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# Ultra-processed food consumption and cardiometabolic risk in Canada: a cross-sectional analysis of the Canadian health measures survey

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## Abstract

**Background** Ultra-processed food (UPF) contributes to nearly 50% of Canadians' diets. Research in other countries has begun to implicate high intakes of UPFs and negative health outcomes, including body mass index, waist circumference, blood pressure, and unfavourable lipid profiles. There have been no population level examinations of the relationship between UPF consumption and cardiometabolic risk in Canada.

**Methods** Drawing on the Canadian Health Measures Survey (2016/17 and 2018/19), this study investigates the relationship between UPF consumption and cardiometabolic risk factors among Canadians (ages 19–79, $n=6517$). Dietary data collected by Food Frequency Questionnaire was classified as UPF or not using the NOVA classification system which scores foods by degree of processing. Participants were grouped into quartiles based on the daily servings of UPF. Sociodemographic and lifestyle variables were collected via household questionnaire and cardiometabolic outcomes were measured during a clinic visit. Multivariable linear regression analyses separately assessed the association between cardiometabolic risk factors and UPF quartiles while adjusting for various sociodemographic and lifestyle variables. Sensitivity analyses additionally adjusted for fruit and vegetable intake (servings/day) to determine the effect of diet quality on this relationship. All analyses were weighted to ensure national representativeness.

**Results** UPF servings per day ranged from 1.2 in the lowest and 5.8 in the highest quartile. Compared to the lowest quartiles of UPF consumption, those in the highest were more likely to be male, in the lowest income quartile, Black or White, have lower household education, and higher physical activity and sedentary time. After adjustments, UPF consumption was positively associated with BMI, WC, diastolic BP, HBA1C, c-reactive protein, white blood cells (WBC), fasting triglycerides (TG), and fasting insulin. Fruit and vegetable intake attenuated the association for all outcomes, while BMI, WC, WBC, and TG remained significantly associated with increased UPF consumption.

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**Conclusion** This study is the first Canadian study looking at population level intakes of UPF across various cardiometabolic risk factors and adds to the growing body of literature demonstrating the detrimental health effects associated with UPF consumption.

**Keywords** Ultra-processed foods, Cardiometabolic risk, Diet, Population health, Adults

## Background

In Canada, roughly one in 12 adults live with diagnosed cardiovascular disease (CVD) [1], nine in 10 have at least one risk factor for CVD [2], and one in five have metabolic syndrome [3]. These health outcomes are in part related to modifiable lifestyle factors including physical activity, sedentary behaviour, smoking, and diet. A macrosimulation model based on a nationally representative sample of Canadian adults demonstrated that 30,540 cardiovascular or cancer related deaths could have been averted or delayed if Canadians adhered to dietary recommendations set out by Canada's Food Guide and Health Canada's Dietary Reference Intake Table [4]. Increasingly, however, eating healthy has become challenging due to the complexity of our current food supply. Ultra-processed foods (UPF) have come to dominate the global food supply, with staple, whole foods increasingly being displaced by UPF in low-, middle-, and high-income countries including Canada [5].

UPFs are highly processed, ready-to-eat, pre-packaged foods, often high in sodium, sugar, and unhealthy fats, while being low in fiber and micronutrients [6, 7]. They tend to be less satiating, hyper-palatable, and heavily marketed; factors contributing to passive overconsumption [8–11]. In 2015, UPFs accounted for 24–73% of total energy intake among Canadian adults [12]. In 2001, 54.4% of household food budget was spent on UPF, a stark increase from the 37.3% observed in 1953 [13]. Conventional diet scoring systems fail to account for compositional factors beyond nutrients, such as food processing and behavioral factors like food marketing and convenience, which can also influence health outcomes. To address this, various classification systems, like the NOVA framework, have been developed to score products based on their level of food processing. The NOVA framework divides food into four groups, with ultra-processed foods representing the most processed products, such as breakfast cereals, chips, and frozen pizza [6, 14]. These foods have begun to be linked to an increased risk of cardiometabolic [15–17], endocrine [18, 19], and mental health issues [20–22], as well as higher rates of morbidity [15, 23, 24] and mortality [25].

