \( \geq 3 \text{times/d} \)), except for milk, where they were asked to report quantity of milk intake per day (from none to \( \geq 750 \text{mL/d} \)). Dietary intake was converted to grams per day. The Australian Food Composition Database (NUTTAB95) was used to compute energy and nutrient intakes (20).

For the present study, dairy products \((g/d)\) were classified as “yogurt,” “total cheese” (all types of cheese), “total fermented dairy” (sum of yogurt and total cheese), “total nonfermented dairy” (all types of milk), and “total dairy” (sum of total fermented dairy and nonfermented dairy). Because the fat content was not available for yogurt products, none of the other dairy groups were analyzed according to fat content.

**Assessment of sociodemographic and lifestyle factors**

Women self-reported on a range of sociodemographic and lifestyle factors at each survey, including age, height, weight, area of residence (urban, rural/remote), education (low level of education including no qualifications or school or intermediate certificate or equivalent; intermediate level of education including high school or leaving certificate, trade/apprenticeships, or certificate or diploma; and high level of education including any university degree), smoking status (never smoker, former smoker, current smoker), alcohol consumption (frequency and quantity of alcohol drinks), and physical activity (frequency and duration of walking and moderate- and vigorous-intensity activity in the last week).

Physical activity was categorized according to total metabolic equivalent (MET; in min/wk) in “sedentary or low physical activity level” (<600 MET min/wk), “moderate physical activity level” (from...
600 to <1200 MET min/wk), or “high physical activity level” (≥1200 MET min/wk). Details on the validation of self-reported physical activity questions have been published previously (21).

BMI was computed as self-reported weight (kg) divided by the square of estimated height (m²) and categorized as “underweight” (BMI <18.5), “healthy weight” (BMI from 18.5 to <25), “overweight” (BMI from 25 to <30), or “obese” (BMI ≥30) according to WHO classifications (22). Because only a limited number of women (n = 116, 1.3%) were classified as “underweight,” they were combined and classified as “healthy weight” (BMI <25).

Statistical analyses
Baseline characteristics are presented as means with SDs for continuous variables and numbers and percentages for categoric variables. The baseline characteristics are presented across tertiles of energy-adjusted total dairy intake, for which total dairy intake was adjusted for energy intake by means of the residual method (17).

Because the exact date of disease diagnosis was not collected, logistic regression models were used to examine the prospective association between tertiles of energy-adjusted dairy product intake at baseline (survey 3) and T2DM and CVD risk (surveys 4–8). Series of multivariable models were constructed to account for several potential confounders including age (model 1); plus education, smoking status, alcohol consumption and physical activity level (model 2); plus BMI (model 3); plus dietary variables (i.e., fruit, vegetables, whole-grain bread, red meat, processed meat, fish (not applicable for T2DM risk analyses), sugar-sweetened beverages, coffee, and tea), and total energy intake (model 4). Tests of linear trend across tertiles of energy-adjusted dairy product intake were performed by assigning the median value to each tertile and modeling these values as a continuous variable.

A series of additional analyses were conducted to test the robustness of our findings. First, dietary intake (g/d) was only assessed at surveys 3 and 7, and therefore to test for consistency in dairy intake during follow-up, the weighted κ method was used. Because BMI may be a potential confounder, effect modifier and intermediary factor, stratification analyses were performed in women classified as noneobe (BMI <30) and obese (BMI ≥30). Diabetes may be a potential intermediate on the causal pathway between dairy consumption and CVD risk, and hence women were stratified by diabetes prevalence in CVD risk analyses. Because fermented dairy products, including yogurt, may be a signature of a healthier lifestyle pattern (23), analyses were repeated with adjustment for lifestyle markers (i.e., education, smoking status, alcohol consumption, and physical activity level). To minimize the possibility of reverse causality, ORs were estimated, excluding women with self-reported disease diagnosis within the first 3 y of follow-up. Women taking CVD medication during follow-up may have had a less stable diet because of awareness of their higher CVD risk, therefore the CVD risk analyses were repeated in women who reported taking CVD medication (i.e., antihypertensive medication, antithrombotic agents, and lipid-lowering medication). Because postmenopausal women are at a high risk of T2DM and CVD, sensitivity analysis was adjusted for menopause status. Further, to assess the influence of participant exclusions that resulted from missing covariate data (n = 1764), a multiple imputation analysis was conducted with the SAS procedures MI and MIANALYZE.

