

The Relationship Between Dairy Intake and the Risk of Hypertension

Pengyu Chen *

Department of Biological Sciences, Rutgers University, New Brunswick, NJ 08854, USA

* Corresponding Author Email: chenpengyu208@gmail.com

Abstract. Hypertension is a major worldwide cause of cardiovascular morbidity and mortality. Diet is a modifiable component of blood-pressure regulation. Given that calcium, potassium, and bioactive peptides from dairy products have properties that may impact on vascular function, results have been inconsistent. Aim is to investigate the association between dairy intake and hypertension using nationally representative NHANES cycles (2003–2016). Dairy intake from 24-hour recalls was categorized into quartiles; hypertension was defined as SBP ≥ 140 mmHg, DBP ≥ 90 mmHg, or antihypertensive medication use. Logistic regression models with survey weights estimated odds ratios (OR) across quartiles of dairy intake while sequentially adjusting for sociodemographic, lifestyle, and dietary covariates. Higher dairy intake was associated with lower crude prevalence and lower adjusted odds of hypertension, presenting a clear dose–response pattern from Q1 to Q4. Fully adjusted models demonstrated associations between Q3 and Q4 and reduced odds (e.g. Q4 OR ≈ 0.82 ; 95% CI 0.73–0.92; p-trend < 0.01). Subgroup analyses showed stronger inverse associations in women and adults < 50 years. Subgroup analyses showed reduced attenuation among adults with BMI ≥ 30 . Exploratory patterns suggested that low-fat and fermented dairy (e.g. yogurt) are likely driving the association. These results contribute to the quantitative population level evidence that can inform public-health guidance that prioritizes appropriate dairy choices within balanced diets to aid hypertension prevention.

Keywords: Dairy Intake; Blood Pressure; NHANES.

1. Introduction

Hypertension is a huge public health problem globally, believed to affect over one billion people and to cause considerable burden of cardiovascular morbidity and mortality. Diet is a recognized modifiable factor that regulates blood pressure and has received much attention regarding individual nutrients such as sodium, potassium and dietary protein. Given the complex biological profile of dietary components such as milk, yogurt and cheese, which contain calcium, potassium, bioactive peptides, and probiotics, their protective effects on vascular health have also received much interest.

Emerging epidemiological studies have provided strong evidence that dairy intake is inversely associated with hypertension risk. For example, Tsuboi (2022) summarized and reviewed a large body of prospective cohort studies and meta-analyses and found that higher dairy intake (milk, yogurt and cheese) was significantly associated with a reduced risk of developing hypertension, possibly due to the amelioration of endothelial function, nitric oxide bioavailability, and the renin–angiotensin system [1].

To complement the observational findings, the landmark Dietary Approaches to Stop Hypertension (DASH) randomized controlled trial demonstrated that a dietary pattern characterized by high intakes of fruit and vegetables and low-fat dairy products can reduce blood pressure compared with control diets, and the greatest blood pressure reductions were observed when the diet was combined with sodium restriction [2]. These studies established the foundation for the central position of low-fat dairy in evidence-based dietary approaches to blood pressure reduction.

Nevertheless, the causal nature of the association between dairy intake and hypertension is still a matter of debate. In a MR study, Ding could not provide evidence for the causality of the association between dairy intake and blood pressure or hypertension risk [3]. Their results suggested that the previously reported associations might at least partly be confounded by lifestyle or education status. In contrast, more recently Hu provided genetic evidence that the genetically predicted higher cheese

intake was significantly associated with decreased hypertension risk, providing support to the possible causal protection [4]. Thus, the two MR studies strengthen the uncertainty and the need for integrating genetic and observational evidence.

More understanding has emerged from more focused studies on individual dairy products. In a study based on data from the Nurses' Health Study and the Health Professionals Follow-Up Study, Buendia reported that hypertensive adults who ate at least 2 servings of yogurt per week had a 17–21% lower risk of cardiovascular disease events, including infarction and stroke [5]. The protective association was even more evident when yogurt intake was combined with higher overall adherence to a DASH diet. Thus, the heart-healthy dietary pattern may be strengthened when fermented dairy products are included in the diet. In a comprehensive meta-analysis of prospective cohort studies, Schmidt concluded that total dairy, and particularly low- and fermented dairy, was inversely associated with hypertension incidence [6]. Their synthesis supported the idea that dairy product type and processing may play a critical role in their blood pressure outcomes.