In Canada, emerging research has begun to explore the association between UPF consumption and health outcomes. For example, analyses using the 2015 Canadian Community Health Survey have linked UPF intake with self-reported diagnoses of type 2 diabetes, hypertension, and obesity [12]. Among Indigenous Cree populations in Northern Quebec, higher UPF consumption has also been associated with increased risk of metabolic syndrome [26]. However, research on UPF intake and cardiometabolic risk factors is limited, particularly when examining these relationships with objectively measured biomarkers at a national scale.

## Methods

### Study design and participants

The aim of the present study was to investigate the association between UPF consumption and cardiometabolic risk factors among Canadian adults, using nationally representative data including objectively measured biomarkers. This study is a cross-sectional analysis of the Canadian Health Measures Survey (CHMS) Cycles 5 & 6 (2016/17 & 2018/19). The CHMS is a nationally representative health survey conducted by Health Canada and Statistics Canada that collects health and lifestyle data from Canadians aged 1–79 yrs across the 10 provinces [27]. The CHMS excludes persons living in the three territories, persons living on Aboriginal reserves/settlements, full-time members of the Canadian Forces, and residents of certain remote regions [27]. Only participants aged 19 and older who completed the food frequency questionnaire (FFQ) were included in this study. Two questionnaires and a mobile examination clinic (MEC) visit were used to collect data in the CHMS. The household questionnaire collected information on sociodemographic variables, self-reported health/disease status, and lifestyle behaviours including dietary data, physical activity participation, smoking, and alcohol consumption. The clinic questionnaire includes screening and administrative questions regarding collected physical measures. Physical measures taken at the MEC visit include anthropometrics, blood pressure (BP), spot urine samples, blood samples as well as fitness testing.

### Dietary data and UPF classification

Dietary data was collected via a 53-item food frequency questionnaire (FFQ) [27]. Foods were coded using the NOVA classification system as UPF or not. The NOVA classification system for UPFs has been described in detail elsewhere [14]. Briefly, group one, *unprocessed/minimally processed foods*, contains whole foods such as fruits, vegetables, nuts, and meat. Group two, *processed culinary ingredients*, are derived from group one foods by minimal processing, for example, salt, sugar, honey, and oil. Group three, *processed foods*, contain few groups

one and two foods and are processed by means of canning, pickling, smoking, etc. (e.g., canned tuna, cheese, whole grain bread). Group 4, *UPF*, consists of foods that are multi-ingredient, industrially formulated, and contain little to no whole foods.

We calculated daily servings of UPF based on the number of servings per year reported by the CHMS and arranged participants into quartiles according to UPF consumption. Since the CHMS does not collect information on serving sizes, we were limited in calculating total caloric consumption. We considered the potential effect of total energy consumption (i.e., consuming greater number of calories with higher UPF consumption) as well as the possibility of energy misreporting on our findings through the total servings of food consumed per day by each participant. To garner better insight into the role of dietary quality, we adjusted for intakes of fruit and vegetables as the total daily servings of fruits and vegetables per participant. A list of foods included in the FFQ and their respective classification can be found in Supplementary Table 1.