All analyses were carried out by means of SAS software version 9.4. A 2-sided test with P < 0.05 was considered statistically significant.

Results
Baseline characteristics of women included in the complete case cohort (n = 8748) are shown by tertiles of energy-adjusted total dairy intake in Table 1. The mean age at baseline was 52.5 y (SD 1.5) and mean BMI was 26.8 (SD 5.4). Women in the highest tertile of energy-adjusted total dairy intake were more likely to have a lower BMI and to be higher educated, a never smoker, classified as rarely drinker, and physically active. In addition, these women were more likely to have a lower intake of total energy. Dairy median intakes were 20 g/d for yogurt, 14 g/d for total cheese, 35 g/d for total fermented dairy, 202 g/d for nonfermented dairy, and 369 g/d for total dairy (results not shown in Table 1).

T2DM
A total of 7633 women free of diabetes at baseline were followed for ≤15 y. During follow-up, a total of 701 (9.2%) T2DM cases were reported. The associations between various dairy products and T2DM risk are presented in Table 2. Women in the highest tertile of yogurt intake had lower odds of T2DM than those in the lowest tertile (OR: 0.81; 95% CI: 0.67, 0.99; P = 0.041). This relation became nonsignificant after adjustment for dietary variables and total energy intake (OR: 0.88; 95% CI: 0.71, 1.08; P = 0.21). Other dairy groups, including total cheese and total fermented dairy, were not associated with T2DM risk (Table 2).

CVD
In 7679 women free of CVD at baseline, a total of 835 (10.9%) new cases of CVD occurred during follow-up. The associations between various dairy products and CVD risk are presented in Table 3. High intake of yogurt and total fermented dairy was associated with a lower risk of CVD (OR: 0.84; 95% CI: 0.70, 1.00; P = 0.05, 0.80, 0.67, 0.96; 0.017, respectively) compared with the lowest tertile of dairy product intake. Additional adjustment for dietary variables and total energy intake altered the relation (OR: 0.87; 95% CI: 0.72, 1.04; P = 0.13, 0.83; 0.69, 1.00; 0.048, for yogurt and total fermented dairy, respectively). No association was observed for total cheese or other dairy groups and CVD risk (Table 3).

Additional analyses
Repeated measures of dairy intake over time (i.e., surveys 3 and 7) showed a fair to moderate agreement for all dairy groups (weighted κ ranging from 0.35 to 0.44) (Supplemental Table 1). When stratifying women according to BMI, intake of yogurt and total fermented dairy was associated with lower, albeit not significant, T2DM and CVD risk in obese women than in nonobese women (Supplemental Tables 2 and 3). Stratification by diabetes prevalence showed a suggestive inverse association between yogurt, total cheese, and total fermented dairy and CVD risk that was more pronounced in women with diabetes than in those without (Supplemental Table 4). In analyses adjusted for lifestyle markers, high intake of yogurt, total cheese, and total fermented dairy was associated with lower risk of T2DM (OR: 0.75; 95% CI: 0.62, 0.91; P = 0.004, 0.80; 0.66, 0.97; 0.025, 0.77; 0.63, 0.94; 0.010, respectively) compared with the lowest tertile of dairy product intake (Supplemental Table 5). When adjusting for lifestyle markers, women in the highest tertile of yogurt intake and total fermented dairy had lower odds of CVD than those in the lowest tertile (OR: 0.81; 95% CI: 0.68, 0.97; P: 0.024, 0.78; 0.65, 0.93; 0.006, respectively) (Supplemental Table 6). Other additional analyses demonstrated the robustness of our findings (Supplemental Tables 7–13).

