Dairy Consumption and Incident Type 2 Diabetes Among American Indians: The Strong Heart Family Study

Kim Kummer

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Public Health

University of Washington

2016

Committee:
Amanda Fretts
Mario Kratz

Program authorized to offer degree:
Public Health - Epidemiology

University of Washington

Abstract

Dairy Consumption and Incident Type 2 Diabetes Among American Indians: The Strong Heart Family Study

Kim Kummer

Chair of the Supervisory Committee:

Amanda Fretts

Epidemiology

Background*:* Type 2 Diabetes (T2D) disproportionately impacts American Indians (AIs); the prevalence of T2D is two to three times higher among AIs than the general US population. Obesity and poor diets are common in AI communities and the relationships of specific dietary factors with T2D have not been well studied in this population. Whether dairy consumption, specifically high-fat intake and low-fat dairy intake, are associated with risk of T2D in AIs has yet to be explored.

Methods: Using data collected as part of the Strong Heart Family Study (SHFS), we examined the associations of high-fat dairy and low-fat dairy intake with incident diabetes. The analytic cohort comprised of SHFS participants free of diabetes at baseline and who participated in a follow-up exam 8 years later (n=1,623). Dietary intake was assessed using a Block FFQ at baseline. Incidence of diabetes was defined based on the American Diabetes Association criteria at the follow-up exam. GEE were used to evaluate the associations between dairy intake and incident diabetes.

Results: Reported intake of dairy products was exceedingly low [median high-fat dairy intake 0.11 servings/1000kcal; median low-fat dairy intake 0.03 servings/1000kcal]. There were 172 participants who developed diabetes during follow-up. No statistically significant associations were observed between high- or low-fat dairy intake and development of diabetes. Despite low reported dairy intake in the SHFS,

those who reported the highest levels of high-fat dairy consumption compared to the lowest showed a trend for an inverse association with T2D [OR (95%CI): 0.69 (0.45,1.05)]. In contrast, higher consumption of low-fat dairy products showed no significant association with T2D.

Conclusions: The SHFS population has very low consumption of both high- and low-fat dairy products.

Introduction

In recent decades, there has been a dramatic increase in the prevalence of obesity and type 2 diabetes (T2D) in the United States. This burden is particularly troubling among American Indians (AIs)—where the prevalence of T2D is two to three times higher than in the general US adult population.(1) Obesity and poor diet are common in AI communities, and this may in part explain the high burden of diabetes.(2) Lifestyle factors, specifically diet, have been thought to play a key role in the development of T2D, however few dietary factors have been consistently established as either being beneficial for T2D or potential risk factors for T2D. Fruit and vegetable intake (3,4) and whole grain intake (5), have shown inverse associations with T2D, while sugar sweetened beverage intake (6) and red and processed meat intake have been shown to be positively associated with T2D (2,7,8). Dairy intake has been increasingly studied in recent years, showing some evidence of decreased risk of T2D, however there is still considerable inconsistency in the conclusions, depending on type of dairy products evaluated and method of assessment. (9–14)

Prior meta-analyses of observational studies examining dairy products and dose response relationships with incident T2D have shown inverse associations of total dairy intake and low-fat dairy intake with T2D.(9,11–13). In contrast, a recent meta-analysis examining 14 prospective studies including three large US cohorts, showed no associations for total dairy, low-fat dairy, and high-fat intake with incident T2D.(10) Furthermore, epidemiologic studies examining specific types of dairy products have also shown mixed results, with inverse associations for low-fat dairy products and T2D (15–19), whereas other studies suggested no association with T2D. (20–23) In comparison, high-fat dairy intake has shown no significant association with incident T2D in many studies (15–17,20,21), with the exception of one study showing evidence of an inverse association with higher intake of high-fat dairy products.(24) Many of these studies ascertained dairy intake using self-report food frequency questionnaires (FFQ)(15–18,23), while one used a 7-day food diary in attempt to overcome limitations of a FFQ.(22)

Additionally, other research groups are concerned about the limitations of self-reported FFQs and have investigated the use of circulating biomarkers of fatty acids to assess intake of dairy fat. There are a number of specific fatty acids primarily obtained from dairy fat intake.(25) Specifically, high-fat dairy intake

is strongly associated with higher levels of plasma *trans*-palmitoleate, and *trans*-palmitoleate is shown to be associated with a lower incidence of T2D. (26–28) In a recent study, plasma biomarkers of dairy fat [pentadecanoic acid (15:0), heptadecanoic acid (17:0), and *trans*-palmitoleic acid (t-16:1n-7)] were shown to be associated with lower risk of incident T2D,(28) strengthening the evidence for both the use of biomarkers in evaluation of dairy intake and the potential benefits of high-fat dairy intake and T2D. The use of biomarkers is promising; however, they are limited in their ability to finely differentiate between different dairy products with varying degrees of fat content, such as non-fat dairy products.(29) Taken all together, the evidence examining the relationship between dairy intake and incident T2D has many promising results, yet needs further research to establish more consistency.