### Outcome variables

During the MEC visit, height and weight were measured via a fixed stadiometer and digital scale, respectively. Body mass index (BMI) was calculated by dividing weight (kg) by height ($m^2$). Waist circumference (WC) was measured following the National Institutes of Health protocol. Blood pressure measurements were taken using an oscillometric blood pressure measurement device and the average of five BP measurements were used to determine average systolic (SBP) and diastolic BP (DBP). Blood samples were collected using a standardized venipuncture technique by a phlebotomist. Those who were assigned to morning appointments (approximately half of respondents) were asked to fast overnight for collection of the blood samples. Specimens were processed quickly after collection to ensure quality and integrity was maintained. Tubes were stored in refrigerator or freezer in the MEC laboratory. Once a week, shipments were sent to the reference laboratories with blood and urine samples for testing. Laboratory tests were used to measure various health markers from the blood samples. For the purposes of this study the following outcomes were investigated: glucose (GLUS), hemoglobin A1C (HbA1C), high-density lipoproteins (HDL), total cholesterol (TC), TC to HDL ratio (TC: HDL), white blood cells (WBC), high-sensitivity c-reactive protein (CRP), fasted insulin (INS), fasted triglycerides (TG), and fasted low-density lipoproteins (LDL).

### Covariates

Sociodemographic variables were considered in the analyses presented below as, age group (19–35, 36–50, 51–64, > 65), sex (male/female), race (white, black, Asian, Latin, multi and other), household education level (< secondary, secondary, post-secondary, and not stated), and household income (grouped into quartiles). Lifestyle factors including smoking (current smoker/not), self-reported sedentary time (hours per week), and self-reported physical activity (high, moderate, or low; according to the International Physical Activity Questionnaire classifications), were considered given known association with these on both eating behaviours and/or cardiometabolic health.[26]

### Statistical analysis

Mean UPF consumption (servings per day) and frequencies were determined overall and by sociodemographic characteristics (e.g., age group, sex, household income) and outcomes (e.g., BMI, WC, SBP, DBP) of interest. Chi-square tests for categorical outcomes and ANOVA for continuous outcomes were conducted to assess differences between quartiles of UPF consumption across these variables of interest. Crude and multivariable linear regression separately assessed the association between quartiles of UPF consumption and outcome variables while adjusting for age, sex, income quartile, education, race (model 1; sociodemographic factors), smoking, total food servings, BMI (for non-BMI and WC variables), sedentary time (ST; model 2; sociodemographic and lifestyle factors) and physical activity group (PA; model 3; sociodemographic and lifestyle factors, including PA). The lowest quartile was used as the reference group. We obtained *p*-values for linear trends by coding UPF quartile as a continuous variable in all models. To estimate the change in each cardiometabolic outcome per 1-serving increase in UPF consumption (servings/day), each model was run with UPF servings/day (continuous variable).

We conducted a sensitivity analysis to investigate the effect of fruit and vegetable intake on the relationship between UPF consumption and various cardiometabolic risk factors by first including daily servings of fruit and vegetables to model 3, then testing the interaction between number of fruit and vegetable servings and UPF quartile.

All analyses were weighted and bootstrapped according to CHMS guidelines to account for the complex survey design and ensure national representativeness [27]. SAS version 9.4 (SAS Institute Inc.) was used to conduct all statistical analyses. Associations are statistically significant at the $P < 0.05$ level.

## Results

### Sample characteristics

The study population consisted of 6517 participants (50.28% female). Canadian adults consumed, on average, 3.13 servings of UPF per day, ranging from 1.22 to 5.79

servings from the lowest to highest quartile. Compared to the lowest quartile, those in the highest quartile were more likely to be male, aged 19–30 yrs., without post-secondary education, in the lowest income quartile, current smokers, and Black, White, or other race (Table 1). Those in the highest UPF quartile had higher BMI, WC, GLUS, HbA1c, TC: HDL, SBP, DBP, WBC, CRP, INS, and TG, and lower TC, LDL, and HDL cholesterol when compared to those in the lowest quartile of UPF consumption (Table 2).