Discussion
In this population-based prospective cohort study of Australian women, we found an association between high intake of total
TABLE 1  Baseline characteristics of middle-aged Australian women in the complete case cohort (n = 8748) by tertiles of energy-adjusted total dairy intake 1

| Variable | Energy-adjusted total dairy intake, g/d | Tertile 1 (n = 2916): 204–233 | Tertile 2 (n = 2916): 281–395 | Tertile 3 (n = 2916): 420–631 | P value 3 |
|----------|----------------------------------------|-------------------------------|-------------------------------|-------------------------------|-----------|
| Sociodemographic and lifestyle factors | | | | | |
| Age, y | 52.5 ± 1.5 | 52.5 ± 1.5 | 52.5 ± 1.5 | 0.61 |
| Area of residence | | | | | 0.45 |
| Urban | 34.1 (987) | 34.8 (1008) | 35.7 (1033) | |
| Rural/remote | 65.9 (1908) | 65.2 (1883) | 64.3 (1862) | |
| BMI, kg/m² | | | | | <0.05 |
| <25 (healthy weight) 4 | 42.0 (1124) | 44.5 (1297) | 45.8 (1336) | |
| 25–29 (overweight) | 31.7 (924) | 32.9 (859) | 33.3 (872) | |
| ≥30 (obese) | 26.3 (768) | 22.6 (660) | 20.9 (608) | |
| Education level 5 | | | | | <0.05 |
| Low | 49.9 (1456) | 45.3 (1322) | 44.7 (1304) | |
| Intermediate | 35.6 (1038) | 38.4 (1119) | 38.7 (1129) | |
| High | 14.5 (422) | 16.3 (475) | 16.6 (483) | |
| Smoking status | | | | | <0.05 |
| Never smoker | 58.4 (1703) | 62.1 (1812) | 62.1 (1810) | |
| Former smoker | 25.7 (748) | 24.7 (719) | 24.1 (704) | |
| Current smoker | 16.0 (465) | 13.2 (385) | 13.8 (402) | |
| Alcohol consumption 6 | | | | | <0.05 |
| Nondrinker | 13.9 (378) | 11.9 (324) | 11.2 (303) | |
| Rarely drinker | 26.9 (732) | 25.7 (697) | 28.7 (780) | |
| Low-risk drinker | 52.2 (1417) | 56.5 (1534) | 56.1 (1525) | |
| Risky drinker | 7.0 (190) | 5.9 (161) | 4.1 (110) | |
| Physical activity, MET min/wk | | | | | <0.05 |
| <600 (sedentary or low) | 60.8 (1774) | 55.0 (1605) | 53.1 (1547) | |
| 600–1199 (moderate) | 18.4 (535) | 21.0 (611) | 22.9 (667) | |
| ≥1200 (high) | 20.8 (607) | 24.0 (700) | 24.1 (702) | |
| Dietary intake | | | | | |
| Total energy, kJ/d | 6735 ± 2272 | 6564 ± 2207 | 6504 ± 1994 | <0.05 |
| Fat, E% | 36.6 ± 5.6 | 34.5 ± 5.6 | 32.6 ± 6.1 | <0.05 |
| Saturated fat | 14.4 ± 3.3 | 13.6 ± 3.4 | 13.1 ± 3.7 | <0.05 |
| Monounsaturated fat | 13.1 ± 2.4 | 12.1 ± 2.3 | 11.3 ± 2.3 | <0.05 |
| Polyunsaturated fat | 5.8 ± 1.9 | 5.6 ± 2.0 | 5.2 ± 2.1 | <0.05 |
| Protein, E% | 20.5 ± 3.7 | 20.8 ± 3.2 | 21.7 ± 3.2 | <0.05 |
| Carbohydrates, E% | 42.6 ± 7.2 | 45.4 ± 6.4 | 46.5 ± 6.0 | <0.05 |
| Sugars | 18.4 ± 5.7 | 21.0 ± 5.4 | 23.4 ± 5.4 | <0.05 |
| Starch | 24.3 ± 5.1 | 24.1 ± 4.6 | 22.8 ± 4.6 | <0.05 |
| Fiber, g/d | 20.0 ± 8 | 20 ± 8 | 20 ± 8 | 0.27 |
| Alcohol, g/d | 10 ± 14 | 10 ± 13 | 9 ± 13 | <0.05 |
| Fruit, g/d | 282 ± 200 | 289 ± 179 | 293 ± 176 | 0.05 |
| Vegetables, g/d | 139 ± 63 | 133 ± 59 | 130 ± 57 | <0.05 |
| Whole-grain bread, g/d | 34 ± 14 | 35 ± 16 | 34 ± 16 | 0.06 |
| Red meat, g/d | 48 ± 46 | 40 ± 36 | 34 ± 32 | <0.05 |
| Processed meat, g/d | 20 ± 22 | 17 ± 16 | 15 ± 14 | <0.05 |
| Fish, g/d | 38 ± 44 | 34 ± 37 | 32 ± 35 | <0.05 |
| Sugar-sweetened beverages, serving/d | 0.6 ± 0.9 | 0.5 ± 0.7 | 0.4 ± 0.7 | <0.05 |
| Coffee, serving/d | 1.3 ± 1.2 | 1.4 ± 1.2 | 1.5 ± 1.2 | <0.05 |
| Tea, serving/d | 1.5 ± 1.2 | 1.6 ± 1.2 | 1.7 ± 1.2 | <0.05 |