Lastly, almost all of the current research exploring the relationship of dairy products and T2D has been studied in populations not generalizable to AI communities, or other ethnic groups. Due to the disproportionate burden of T2D and obesity among the AI community, it is important to understand whether differences in the source of dietary fat are associated with differential effects on development of T2D to help strengthen local nutritional dietary guidelines in these communities. Previous analyses in the Strong Heart Family Study (SHFS) have suggested that consumption of processed meat is associated with a higher risk of T2D, while there is no association of consumption of unprocessed red meat with T2D. Currently there is no research that has examined the impact of dairy intake (i.e., high-fat dairy, low-fat dairy,) on incident T2D among AI communities. This information may be important in developing interventions to combat T2D in AI communities.

The goal of this study was to assess the relationship of dairy consumption (high-fat dairy and low-fat dairy) with the risk of developing T2D among AIs from 12 communities who participated in the SHFS, a population-based cohort.

Methods

Study setting

This data was collected as part of a cohort study designed to better understand risk factors for cardio-metabolic diseases among AIs from 12 communities in Arizona, North Dakota, South Dakota, and Oklahoma. The study was conducted during 2001-2009. All data were collected using standardized forms and procedures by trained staff.

Data collection

Data was collected at a baseline examination (2001-2003) and a follow-up exam (2007-2009). Each exam included a standardized personal interview, physical examination, medication review, laboratory testing, and food frequency questionnaire (FFQ), as described previously.(30,31)

Study subjects

Subjects who completed both the baseline and follow-up examinations were included in the analytic sample. Briefly, 1,122 men and 1,658 women from 92 large families completed a baseline exam. We excluded SHFS participants who had diabetes at the baseline examination (n=527) and those without a follow-up examination (n=245). There were no differences in baseline characteristics between those who did and did not have a follow-up exam with the exception of gender, where there were a slightly higher proportion of men who did not have a follow-up exam. Additionally, we excluded individuals with a history of kidney failure (n=14), myocardial infarction (n=64), stroke (n=22), heart failure (n=12), or who were pregnant at baseline (n=3). This was done because these conditions may influence our dietary exposures and diabetes risk. Patients with unreliable or large amounts of missing dietary information were also excluded. This included those who skipped >15% of the questions on the dietary assessment instrument (n=31), those missing baseline data on food intake (n=128), and those who reported having extreme caloric intakes [intakes of <600 kcal/day or >6000 kcal/day for women (n=71) and <600kcal/day or >8000 kcal/day for men (n=40)]. The remaining 1,623 persons comprised the study population for this analysis.

Dietary assessment and exposure measures

An interviewer-administered Block food frequency questionnaire (FFQ) with 119 items was used to measure usual food intake during the past year among individuals at baseline. The Block FFQ is a widely used food questionnaire, and its validity and reliability has been well established against multiple dietary food records and 24-hour food recalls. (32,33) Each participant was asked how often, on average, a particular food was consumed during the past year. The quantity was assessed using measures of consumption frequency (i.e., seasonally, never, a few times per year, once per month, 2-3 times per month, once per week, twice per week, 2-3 times per week, 5-6 times per week, daily) and portion size. Average daily energy and nutrient intakes were then calculated for each study participant using the Block database (Block Dietary Systems, Berkeley, CA).

For this study, we were primarily interested in high-fat dairy intake low-fat dairy intake. Total intake of high-fat dairy products was defined as the sum of portions (servings/day) of whole milk and cheese and cheese spreads. Total intake of low-fat dairy products was defined as the sum of portions (servings/day) of non-fat milk, 1% milk, 2% milk, and low-fat or reduced-fat cheese alternatives (<20% fat). High-fat dairy intake and low-fat dairy intake groups were each categorized into tertiles for meaningful comparisons. Each of these dietary factors were then examined across tertiles of nutrient density expressed in terms of servings/1000kcal. This is done to attempt to help correct for over- and under- reporting of nutrient intake from the FFQ, and to normalize the dairy intake to the total amount of food/energy consumed. The standard daily serving sizes used for these analyses were consistent with USDA serving sizes: 8 oz. for whole milk, 2% milk, 1 % milk, or non-fat milk, and 1.5 ounces for cheese. Other dairy products such as cream, butter, and yogurt were not considered for a number of reasons. Cream and butter were not classified into the high-fat dairy group since there would be no low-fat equivalents for comparison commonly used in the SHFS population. Consumption of yogurt was excluded from analyses because the Block FFQ administered at baseline combines yogurt intake with other frozen deserts, and I believed this was not a valid representation of yogurt consumption. Additionally the SHFS population has very simple diets with limited access to diverse dairy products.