### Associations between UPF consumption and cardiometabolic risk factors

Table 3 presents associations between UPF quartiles and cardiometabolic outcomes. After adjusting for sociodemographic variables, we found a significant positive relationship between UPF and BMI (quartile 1 *v.* 4; β 3.08; SE 9.86), WC (quartile 1 *v.* 4; β 17.33; SE 7.89), DBP (quartile 1 *v.* 4; β 1.39; SE 4.49), HbA1c (quartile 1 *v.* 4; β 0.0015; SE 0.00076), WBC (quartile 1 *v.* 4; β 0.78; SE 0.11), CRP (quartile 1 *v.* 4; β 0.75; SE 0.25), INS (quartile 1 *v.* 4; β

**Table 1** General characteristics of Canadian adults across quartiles of UPF consumption

| Variables | UPF consumption | | | | | |
|---|---|---|---|---|---|---|
| | Full Sample | Q1 | Q2 | Q3 | Q4 | *p*-value |
| ***Dietary Characteristics*** | | | | | | |
| Total servings (mean, SE) | 9.84 (0.11) | 7.71 (1.03) | 9.29 (1.02) | 10.28 (0.12) | 12.47 (1.09) | **< 0.0001** |
| UPF servings (mean, SE) | 3.13 (0.08) | 1.22 (0.03) | 2.39 (0.02) | 3.49 (0.02) | 5.79 (0.09) | **< 0.0001** |
| FV servings (mean, SE) | 3.44 (0.05) | 3.48 (0.03) | 3.71 (0.02) | 3.38 (0.10) | 3.14 (0.09) | **< 0.0001** |
| ***Sociodemographic Characteristics*** | | | | | | |
| **Sex (%, SE)** | | | | | | **< 0.0001** |
| Male | 49.72 (0.07) | 43.33 (2.14) | 45.97 (1.41) | 50.37 (2.12) | 60.59 (2.14) | |
| Female | 50.28 (0.07) | 56.67 (2.14) | 54.03 (1.41) | 49.63 (1.12) | 39.41 (2.14) | |
| **Age group (%, SE)** | | | | | | **0.0003** |
| 19-30yrs | 19.79 (0.81) | 14.58 (1.62) | 18.83 (1.98) | 19.78 (1.98) | 26.84 (1.62) | |
| 31-50yrs | 37.84 (1.49) | 41.98 (2.85) | 37.27 (2.47) | 37.39 (2.14) | 34.21 (2.85) | |
| 51-64yrs | 26.15 (0.92) | 26.84 (1.82) | 29.70 (2.06) | 25.88 (2.94) | 21.64 (1.82) | |
| 65 + yrs | 16.22 (0.43) | 16.60 (1.70) | 14.21 (0.98) | 16.95 (0.20) | 17.31 (1.70) | |
| **Income quartile (%, SE)** | | | | | | **0.0014** |
| Quartile 1 | 24.29 (1.56) | 21.64 (2.44) | 23.16 (1.99) | 22.22 (1.05) | 30.70 (2.44) | |
| Quartile 2 | 24.66 (1.08) | 24.27 (1.70) | 21.32 (1.45) | 25.56 (1.18) | 27.91 (1.70) | |
| Quartile 3 | 25.24 (1.08) | 28.21 (2.10) | 25.65 (1.88) | 26.06 (1.85) | 20.51 (2.10) | |
| Quartile 4 | 25.82 (1.08) | 25.87 (1.93) | 29.87 (1.72) | 26.15 (1.34) | 20.87 (1.93) | |
| **Educational attainment (%, SE)** | | | | | | **< 0.0001** |
| < Secondary | 3.35 (0.39) | 1.34 (0.29) | 2.24 (0.40) | 3.28 (0.83) | 6.98 (0.29) | |
| Secondary | 12.41 (0.71) | 7.85 (1.34) | 12.20 (1.35) | 12.17 (0.60) | 18.12 (1.34) | |
| Post-secondary | 81.53 (0.94) | 88.18 (1.65) | 83.91 (1.42) | 81.16 (0.95) | 71.60 (1.65) | |
| Not stated | 2.71 (0.48) | 2.64 (0.88) | 1.66 (0.58) | 3.39 (0.97) | 3.29 (0.88) | |
| **Race (%, SE)** | | | | | | **< 0.0001** |
| Other | 4.65 (0.63) | 4.08 (1.06) | 3.50 (0.62) | 4.32 (0.90) | 6.91 (1.06) | |
| Asian | 18.05 (3.21) | 27.90 (4.93) | 18.65 (4.41) | 15.58 (3.87) | 8.62 (4.93) | |
| Black | 3.01 (0.70) | 2.33 (0.68) | 2.18 (0.77) | 3.36 (0.92) | 4.35 (0.68) | |
| Latin | 2.51 (0.71) | 3.03 (1.06) | 3.06 (1.50) | 2.26 (0.05) | 1.54 (1.06) | |
| Multi | 3.25 (0.62) | 6.30 (1.65) | 2.26 (0.58) | 2.11 (0.90) | 2.02 (1.65) | |
| White | 68.54 (4.13) | 56.35 (5.65) | 70.35 (4.73) | 72.37 (4.42) | 76.56 (5.65) | |
| ***Lifestyle Characteristics*** | | | | | | |
| **Current smoker (%, SE)** | | | | | | **< 0.0001** |
| Yes | 16.02 (0.75) | 11.04 (1.18) | 13.08 (1.67) | 17.07 (0.16) | 23.94 (1.18) | |
| No | 83.98 (0.75) | 88.96 (1.18) | 86.92 (1.67) | 82.93 (0.16) | 76.06 (1.18) | |
| **PA group (%, SE)** | | | | | | 0.8466 |
| Low | 91.50 (0.85) | 92.72 (1.40) | 90.75 (1.65) | 90.73 (0.70) | 91.74 (1.40) | |
| Moderate | 3.38 (0.58) | 2.47 (0.91) | 4.07 (1.02) | 4.09 (0.07) | 2.94 (0.91) | |
| High | 5.11 (0.61) | 4.81 (1.00) | 5.18 (1.12) | 5.18 (0.01) | 5.32 (1.00) | |
| **Sedentary time (hrs/week, SE)** | 26.68 | 25.26 | 24.56 | 27.00 | 30.36 | **< 0.0001** |