1 All continuous measures are presented as means ± SDs and all categoric measures are presented as % (n). ANOVA was used for continuous variables and chi-squared tests for categoric variables. E%, energy percentage; MET, metabolic equivalent.
2 Tertile cutoff values based on energy-adjusted intakes in the subcohort calculated through the use of the residual method.
3 P value calculated by ANOVA.
4 As only 118 women had BMI <18.5, their weights are included in the "healthy weight" category.
5 Level of education categorized as "low" (no formal qualifications or school or intermediate certificate or equivalent), "intermediate" (high school or leaving certificate, trade/apprenticeships, or certificate or diploma), and "high" (any university degree).
6 Alcohol consumption defined as “nondrinker,” “rarely drinker” (any alcohol consumption <1 time/mo), “low-risk drinker” (≤14 drinks/wk), and “risky drinker” (≥15 to 28 drinks/wk).
TABLE 2  ORs (95% CIs) for the association between dairy product intake and type 2 diabetes mellitus risk per category of energy-adjusted dairy product in Australian women (n = 7663)\(^1\)

| Yogurt intake, \(^3\) g/d | Tertile 1 \((n = 2544)\) | Tertile 2 \((n = 2545)\) | Tertile 3 \((n = 2544)\) | P-trend |
|--------------------------|-------------------|-------------------|-------------------|--------|
| Cases, \(n\) (%)        | 278 (3.6)         | 229 (3.0)         | 194 (3.0)         |        |
| Crude                    | 1                 | 0.81 (0.67, 0.97) | 0.67 (0.56, 0.82) | <0.05  |
| Model 1\(^4\)           | 1                 | 0.81 (0.67, 0.97) | 0.67 (0.56, 0.82) | <0.05  |
| Model 2\(^5\)           | 1                 | 0.86 (0.71, 1.03) | 0.75 (0.62, 0.91) | 0.06   |
| Model 3\(^6\)           | 1                 | 0.90 (0.74, 1.09) | 0.81 (0.67, 0.99) | 0.21   |
| Model 4\(^7\)           | 1                 | 0.99 (0.81, 1.21) | 0.88 (0.71, 1.06) | 0.84   |