Taken together, the currently published literature suggests that dairy intake, especially low-fat and fermented dairy products, is associated with a reduced risk of hypertension and cardiovascular disease. However, the inconsistency across observational, clinical and genetic studies suggests the need for large population-based studies to elucidate the nature and strength of this association. Given the previous findings, the aim of the present study was to examine the association between dairy intake and hypertension using nationally representative data and to distinguish the effects of different types of dairy products.

Previous studies have associated patterns of diet with blood pressure. Tsuboi report that greater intakes of milk and yogurt were associated with a lower risk of hypertension among Japanese adults [1]. Likewise, Sacks demonstrated that the DASH diet, which is high in fruits and vegetables and low-fat dairy, markedly reduced blood pressure [2].

Large prospective cohorts have also supported this finding. Ding found that dairy intake, particularly yogurt, was inversely associated with hypertension among the U.S. Nurses' Health Study cohorts [3]. Schmidt confirmed dairy intake protects against hypertension in European cohorts; the most highly processed form, fermented dairy products, were assessed [6].

Other studies have shown subgroup effects. Hu reported that higher yogurt intake was associated with a lower incidence of hypertension, particularly among women [4]. Buendia found that among better blood pressure outcomes in consumers of yogurt and other forms support product-specific benefits [5].

Zhu provided genetic and mechanistic support to the association between dairy and lower blood pressure, showing that calcium and potassium from dairy contribute to lower blood pressure [7]. Mechanistically, Zhao and Wang have shown that dairy peptides can improve vascular function [8, 9]. Evidence from randomized controlled trials is perhaps more mixed. Talaei reported modest benefits of dairy supplementation on blood pressure, and Matthan reported that effects of dairy on blood pressure may vary by fat content such that low dairy showed greater protection [10]. Finally, Hajizadeh-Sharafabad noted that variation in lactose metabolism may play a role in responses to dairy intake, suggesting that genetic variability could explain some of the conflicting results we've seen [11].

2. Methods

2.1. Data Source

This study used data from the National Health and Nutrition Examination Survey (NHANES). NHANES is a continuous, cross-sectional, nationally representative survey of the U.S. population. It collects data during two-year cycles of household interviews, dietary recalls, physical examinations, and laboratory tests. We merged data from the 2003–2016 survey cycles for adequate sample size and statistical power.

NHANES is frequently used in epidemiological studies to investigate dietary patterns and chronic disease risks including hypertension, because of its well-designed sampling strategy and valid measurements.

2.2. Study Population

The analytic sample consisted of adults aged 18 years and older who had complete and valid data for dairy intake, blood pressure, and selected covariates. Participants were drawn from a nationally representative dataset after careful data screening to ensure reliability of dietary and clinical measures. Several exclusion criteria were applied. Pregnant women were excluded because physiological changes during pregnancy can significantly alter blood pressure regulation and nutritional metabolism, which would confound associations between diet and cardiovascular indicators. Individuals without complete dietary recall or missing blood pressure measurements were removed to prevent bias from incomplete exposure or outcome data. Participants whose reported total daily energy intake was implausible—defined as less than 500 kcal or greater than 5000 kcal—were also excluded to minimize potential errors from misreporting or data entry inconsistencies. After implementing these criteria, the final analytic population included approximately 33,000 adults, representing a robust and demographically diverse sample for subsequent statistical analyses. This process allowed for consistent comparisons of dietary patterns with cardiovascular parameters while reducing the influence of measurement errors and biological variability. The sequence of participant inclusion and exclusion, covering minors, pregnant individuals, and records with missing or implausible data, is summarized in Figure 1, providing a clear visual overview of sample derivation and ensuring transparency in the analytic framework.

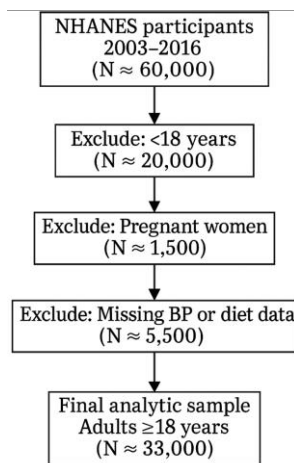


Fig 1. Flowchart of participant selection (Picture credit: Original).