Assessment of T2D

Incidence of diabetes was defined based on the American Diabetes Association criteria as fasting glucose concentration ≥126 mg/dL, or use of insulin, or oral anti-diabetic medications at the follow-up examination.(34) We treated all new occurrences of diabetes as T2D since type 1 diabetes is rare in AI populations.

Statistical analyses

We examined associations for each dietary exposure category with risk of T2D using generalized estimating equation (GEE) with an independent working correlation structure and robust standard errors. The general form of the model is given by:

$$logit(p) = \alpha_o + \beta_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 \ldots.$$

GEE was selected for the analysis to allow for clustering/correlation within the data since the SHFS data are comprised of extended families. Participants in the lowest tertile of dietary intake comprised the reference group. All statistical analyses were conducted using STATA version 13.0 (STATA Corp, College Station, Texas).

Four models were fit to examine the association of high-fat dairy intake and low-fat dairy intake with incident T2D.

- Model 1 (crude model) included minimal adjustments for age, sex, study site, and total energy intake.

- Model 2 (potential confounders) additionally adjusted for *a priori* confounders, including ambulatory physical activity, education, smoking status, and alcohol consumption.

- Model 3 (other dietary factors) additionally adjusted for other, a priori-defined dietary factors including total fat (% of energy), trans-fat intake (% of energy), saturated fat intake (% of energy), nut intake (peanuts, peanut butter, other nuts, seeds), dietary fiber,

unprocessed meat intake, processed meat intake, fruit and vegetable intake, and sugar sweetened beverage (SSB) intake.

- Model 4 (BMI model) BMI may partially confound or mediate the relationship of dietary fat intake and incident T2D; therefore we additionally adjusted for BMI in Model 4.

The relationship between dairy intake and T2D may differ among men versus women, obese versus non-obese, or by age, and we examined potential effect modification of these factors with high-fat dairy intake and low-fat dairy intake on incident T2D in sensitivity analyses. To evaluate this, a multiplicative term was created individually for gender, BMI, and age with dairy intake on incident T2D. Wald tests were then used to test the statistical significance of these interaction terms.

Additionally, in recognition of the challenges in creating comparable exposure groups of high-fat and low-fat dairy intake, we conducted further sensitivity analysis to look at differences in inclusion of cream and butter products in the high-fat dairy products, as well as separate exposures associated with incident T2D.

Missing data

There were some missing data on covariates of interest including smoking status (n=1), BMI (n=6), education (n=5), physical activity (n=103), total fat intake (n=5), saturated fat intake (n=5), and trans-fat intake (n=5). In order to maintain our sample size through the analyses and minimize potential for selection bias, we used multiple imputation to replace these missing covariate values with plausible values. The set of variables that were used to predict these imputed values were sex, age, site, alcohol consumption, total caloric intake, fruit and vegetable consumption, SSB consumption, processed meat intake, unprocessed meat intake, and total dietary fiber intake.

Results

The final analytic cohort consisted of 1,623 individuals, of which 60.7% were female with a median age at baseline of 35.8 y (range: 14.0-85.9 y). Consumption of high-fat dairy products and low-fat dairy products was very low in the study population [median daily high-fat intake 0.11 servings/1000kcal (range: 0-2.5 servings/1000kcal), median daily low-fat dairy intake 0.03 servings/1000kcal (range: 0-4.5 servings/1000kcal)]. Nine percent (n=148) of participants reported not consuming any high-fat dairy products including whole milk, cheese & cheese spreads. In contrast, 39.8% (n=646) of participants reported not consuming any low-fat dairy products including 2% milk, 1% milk, non-fat milk, or low-fat cheese & cheese spreads.

Baseline characteristics of study participants according to tertile of high-fat dairy intake and low-fat dairy intake are shown in **Table 1a**, and **Table 1b**, respectively. Participants who reported consuming higher amounts of high-fat dairy products were younger and more likely to be male. They also had a higher daily total caloric intake, and higher consumption of processed and unprocessed red meat intake compared to those who reported lower intakes of high-fat dairy products. Participants who reported consuming higher amounts of low-fat dairy products were more likely to be female and tended to be more physically active according to pedometer measurements (steps/day). Additionally, those who consumed higher amounts of low-fat dairy products had a slightly higher total daily caloric intake and lower consumption of unprocessed meats compared to those who reported lower intakes of low-fat dairy products.

During 8 years of follow-up, there were 172 participants who developed T2D among the 1,623 study participants who were free of T2D at baseline. Although no statistically significant associations of high-or-low fat dairy intake with diabetes development were found, participants who reported the highest levels of high-fat dairy consumption tended to have lower odds of developing T2D when compared to participants who reported the lowest intake of high-fat dairy consumption. When comparing the upper tertile of high-fat dairy intake to the lowest tertile of intake, the odds ratio (95% CI) of developing T2D was 0.69 (0.45,1.05), after adjustment for age, sex, site, total calories/day, education, smoking status, alcohol use, steps/day, and additional dietary factors (*P*-trend=0.08) (**Table 3a**). For low-fat dairy consumption, no trend for an

association with T2D risk was seen. For all analyses, additional adjustment for BMI attenuated odds ratios

Sensitivity analyses that additionally incorporated heavy cream and butter in the high-fat consumption group did not materially alter the ORs. Also, there were no significant interactions between dietary factors and age, gender, or BMI on risk of T2D (results not shown).