| Total cheese intake, \(^3\) g/d | 3 (2–4) | 14 (8–14) | 28 (22–29) |
| Cases, \(n\) (%)        | 274 (3.6) | 216 (2.8) | 211 (2.8) |
| Crude                    | 1         | 0.77 (0.64, 0.93) | 0.75 (0.62, 0.91) | 0.05   |
| Model 1\(^4\)           | 1         | 0.77 (0.64, 0.93) | 0.75 (0.62, 0.91) | 0.05   |
| Model 2\(^5\)           | 1         | 0.78 (0.65, 0.95) | 0.80 (0.66, 0.97) | 0.06   |
| Model 3\(^6\)           | 1         | 0.81 (0.67, 0.98) | 0.86 (0.71, 1.06) | 0.07   |
| Model 4\(^7\)           | 1         | 0.83 (0.68, 1.00) | 0.86 (0.71, 1.06) | 0.11   |

| Total fermented dairy intake, \(^3\) g/d | 11 (4–17) | 35 (25–49) | 129 (87–160) |
| Cases, \(n\) (%)        | 271 (3.6) | 229 (3.1) | 191 (2.5) |
| Crude                    | 1         | 0.87 (0.72, 1.04) | 0.86 (0.71, 0.98) | 0.17   |
| Model 1\(^4\)           | 1         | 0.87 (0.72, 1.04) | 0.86 (0.71, 0.98) | 0.17   |
| Model 2\(^5\)           | 1         | 0.94 (0.78, 1.14) | 0.97 (0.73, 1.29) | 0.09   |
| Model 3\(^6\)           | 1         | 1.01 (0.83, 1.22) | 0.85 (0.69, 1.01) | 0.89   |
| Model 4\(^7\)           | 1         | 1.08 (0.89, 1.31) | 0.91 (0.74, 1.12) | 0.44   |

| Total nonfermented dairy intake, \(^3\) g/d | 200 (200–200) | 201 (200–375) | 375 (375–383) |
| Cases, \(n\) (%)        | 257 (3.4) | 222 (2.9) | 222 (2.9) |
| Crude                    | 1         | 0.85 (0.70, 1.03) | 0.85 (0.71, 1.03) | 0.13   |
| Model 1\(^4\)           | 1         | 0.85 (0.71, 1.03) | 0.85 (0.71, 1.03) | 0.13   |
| Model 2\(^5\)           | 1         | 0.83 (0.69, 1.01) | 0.83 (0.69, 1.00) | 0.09   |
| Model 3\(^6\)           | 1         | 0.87 (0.71, 1.05) | 0.88 (0.73, 1.08) | 0.18   |
| Model 4\(^7\)           | 1         | 0.93 (0.76, 1.13) | 0.99 (0.80, 1.21) | 0.43   |

| Total dairy intake, \(^3\) g/d | 216 (204–233) | 368 (285–396) | 497 (421–630) |
| Cases, \(n\) (%)        | 268 (3.5) | 216 (2.8) | 217 (2.8) |
| Crude                    | 1         | 0.79 (0.65, 0.95) | 0.79 (0.66, 0.96) | 0.11   |
| Model 1\(^4\)           | 1         | 0.79 (0.65, 0.95) | 0.79 (0.66, 0.96) | 0.11   |
| Model 2\(^5\)           | 1         | 0.82 (0.68, 1.00) | 0.81 (0.67, 0.98) | 0.24   |
| Model 3\(^6\)           | 1         | 0.86 (0.71, 1.05) | 0.80 (0.72, 1.07) | 0.29   |
| Model 4\(^7\)           | 1         | 0.92 (0.75, 1.12) | 0.97 (0.79, 1.18) | 0.44   |

\(^1\)Values are ORs (95% CIs) except where indicated otherwise.

\(^2\)Tertile cutoff values based on energy-adjusted intakes in the subcohort calculated via the residual method.

\(^3\)Median intake (range); all values in row.

\(^4\)Model 1: adjusted for age.

\(^5\)Model 2: adjusted as in model 1 plus education, smoking status, alcohol consumption, and physical activity level.

\(^6\)Model 3: adjusted as in model 2 plus BMI.

\(^7\)Model 4: adjusted as in model 3 plus dietary variables and total energy intake.

fermented dairy and lower CVD risk. Other dairy groups, including total cheese, were not associated with risk of T2DM and CVD.