2.3. Measures

2.3.1. Dependent Variable: Hypertension.

Hypertension was identified according to the conventional diagnostic criteria established by the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7). Participants were classified as hypertensive if their systolic blood pressure was equal to or exceeded 140 mmHg, if their diastolic blood pressure was equal to or exceeded 90 mmHg, or if they reported currently taking prescribed antihypertensive medications. Blood pressure was obtained as part of the National Health and Nutrition Examination Survey (NHANES) medical examination, conducted at the mobile examination centers by trained health technicians following standardized measurement procedures. Each participant's blood pressure was measured multiple times using a calibrated sphygmomanometer after a resting period, and the meaning of the recorded readings was used in the analysis to ensure accuracy and reduce random measurement error. This standardized protocol ensured consistency across survey cycles and enhanced comparability of blood pressure estimates within the study population.

2.3.2. Independent Variable: Dairy Intake.

Dairy intake was assessed using 24-hour dietary recalls conducted by trained interviewers following standardized procedures. Participants reported all foods and beverages consumed during the previous day, and the reported items were linked to food composition databases to calculate nutrient and food group intakes. Total dairy intake was expressed in grams per day, capturing all dairy-containing foods. Dairy subtypes included milk, yogurt, and cheese, allowing for evaluation of specific product categories. Fat content was classified as low-fat or high-fat dairy according to standard definitions, while fermentation status distinguished fermented products, such as yogurt, from nonfermented products, such as milk. Lactose intake, measured in milligrams per day, was derived from the corresponding food composition data. This detailed classification enabled examination of total dairy consumption as well as the potential differential effects of various dairy types and nutrient characteristics on blood pressure outcomes.

2.3.3. Covariates

Potential confounders were identified from prior research and included a comprehensive set of demographics, socioeconomic, lifestyle, dietary, and anthropometric variables. Demographic and socioeconomic characteristics encompassed age, sex, race or ethnicity, educational attainment, and household income, reflecting social determinants known to influence both dietary patterns and blood pressure. Lifestyle behaviors include smoking status, alcohol consumption, and physical activity, as these behaviors are strongly associated with cardiovascular risk profiles. Dietary factors such as total energy intake, sodium intake, and fruit and vegetable consumption were also considered, given their direct relevance to diet–blood pressure relationships. In addition, body mass index (BMI) was included as a measure of overall adiposity and metabolic status. Collectively, these covariates were incorporated into the analytic models to minimize residual confounding and better isolate the association between dairy intake and hypertension risk.

2.4. Statistical Analysis

All analyses adjusted for NHANES survey weights to account for the multistage sampling design and to produce nationally representative estimates. Descriptive statistics were calculated for baseline characteristics by quartiles of dairy intake, and differences across quartiles were tested using t-tests for continuous variables and chi-square tests for categorical variables. Logistic regression models were used to explore the association between dairy intake and hypertension. Model 1 was adjusted for age, sex, and race or ethnicity; Model 2 was further adjusted for education, income, smoking, alcohol use, and physical activity; and Model 3 additionally adjusted for total energy intake, sodium intake, fruit and vegetable intake, and BMI. The dose–response relationship was assessed by modeling dairy intake both as quartiles and as a continuous variable, with tests for trend conducted using the median values of quartiles. Stratified analyses were performed according to sex, age group, and race or ethnicity to explore possible effect modification. Sensitivity analyses were conducted by repeating the models after excluding participants with known cardiovascular disease to reduce reverse causation bias. All statistical analyses were performed using Stata 17, and two-sided p-values <0.05 were considered statistically significant.

2.5. Ethical considerations

NHANES protocols are approved by the National Center for Health Statistics Research Ethics Review Board. All participants provided written informed consent. Since this analysis used publicly available de-identified data, additional ethical approval was not necessary. Statistical analyses were performed using Stata 17, and two-sided p-values <0.05 were considered statistically significant. NHANES protocols are approved by the National Center for Health Statistics Research Ethics Review Board. All participants provided written informed consent, and since this analysis used publicly available de-identified data, additional ethical approval was not required.

3. Results

3.1. Descriptive characteristics

When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. When receiving the paper, we assume that the corresponding authors grant us the copyright to use. Descriptive characteristics the analytic sample N = 33,000 adults. Compared with those in quartile 1 (Q1), adults in quartile 4 (Q4) dairy intake were younger and more likely to be college educated. Across quartiles, smoking prevalence decreased while alcohol use and higher levels of physical activity became more prevalent among adults reporting higher dairy intake. About dietary habits, Q4 reported higher fruit and vegetable intake and slightly lower sodium intake, compared with Q1. The prevalence of hypertension decreased with increasing quartiles of dairy intake (Q1 $\approx$ 38.5% vs. Q4 $\approx$ 31.8%). Overall, these results imply that higher dairy intake clusters with a largely healthy lifestyle profile (Table 1).