Discussion

Our primary findings from this analysis indicate that the SHFS has a much lower consumption of both high-fat and low-fat dairy products compared to other large cohort studies in the US and the general US population. The magnitude of risk estimates suggested trends towards an inverse relationship between high-fat dairy intake and incident T2D and no association between low-fat dairy intake and T2D, however these relationships were not statistically significant.

The median daily intakes of high-fat dairy ranged from 0.02-0.33 servings/1000 kcal in the three tertiles, and those of low-fat dairy ranged from 0-0.40 servings/1000kcal. In other studies done in large cohorts in the US, the median daily intake of high-fat dairy products ranged ~ 0.5-1.5 servings/1000kcal and ~ 0.5-2.0 servings/1000kcal for low-fat intake.(15,10,17) These studies also consisted of older female cohorts with much different underlying demographics than the SHFS (15,24) Despite some interesting trends, the limited range of dairy intake in the population in combination with a relatively small sample size made it challenging to detect meaningful differences in T2D risk .

Consistent with the odds ratios reported herein, previous studies have reported inverse associations of high-fat dairy consumption with T2D with similar magnitude.(24,17) However, some other studies, including a large meta-analysis, have reported inverse associations of low-fat dairy with T2D.(9,11–13,15–19) A major challenge in synthesizing available literature on the association of dairy-intake with diabetes risk is the lack of homogeneity between dietary ascertainment methods (e.g., different types of FFQ, diet recall, biomarkers) or in the definitions of high- versus low-fat dairy products across studies;

many published studies do not clearly and/or consistently distinguish between high- and low-fat dairy products. As such, discordance across study results may be due to the different dairy foods included in high- and low-fat dairy groups, different categorization methods used to capture consumption ranges, and different dietary factors used as covariates in regression models.

Current USDA dietary guidelines recommend that adults consume three servings of dairy products per day as part of a healthy diet. SHFS participants report consuming much less dairy than these recommendations. The observed ORs in the highest tertile of high-fat dairy intake were partially attenuated after adjustment for other dietary factors (model 3). Part of this attenuation might be due to control for the potential confounding by other foods the consumption of which is associated with both dairy intake and diabetes risk. At first glance, the inclusion of saturated fat in this model might appear like an over-adjustment since dairy products are a major source of saturated fat. However, in the SHFS, saturated fat intake is high [median %kcal (IQR): 11.5% (10.%,12.8%)] and dairy intake is low; as such dairy products do not seem to be a major source of saturated fat in this population. Adjustment for BMI attenuated the observed OR for analyses of low-fat dairy consumption with T2D, while adjustment for BMI in analyses of high-fat dairy and T2D had only modest effects on reported odds ratios. On the other hand, it is possible that BMI may be the mechanism by which fat intake influences diabetes risk (i.e., dairy intake influences BMI, and BMI influences risk of T2D). If BMI is in the causal pathway between dairy-intake and T2D, the model that adjusts for BMI may underestimate the association of dairy-intake and T2D risk (over-adjustment).

This study has limitations. First, the use of self-report to estimate diet is challenging, and some participants may have over-or-under-reported usual dietary intake. Our use of nutrient densities to describe high- and low-fat dairy intake is one way to partly correct for over-and underreporting among participants, assuming that dairy product intake was not systematically over- or under-reported relative to other foods. Additionally, dairy consumption in the SHFS was very low, and it was challenging to categorize dairy in a meaningful way given such low intake. Although we adjusted for many factors associated with diet and T2D, we cannot rule out residual confounding by unmeasured factors.

This study also has strengths. This was the first time, to our knowledge, a study has examined the role of

high-fat and low-fat dairy consumption on incident T2D among AIs, an underserved population with an exceedingly high incidence of T2D. Although there were no statistically significant associations found, the magnitude of the ORs highlight some interesting trends worth further exploration in future studies. Additionally, the relatively low overall consumption of both high- and low-fat dairy products within this population is a key finding worth further consideration.