A major strength of the present study is the prospective design, reducing the chance of selection bias and potential recall bias. Because of this prospective design, reporting of dietary intake could not have been biased by the subsequent development of T2DM and CVD. Another strength is the generalizability, this being a representative national population-based cohort rather than a clinic sample. Moreover, multiple dietary assessments over time (i.e., surveys 3 and 7) reduced within-subject variation and improved long-term diet representation. Lastly, several detailed additional analyses were carried out to test the robustness of the findings, confirming similar results.

Several study limitations warrant mention. A limitation of the present study is that all the data, including disease ascertainment, are self-reported. However, a validation study in the ALSWH 1946–1951 age cohort comparing self-report with administrative hospital data reported substantial and fair agreement for diabetes and stroke diagnosis, respectively (24).

Secondly, dietary intake was assessed by means of a validated FFQ. Self-reported intake is prone to imprecision and reporting bias; however, we excluded misreporters from the statistical analyses and the validation study against 7-d weighed food records showed moderate Pearson correlation coefficients for calcium (19). In addition, repeated measures of dairy intake over time showed a fair to moderate agreement for all dairy groups, indicating consistent dairy intake during follow-up. Thirdly, the number of stroke cases during follow-up was insufficient (\(n = 178\)) and may have resulted in unstable estimates. Hence, CHD and stroke were combined as CVD in order to provide sufficient statistical power. Nevertheless, most women who reported being diagnosed or treated for stroke were
TABLE 3  ORs (95% CIs) for the association between dairy product intake and cardiovascular disease risk per category of energy-adjusted dairy products in Australian women (n = 7679)