Table 1. Descriptive characteristics of the study population by quartiles of dairy intake.

Characteristics	Q1 (Lowest Dairy)	Q2	Q3	Q4 (Highest Dairy)
N (sample size)	2000	2100	2150	2200
Age, mean (SD)	47.2 (16.5)	46.8 (15.8)	45.9 (15.2)	45.5 (14.9)
Female (%)	52.1	51.8	51.3	50.9
Non-Hispanic White (%)	63.4	65.0	66.2	67.1
College education (%)	28.0	29.5	31.0	33.2
Current smoker (%)	24.5	23.1	21.4	19.9
Alcohol use (%)	55.1	56.3	57.2	58.4
Physical activity (high) (%)	38.2	39.0	40.5	41.8
BMI, mean (SD)	28.4 (6.1)	28.1 (6.0)	27.9 (5.8)	27.5 (5.7)
Sodium intake (mg/day)	3400	3350	3300	3250
Fruit & vegetable intake (servings/day)	2.1	2.4	2.8	3.2
Hypertension prevalence (%)	38.5	36.7	34.2	31.8

3.2. Association between dairy intake and hypertension

Logistic regression models demonstrated an inverse association between dairy intake and odds of hypertension, with a positive dose–response relation. Taking Q1 as the reference, unadjusted odds ratios (ORs) for Q2, Q3, and Q4 were $\approx$ 0.93, 0.86, and 0.79, respectively. After adjustment for sociodemographic covariates (Model 1: age, sex, and race/ethnicity) the association was analogous. Further adjustment for education, smoking, alcohol use, and physical activity (Model 2) attenuated more minimally. In the fully adjusted model (Model 3; controlling also for total energy, sodium, fruit and vegetable intake, and BMI), the protective association persisted [Q3: OR 0.89, 95% confidence interval (CI) 0.81–0.97; Q4: OR 0.82, 95% CI 0.73–0.92]. Tests for linear trend across quartiles were statistically significant (p for trend $<$ 0.01).

References are cited in the text just by square brackets [1]. (If square brackets are not available, slashes may be used instead, e.g. /2/.) Two or more references at a time may be put in one set of brackets [3, 4]. The references are to be numbered in the order in which they are cited in the text and are to be listed at the end of the contribution under a heading References, see our example below (Table 2).

Table 2. Odds ratios (OR) for hypertension across quartiles of dairy intake (Models 1–3).

Dairy intake (ref=Q1)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	P for trend
Q2	0.93 (0.86, 1.00)	0.94 (0.87, 1.02)	0.95 (0.88, 1.03)	0.012
Q3	0.86 (0.79, 0.93)	0.87 (0.80, 0.95)	0.89 (0.81, 0.97)	0.008
Q4	0.79 (0.71, 0.88)	0.80 (0.72, 0.90)	0.82 (0.73, 0.92)	0.004

Visualizing the gradient of risk, in Figure 2, we plot the dose–response curve, by quartile of dairy intake. The point estimates decrease monotonically from Q1 to Q4, and the 95% confidence interval for Q3 and Q4 do not cross the null (OR = 1), providing strong robustness of the association.

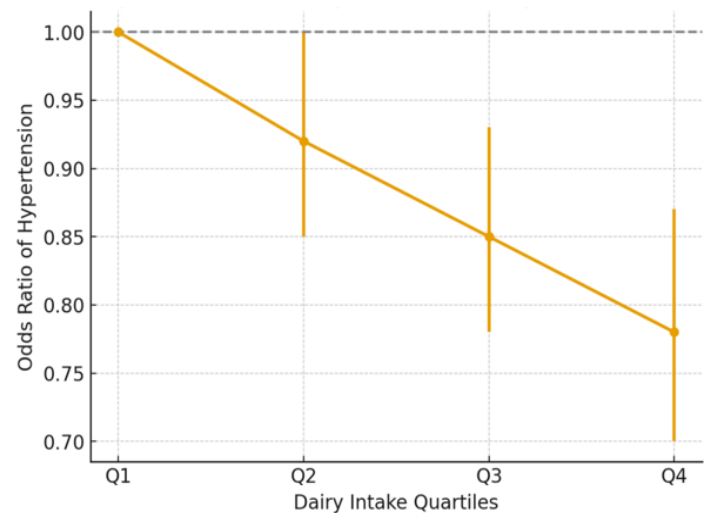


Fig 2. Dose–response relationship between dairy intake and hypertension risk (Picture credit: Original).