Tables

Table 1a. Baseline characteristics of study participants according to tertiles of high-fat dairy product consumption

	High-fat dairy intake (servings/1000 kcal)[1]		
Characteristics	<0.05	0.05 to <0.18	≥0.18
	n=541	n=541	n=541
Median intake (IQR) of high-fat dairy products	0.02 (0,0.03)	0.11 (0.08,0.14)	0.34 (0.25,0.51)
Median intake (IQR) of low-fat dairy products	0.09 (.01,0.35)	0.05 (0,0.28)	0 (0,0.05)
Age (y)	38.5 ± 16.2[2]	36.1 ± 14.7	35.6 ± 14.6
Female (%)	63.6	61.2	57.5
BMI (kg/m^2)	30.8 ± 7.4	30.5± 7.3	30.1 ± 7.0
Fasting glucose(mg/dl)	93.6 ± 10.5	93.5 ± 10.0	93.7 ± 10.1
Insulin (μU/mL)	15.5 ± 15.9	14.6 ± 11.7	15.4 ± 16.9
HDL cholesterol	53.1 ± 15.7	52.4 ± 14.6	52.2 ± 13.7
Education (y)	12.4 ± 2.4	12.4 ± 2.2	12.1 ± 2.1
Pedometer (Steps/day)	6236.6 ± 4168.1	6396.4 ± 4101.7	6516.7 ± 3728.4
Alcohol (%)			
Never	14.2	11.5	7.9
Ever	28.8	23.3	24.6
Current	56.9	65.2	67.5
Smoking (%)			
Never	42.7	41.3	40.5
Ever	21.3	20	21.1
Current	36.0	38.7	38.4
Dietary factors			
Total calories (kcal)	2336.615 ± 1301.1	2522.2 ± 1372.4	2573.3 ± 1330.5
Fruit & vegetables (servings/day)	3.6 ± 2.7	3.6 ± 2.5	3.6 ± 2.4
Processed meat (g/day)	33.4 ± 38.7	37.7 ± 33.7	37.3 ± 34.5
Unprocessed meat (g/day)	56.1 ± 55.8	60.2 ± 56.8	62.7 ± 66.3
Sugar sweetened beverages (g/day)	508.5 ± 533.6	544.5 ± 505.5	547.4 ± 512.2
Other sources of fats (peanut butter, nuts, seeds)(g/day)	15.3 ± 28.7	14.2 ± 25.6	13.7 ± 27.9
Total fat (% kcal)	37.7 ± 7.6	38.1 ± 6.8	39.1 ± 8.5
Saturated fat (% kcal)	10.8 ± 2.2	11.2 ± 2.1	12.4 ± 2.9
Trans fat (% kcal)	1.6 ± 0.6	1.6 ± 0.5	1.6 ± 0.6
Total dietary fiber (g/1000kcal)	7.6 ± 2.8	7.1 ± 2.1	6.9 ± 2.1

[1] One serving/day= 8 oz. of milk and 1.5 oz. of cheese.
[2] Mean ± SD

Table 1b. Baseline characteristics of study participants according to tertiles of low-fat dairy product consumption

	Low-fat dairy intake (servings/1000 kcal)[1]		
Characteristics	0	0 t <0.13	≥0.13
	n=646	n=426	n=551
Median intake (IQR) low-fat dairy products	0 (0,0)	0.04 (0.02,0.08)	0.40 (0.24,0.70)
Median intake (IQR) high-fat dairy products	0.22 (0.09,0.42)	0.07 (0.02, 0.14)	0.07(0.02,0.15)
Age (y)	36.4 ± 14.7[2]	37.4 ± 14.5	36.6 ± 16.4
Female (%)	57.7	65.6	60.4
BMI (kg/m^2)	29.7 ± 6.6	31.6 ± 7.6	30.6 ± 7.6
Fasting glucose(mg/dl)	93.4 ± 10.3	94.0 ± 10.0	93.5 ± 10.2
Insulin (μU/mL)	14.8 ± 15.9	15.4 ± 12.7	15.4 ± 15.8
HDL cholesterol	53.0 ± 14.3	52.8 ± 15.2	51.9 ±14.8
Education (y)	12.1 ± 1.9	12.5 ± 2.2	12.3 ± 2.6
Pedometer (Steps/day)	6174.5 ± 3621.3	6005.8 ± 3685.8	6937.4 ± 4581.3
Alcohol (%)			
Never	9.6	11.0	13.3
Ever	24.8	26.4	25.9
Current	65.6	62.6	60.8
Smoking (%)			
Never	39.2	41.5	44.3
Ever	17.3	20.9	24.8
Current	43.5	37.6	30.9
Total calories (kcal)	2488.7 ± 1360.6	2416.1 ± 1297.1	2513.1 ± 1344.2
Fruit & vegetables (servings/day)	3.4 ± 2.6	3.5 ± 2.4	3.9 ± 2.6
Processed meat (g/day)	37.9 ±35.3	34.5 ± 36.9	35.4 ± 35.2
Unprocessed meat (g/day)	60.7 ± 59.3	61.1 ± 59.3	57.3 ± 60.9
Sugar sweetened beverages (g/day)	580.6 ± 533.3	570.8 ± 544.5	447.1 ± 462.4
Other sources of fats (peanut butter, nuts, seeds)(g/day)	14.1 ± 29.7	15.7 ± 29.1	13.7 ± 22.9
Total fat (% kcal)	38.6 ± 8.9	38.5 ± 7.4	37.8 ± 6.1
Saturated fat (% kcal)	11.7 ± 3.0	11.1 ± 2.1	11.6 ± 2.1
Trans fat (% kcal)	1.6 ± 0.63	1.6 ± 0.6	1.6 ± 0.4
Total dietary fiber (g/1000kcal)	6.8 ± 2.2	7.3 ± 2.3	7.6 ± 2.6

[1] One serving/day= 8 oz. of milk and 1.5 oz. cheese.
[2] Mean ± SD

Table 2. Baseline characteristics according to T2D outcome status.