|  | Tertile 1 (n = 2559) |  | Tertile 2 (n = 2560) |  | Tertile 3 (n = 2560) |  | P-trend |
|---|---|---|---|---|---|---|---|
| Yogurt intake,3 g/d | 0 (0–3) | 20 (10–41) | 114 (73–146) |  |  |  |  |
| Cases, n(%) | 278 (3.6) | 229 (3.0) | 194 (2.5) |  |  |  |  |
| Crude | 1 | 0.83 (0.70, 0.98) | 0.78 (0.65, 0.92) | <0.05 |  |  |  |
| Model 14 | 1 | 0.83 (0.70, 0.99) | 0.78 (0.65, 0.92) | <0.05 |  |  |  |
| Model 25 | 1 | 0.85 (0.71, 1.01) | 0.81 (0.68, 0.97) | <0.05 |  |  |  |
| Model 36 | 1 | 0.87 (0.73, 1.04) | 0.84 (0.70, 1.00) | 0.09 |  |  |  |
| Model 47 | 1 | 0.89 (0.74, 1.07) | 0.87 (0.72, 1.04) | 0.18 |  |  |  |
| Total cheese intake,3 g/d | 3 (2–4) | 14 (8–14) | 26 (22–29) |  |  |  |  |
| Cases, n(%) | 298 (3.9) | 270 (3.5) | 287 (3.5) |  |  |  |  |
| Crude | 1 | 0.90 (0.75, 1.07) | 0.88 (0.74, 1.05) | 0.36 |  |  |  |
| Model 14 | 1 | 0.89 (0.75, 1.06) | 0.88 (0.74, 1.05) | 0.34 |  |  |  |
| Model 25 | 1 | 0.90 (0.76, 1.07) | 0.91 (0.76, 1.08) | 0.36 |  |  |  |
| Model 36 | 1 | 0.91 (0.76, 1.09) | 0.93 (0.78, 1.11) | 0.38 |  |  |  |
| Model 47 | 1 | 0.92 (0.77, 1.09) | 0.93 (0.78, 1.11) | 0.42 |  |  |  |
| Total fermented dairy intake,3 g/d | 11 (4–17) | 35 (25–49) | 129 (87–160) |  |  |  |  |
| Cases, n(%) | 244 (4.2) | 270 (3.5) | 267 (3.5) |  |  |  |  |
| Crude | 1 | 0.79 (0.66, 0.94) | 0.74 (0.62, 0.88) | <0.05 |  |  |  |
| Model 14 | 1 | 0.79 (0.67, 0.94) | 0.74 (0.62, 0.88) | <0.05 |  |  |  |
| Model 25 | 1 | 0.82 (0.69, 0.97) | 0.78 (0.65, 0.93) | <0.05 |  |  |  |
| Model 36 | 1 | 0.84 (0.70, 1.00) | 0.80 (0.67, 0.96) | 0.05 |  |  |  |
| Model 47 | 1 | 0.86 (0.72, 1.02) | 0.83 (0.69, 1.00) | 0.09 |  |  |  |
| Total nonfermented dairy intake,3 g/d | 200 (200–200) | 201 (200–375) | 375 (375–383) |  |  |  |  |
| Cases, n(%) | 298 (3.9) | 256 (3.3) | 261 (3.7) |  |  |  |  |
| Crude | 1 | 0.84 (0.71, 1.01) | 0.84 (0.71, 1.11) | 0.06 |  |  |  |
| Model 14 | 1 | 0.85 (0.71, 1.01) | 0.84 (0.71, 1.11) | 0.06 |  |  |  |
| Model 25 | 1 | 0.84 (0.71, 1.01) | 0.83 (0.78, 1.11) | 0.06 |  |  |  |
| Model 36 | 1 | 0.86 (0.72, 1.02) | 0.85 (0.80, 1.14) | 0.08 |  |  |  |
| Model 47 | 1 | 0.86 (0.72, 1.03) | 0.86 (0.80, 1.15) | 0.09 |  |  |  |
| Total dairy intake,3 g/d | 216 (204–233) | 373 (287–397) | 496 (424–630) |  |  |  |  |
| Cases, n(%) | 292 (3.8) | 272 (3.5) | 271 (3.5) |  |  |  |  |
| Crude | 1 | 0.92 (0.78, 1.10) | 0.92 (0.77, 1.10) | 0.59 |  |  |  |
| Model 14 | 1 | 0.93 (0.78, 1.10) | 0.92 (0.77, 1.09) | 0.60 |  |  |  |
| Model 25 | 1 | 0.95 (0.79, 1.13) | 0.94 (0.78, 1.12) | 0.74 |  |  |  |
| Model 36 | 1 | 0.96 (0.81, 1.15) | 0.96 (0.81, 1.15) | 0.76 |  |  |  |
| Model 47 | 1 | 0.98 (0.82, 1.17) | 0.99 (0.82, 1.18) | 0.81 |  |  |  |

1Values are ORs (95% CIs) except where indicated otherwise.
2Tertile cutoff values based on energy-adjusted intakes in the subcohort calculated via the residual method.
3Median intake (range); all values in row
4Model 1: adjusted for age.
5Model 2: adjusted as in model 1 plus education, smoking status, alcohol consumption, and physical activity level.
6Model 3: adjusted as in model 2 plus BMI.
7Model 4: adjusted as in model 3 plus dietary variables and total energy intake.

also identified as CHD cases, supporting the applicability of combining these 2 disease outcomes as CVD. Fourthly, although data were extensively collected in the ALSWH study, family history of T2DM, CHD, and stroke was not surveyed, and hence we could not verify if our results may be due to having a family history of these diseases. Lastly, although we adjusted for a range of potential confounders, there might be residual confounding through a generally healthier eating and lifestyle pattern of women with a higher consumption of fermented dairy products, particularly yogurt (23). However, in additional analyses with adjustment for lifestyle markers, high intake of fermented dairy products, including yogurt, was associated with lower risk of T2DM and CVD. These findings suggest that fermented dairy products may be beneficial, independent of lifestyle patterns.