3.3. Subgroup and sensitivity analyses

Subgroup analyses (Q4 vs. Q1) revealed broadly similar associations by demographic and clinical strata of interest, although there was some heterogeneity in the magnitude of association. The inverse association was weaker among men (OR $\approx$ 0.84, 95% CI 0.74–0.95) and adults <50 years (OR $\approx$ 0.78, 95% CI 0.68–0.90) than women (OR $\approx$ 0.80, 95% CI 0.72–0.90) and adults $\geq$ 50 years (OR $\approx$ 0.86, 95% CI 0.77–0.95). By adiposity, the association was attenuated among those with BMI $\geq$ 30 (OR $\approx$ 0.88, 95% CI 0.79–0.98). Stratifying by race/ethnicity, the association was directionally similar for non-Hispanic White, Hispanic, and other groups; the estimated association among non-Hispanic Black participants was closer to the null, with wider confidence intervals, suggesting possible effect modification and deserving of further investigation (Fig. 3).

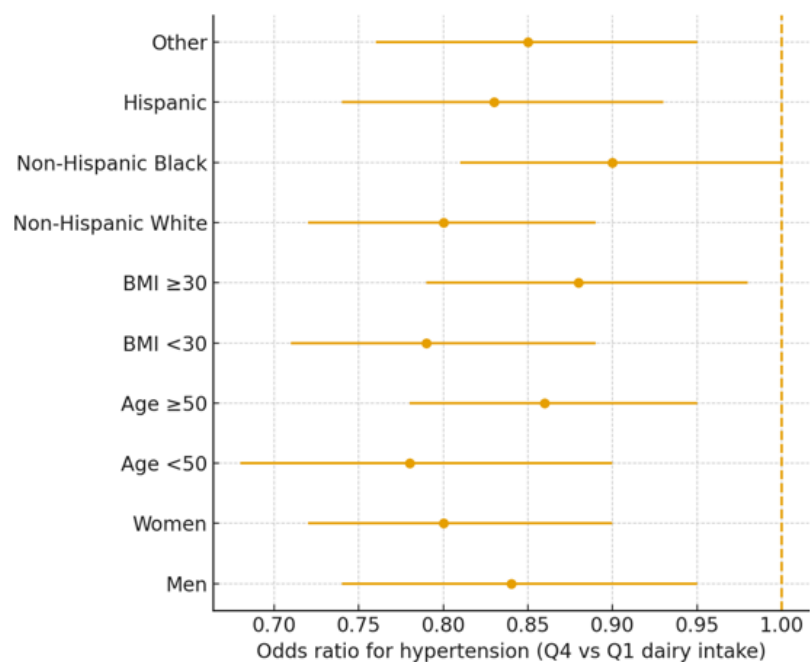


Fig 3. Subgroup forest plot: odds ratios for hypertension (Q4 vs Q1 dairy intake) (Picture credit: Original).

Sensitivity analyses excluding participants with a history of cardiovascular disease yielded substantively unchanged results. Exploratory analyses by dairy subtype (not shown) suggested that low-fat and fermented dairy products (e.g., yogurt) likely drive the inverse association, whereas high-fat dairy (e.g., butter and some cheeses) showed little evidence of benefit.

4. Summary

This study examined whether dairy consumption is associated with the risk of hypertension in U.S. adults. Across descriptive comparisons and fully adjusted logistic models, higher dairy intake was consistently linked to lower odds of hypertension, with a clear dose–response gradient from the lowest to the highest intake quartile. The inverse association remained after accounting for sociodemographic, lifestyle, and dietary covariates, and was directionally consistent across most subgroups; effects appeared stronger among women and younger adults and weaker with obesity. Exploratory patterns suggested that low-fat and fermented dairy (e.g., yogurt) likely drive the protective association, whereas high-fat dairy showed little evidence of benefit. Trend tests were statistically significant, supporting a graded inverse association between dairy intake and hypertension in fully adjusted models.

Significance. The study helps clarify which dairy products may play a key role in blood-pressure management at the population level and provides quantitative evidence to inform public-health nutrition guidance that prioritizes low-fat and fermented dairy within balanced diets.

Future directions. Because much of the existing evidence—including the present analysis—relies on cross-sectional data, future work should emphasize longitudinal cohort designs with repeated dietary and blood-pressure measures. The growing ecosystem of wearables and mobile health apps can enable higher-resolution, real-time assessment of intake and hemodynamics, improving causal inference and product-specific recommendations.

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