	Outcome status	
	T2D (n=172)	No-T2D (n=1,451)
Age (y)	40.0 ± 14.4	36.4 ± 15.3
Female (%)	61.6	60.7
BMI (kg/m^2)	35.7 ± 7.7[1]	29.9 ± 6.9
Fasting glucose(mg/dl)	103.2 ± 11.5	92.5 ± 9.4
Insulin (μU/mL)	23.7 ± 19.9	14.1 ± 14.0
HDL cholesterol	48.1 ± 13.3	53.1 ± 14.8
Education (y)	12.4 ± 2.4	12.3 ± 2.1
Pedometer (Steps/day)	5691.1 ± 4299.4	6467.5 ± 3957.4
Alcohol (%)		
Never	11.1	11.2
Ever	33.7	24.6
Current	55.2	64.2
Smoking (%)		
Never	40.1	41.6
Ever	25.0	20.3
Current	34.9	38.1
Total calories (kcal)	2450.0 ± 1273.6	2480.6 ± 1345.9
Fruit & vegetables (servings/day)	3.7 ± 2.6	3.6 ± 2.5
Processed meat (g/day)	38.7 ± 39.5	35.9 ± 35.2
Unprocessed meat (g/day)	55.7 ± 57.6	60.2 ± 60.1
Sugar sweetened beverages(SSB) (g/day)	503.8 ± 513.9	537.0 ± 517.7
Other sources of fats (peanut butter, nuts, seeds)(g/day)	11.9 ± 21.8	14.7 ± 28.0
Total fat (% kcal)	38.8 ± 12.7	38.2 ± 6.9
Saturated fat (% kcal)	11.8 ± 4.4	11.4 ± 2.2
Trans fat (% kcal)	1.6 ± 0.70	1.6 ± 0.57
Total dietary fiber (g/1000kcal)	7.5 ± 2.3	7.2 ± 2.4

[1] Mean ± standard deviation (SD)

Table 3a. ORs (95% CIs) of T2D according to tertiles of high-fat dairy intake.[1]

	Tertile 1	Tertile 2	Tertile 3	*P-trend*
High-fat dairy intake (servings/1000 kcal)[2]	<0.05	0.05 to <0.18	≥0.18	
Median intake (IQR)	0.02 (0,0.03)	0.11 (0.08,0.14)	0.34 (0.25,0.51)	
No. of cases	65	54	53	
Total no. at risk	541	541	541	
Models				
Minimally adjusted[3]	1.0	0.83 (0.54,1.29)	0.82 (0.57, 1.20)	0.30
Multivariate[4]	1.0	0.85 (0.55,1.31)	0.84 (0.57,1.21)	0.34
Dietary factors[5]	1.0	0.81 (0.52,1.25)	0.69 (0.45,1.05)	0.08
BMI[6]	1.0	0.83 (0.54,1.31)	0.76 (0.47,1.22)	0.25

[1]Generalized estimating equations (GEE) were used to assess the association of dietary exposure and incident T2D.

[2] High-fat dairy group consisted of whole milk and cheese and cheese spreads.

[3] Model 1: Adjusted for age, sex, site, and total calories/day.

[4] Model 2: Additionally adjusted for education, physical activity (steps/day), smoking status, and alcohol consumption.
[5] Model 3: Additionally adjusted for processed and unprocessed meat intake, total fat, trans-fat, saturated fat, dietary fiber, other sources of fats (peanut butter, nuts, seeds), fruits & vegetables, and SSB intake.

[6] Model 4: Additionally adjusted for BMI.

Table 3b. ORs (95% CIs) of T2D according to tertiles of low-fat dairy intake.[1]

	Tertile 1	Tertile 2	Tertile 3	*P-trend*
Low-fat dairy intake (servings/1000kcal)[2]	0	0 to <0.13	≥0.13	
Median intake (IQR)	0 (0,0)	0.04 (0.02,0.08)	0.40 (0.24,0.70)	
No. of cases	61	48	63	
Total no. at risk	646	426	551	
Models				
Minimally adjusted[3]	1.0	1.18 (0.80,1.72)	1.32 (0.92,1.89)	0.12
Multivariate[4]	1.0	1.18 (0.79,1.75)	1.34 (0.93,1.94)	0.11
Dietary factors[5]	1.0	1.26 (0.85,1.89)	1.29 (0.89,1.88)	0.16
BMI[6]	1.0	1.03 (0.69,1.54)	1.08 (0.73,1.61)	0.68

[1] Generalized estimating equations (GEE) were used to assess the association of dietary exposure and incident T2D.