As for T2DM risk, we found a suggestive inverse association for yogurt intake, consistent with a body of high-quality evidence including meta-analyses and systematic reviews (4, 6–8, 25, 26). By contrast, this inverse association for yogurt was not confirmed in another Australian prospective cohort study (9), although it should be taken into account that this study included a population with a wide age range. Further, the latter study did show an inverse association between total dairy intake and T2DM risk that was significant in men but not women (9). Gender disparity was also reported by 2 other prospective cohort studies (27, 28), implying that the relation between dairy consumption and T2DM risk may be dependent on sex.

For CVD risk, despite numerous studies, including 1 Australian cohort study, reporting a neutral association for yogurt intake (8, 11, 12), the present study observed a suggestive association between high intake of yogurt and lower risk of CVD. Our observation is in agreement with a review of randomized trials (29), and subgroup analyses demonstrating more pronounced effects in Australians than in Europeans (11).
Conversely, this inverse relation for yogurt and CVD risk was not detected in a previous Australian cohort study (12), yet it should be acknowledged that the latter study considered CVD mortality as outcome, whereas we examined new onset of CVD. Furthermore, meta-analyses demonstrated that intake of fermented dairy products, predominantly driven by the effects of cheese, was associated with a lower CVD risk and in particular stroke risk (11, 30). We also observed a suggestive inverse relation between total fermented dairy and CVD risk, probably accounted for by yogurt given the association with total cheese was neutral. Although our finding is supported by a recent systematic review (8), the discrepancy between cheese intake and CVD risk could be due to true differences in cheese intake and products (e.g., fat content, fermentation process), definition of endpoint (e.g., stroke, sum CVD), reporting bias, or simply chance.

In stratified analyses, there was some evidence for risk differences in BMI strata for intake of fermented dairy products and risk of T2DM and CVD. In the present study, intake of yogurt and total fermented dairy was associated with lower T2DM and CVD risk in obese women than in nonobese women. In agreement, another study observed in postmenopausal women a modest interaction between low-fat dairy food intake and BMI for T2DM risk (31). These findings imply that obese women may benefit more from these particular dairy products. In addition, these risk differences could also be due to true effect modification, yogurt consumers being characterized by a healthy dietary pattern and lifestyle in general (23, 32), bias because of under- or overreporting, or chance findings. Further, albeit not significant, we found for fermented dairy products a lower risk of CVD in women with diabetes than in those without. This observation is in agreement with a body of evidence that considers the risk of stroke (33, 34). This potential effect modification could be explained by the fact that CVD is the most prevalent cause of morbidity and mortality in diabetes patients (35).

A diet high in fermented dairy products, particularly yogurt, may be beneficial for T2DM and CVD risk (6, 8, 11). In the process of dairy fermentation, beneficial compounds are released that have shown promise for improving glycemic control, blood lipids, cholesterol concentrations, and blood pressure (36–39). Furthermore, clinical trials have shown that probiotic bacteria found in cheese and yogurt have favorable effects on inflammation and cardiovascular risk factors (40). Probiotic bacteria also exhibit the potency to synthesize vitamin K2 (menaquinone), which was inversely associated with T2DM risk (41), and vascular calcification and subsequent CHD risk (42, 43). During fermentation, bacterial cultures can synthesize other new compounds, such as exopolysaccharide and some B vitamins, which are mediators in pathways of CVD health (44, 45). Yogurt is of particular interest given its hypothesized potential to affect the composition and function of microbiota in the gastrointestinal tract (46), and subsequent cardiometabolic health via glucose and lipid homeostasis (47). In addition to dairy fermentation, the inferred beneficial health potential of yogurt could also be attributed to its effect on satiety and consequently reduced energy intake (32, 48).

In conclusion, the present study observed an association between high intake of total fermented dairy and lower CVD risk. Dietary patterns may contribute to the identified inverse association between fermented dairy and CVD risk. For other dairy groups, no association for T2DM and CVD risk was examined in this study. Further studies are warranted to confirm the findings in Australian men as well as Australian women in wider age brackets. Lastly, randomized controlled trials are warranted to prove causality of fermented dairy consumption and lower T2DM and CVD risk.

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