[2] Low-fat dairy group consisted of 2% milk, 1% milk, non-fat milk, and low-fat cheese & cheese spreads.

[3] Model 1: Adjusted for age, sex, site, and total calories/day.

[4] Model 2: Additionally adjusted for education, physical activity (steps/day), smoking status, and alcohol consumption.
[5] Model 3: Additionally adjusted for processed and unprocessed meat intake, total fat, trans-fat, saturated fat, dietary fiber, other sources of fats (peanut butter, nuts, seeds), fruits & vegetables, and SSB intake.

[6] Model 4: Additionally adjusted for BMI.

References

1. Acton KJ, Burrows NR, Geiss LS TT. Diabetes Prevalence Among American Indians and Alaska Natives and the Overall Population --- United States, 1994--2004 [Internet]. MMWR. Surveillance summaries. 2006.
2. Fretts AM, Howard B V, McKnight B, Duncan GE, Beresford SAA, Mete M, Eilat-Adar S, Zhang Y, Siscovick DS. Associations of processed meat and unprocessed red meat intake with incident diabetes: the Strong Heart Family Study. Am J Clin Nutr [Internet]. 2012;95:752–8.
3. Wu Y, Zhang D, Jiang X, Jiang W. Fruit and vegetable consumption and risk of type 2 diabetes mellitus: a dose-response meta-analysis of prospective cohort studies. Nutr Metab Cardiovasc Dis [Internet]. 2015;25:140–7.
4. Li M, Fan Y, Zhang X, Hou W, Tang Z. Fruit and vegetable intake and risk of type 2 diabetes mellitus: meta-analysis of prospective cohort studies. BMJ Open [Internet]. 2014;4:e005497.
5. de Munter JSL, Hu FB, Spiegelman D, Franz M, van Dam RM. Whole grain, bran, and germ intake and risk of type 2 diabetes: a prospective cohort study and systematic review. PLoS Med [Internet]. 2007;4:e261.
6. Wang M, Yu M, Fang L, Hu R-Y. Association between sugar-sweetened beverages and type 2 diabetes: A meta-analysis. J Diabetes Investig [Internet]. 2015;6:360–6.
7. Aune D, Ursin G, Veierød MB. Meat consumption and the risk of type 2 diabetes: a systematic review and meta-analysis of cohort studies. Diabetologia [Internet]. 2009;52:2277–87.
8. Pan A, Sun Q, Bernstein AM, Schulze MB, Manson JE, Willett WC, Hu FB. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. Am J Clin Nutr [Internet]. 2011;94:1088–96.
9. Gijsbers L, Ding EL, Malik VS, de Goede J, Geleijnse JM, Soedamah-Muthu SS. Consumption of dairy foods and diabetes incidence: a dose-response meta-analysis of observational studies. Am J Clin Nutr [Internet]. 2016;103:1111–24.
10. Chen M, Sun Q, Giovannucci E, Mozaffarian D, Manson JE, Willett WC, Hu FB. Dairy consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. BMC Med [Internet]. 2014;12:215.
11. Aune D, Norat T, Romundstad P, Vatten LJ. Dairy products and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. Am J Clin Nutr [Internet]. 2013;98:1066–83.
12. Gao D, Ning N, Wang C, Wang Y, Li Q, Meng Z, Liu Y, Li Q. Dairy products consumption and risk of type 2 diabetes: systematic review and dose-response meta-analysis. PLoS One [Internet]. 2013;8:e73965.
13. Tong X, Dong J-Y, Wu Z-W, Li W, Qin L-Q. Dairy consumption and risk of type 2 diabetes mellitus: a meta-analysis of cohort studies. Eur J Clin Nutr [Internet]. 2011;65:1027–31.
14. Elwood PC, Pickering JE, Givens DI, Gallacher JE. The consumption of milk and dairy foods and the incidence of vascular disease and diabetes: an overview of the evidence. Lipids [Internet]. 2010;45:925–39.
15. Choi,HK Willett, WC Stampfer, MJ Rimm, E Hu F. Dairy Consumption and Risk of Type 2 Diabetes Mellitus in Men. Arch Intern Med. 2005;165:997–1003.
16. Liu S, Choi HK, Ford E, Song Y, Klevak A, Buring JE, Manson JE. A prospective study of dairy intake and the risk of type 2 diabetes in women. Diabetes Care [Internet]. 2006;29:1579–84.
17. Malik VS, Sun Q, van Dam RM, Rimm EB, Willett WC, Rosner B, Hu FB. Adolescent dairy product consumption and risk of type 2 diabetes in middle-aged women. Am J Clin Nutr [Internet]. 2011;94:854–61.
18. Margolis KL, Wei F, de Boer IH, Howard B V, Liu S, Manson JE, Mossavar-Rahmani Y, Phillips LS, Shikany JM, Tinker LF. A diet high in low-fat dairy products lowers diabetes risk in postmenopausal women. J Nutr [Internet]. 2011;141:1969–74.
19. van Dam RM, Hu FB, Rosenberg L, Krishnan S, Palmer JR. Dietary calcium and magnesium, major food sources, and risk of type 2 diabetes in U.S. black women. Diabetes Care [Internet]. 2006;29:2238–43.
20. Soedamah-Muthu SS, Masset G, Verberne L, Geleijnse JM, Brunner EJ. Consumption of dairy products and associations with incident diabetes, CHD and mortality in the Whitehall II study. Br J Nutr [Internet]. 2013;109:718–26.

21. Struijk EA, Heraclides A, Witte DR, Soedamah-Muthu SS, Geleijnse JM, Toft U, Lau CJ. Dairy product intake in relation to glucose regulation indices and risk of type 2 diabetes. Nutr Metab Cardiovasc Dis [Internet]. 2013;23:822–8.
22. O'Connor LM, Lentjes MAH, Luben RN, Khaw K-T, Wareham NJ, Forouhi NG. Dietary dairy product intake and incident type 2 diabetes: a prospective study using dietary data from a 7-day food diary. Diabetologia [Internet]. 2014;57:909–17.
23. von Ruesten A, Feller S, Bergmann MM, Boeing H. Diet and risk of chronic diseases: results from the first 8 years of follow-up in the EPIC-Potsdam study. Eur J Clin Nutr [Internet]. 2013;67:412–9.
24. Ericson U, Hellstrand S, Brunkwall L, Schulz C-A, Sonestedt E, Wallström P, Gullberg B, Wirfält E, Orho-Melander M. Food sources of fat may clarify the inconsistent role of dietary fat intake for incidence of type 2 diabetes. Am J Clin Nutr [Internet]. 2015;101:1065–80.
25. Brevik A, Veierød MB, Drevon CA, Andersen LF. Evaluation of the odd fatty acids 15:0 and 17:0 in serum and adipose tissue as markers of intake of milk and dairy fat. Eur J Clin Nutr [Internet]. 2005;59:1417–22.
26. Mozaffarian D, de Oliveira Otto MC, Lemaitre RN, Fretts AM, Hotamisligil G, Tsai MY, Siscovick DS, Nettleton JA. trans-Palmitoleic acid, other dairy fat biomarkers, and incident diabetes: the Multi-Ethnic Study of Atherosclerosis (MESA). Am J Clin Nutr [Internet]. 2013;97:854–61.
27. Mozaffarian D, Cao H, King IB, Lemaitre RN, Song X, Siscovick DS, Hotamisligil GS. Trans-palmitoleic acid, metabolic risk factors, and new-onset diabetes in U.S. adults: a cohort study. Ann Intern Med [Internet]. 2010;153:790–9.
28. Yakoob MY, Shi P, Willett WC, Rexrode KM, Campos H, Orav EJ, Hu FB, Mozaffarian D. Circulating Biomarkers of Dairy Fat and Risk of Incident Diabetes Mellitus Among Men and Women in the United States in Two Large Prospective Cohorts. Circulation [Internet]. 2016;133:1645–54.
29. Hirahatake KM, Slavin JL, Maki KC, Adams SH. Associations between dairy foods, diabetes, and metabolic health: potential mechanisms and future directions. Metabolism [Internet]. 2014;63:618–27.
30. Lee ET, Welty T, Fabsitz R, Cowan L, Le N, Oopik A, Cucchiara A, Savage P, Howard B. The Strong Heart Study. A study of cardiovascular disease in American Indians: design and methods. Am J Epidemiol. 1990;132(6):1141–55.
31. North KE, Howard B V, Welty TK, Best LG, Lee ET, Yeh JL, Fabsitz RR, Roman MJ, MacCluer JW. Genetic and environmental contributions to cardiovascular disease risk in American Indians: the strong heart family study. Am J Epidemiol [Internet]. 2003;157:303–14.
32. Block G, Thompson FE, Hartman AM, Larkin FA, Guire KE. Comparison of two dietary questionnaires validated against multiple dietary records collected during a 1-year period. J Am Diet Assoc [Internet]. 1992;92:686–93.
33. Subar AF, Thompson FE, Kipnis V, Midthune D, Hurwitz P, McNutt S, McIntosh A, Rosenfeld S. Comparative validation of the Block, Willett, and National Cancer Institute food frequency questionnaires : the Eating at America's Table Study. Am J Epidemiol [Internet]. 2001;154:1089–99.
34. American Diabetes Association. Evidence-Based Nutrition Principles and Recommendations for the Treatment and Prevention of Diabetes and Related Complications. Clin Diabetes [Internet]. 2002;20:53–64.