SE, standard error; UPF, ultra-processed food; FV, fruit and vegetables; PA, physical activity

*P*-values were generated by ANOVA for continuous and $X^2$ tests for categorical variables. Significant associations at the $p < 0.05$ level are presented in bold

**Table 2** Cardiometabolic outcomes of Canadian adults across quartiles of UPF consumption

| Variables | UPF consumption[a] | | | | | |
|---|---|---|---|---|---|---|
| | Full Sample | Q1 | Q2 | Q3 | Q4 | *p*-value[b] |
| ***Cardiometabolic Measures (mean, SE)*** | | | | | | |
| BMI (kg/m2) *n* = 6517 | 28.47(0.41) | 26.83 (0.40) | 27.84 (0.46) | 29.53 (0.88) | 29.95 (0.74) | **< 0.0001** |
| WC (cm) *n* = 6517 | 107.76(2.77) | 96.15 (1.87) | 104.61 (3.44) | 117.73 (9.02) | 114.36 (6.62) | **< 0.0001** |
| DBP (mmHg) *n* = 6473 | 72.43(0.22) | 71.50 (0.48) | 73.01 (0.51) | 72.40 (0.43) | 72.85 (0.34) | **0.0011** |
| SBP (mmHg) *n* = 6473 | 113.43(0.50 | 112.42 (1.07) | 114.24 (1.04) | 112.80 (0.75) | 114.33 (0.58) | **0.0100** |
| GLUS (mmol/L) *n* = 6350 | 5.54(0.03) | 5.54 (0.06) | 5.49 (0.05) | 5.47 (0.04) | 5.67 (0.06) | **0.0300** |
| HbA1c *n* = 6330 | 0.0549(0.0006) | 0.0546 (0.0006) | 0.0544 (0.0003) | 0.0549 (0.0003) | 0.0558 (0.0005) | **< 0.0001** |
| HDL (mmol/L) *n* = 6345 | 1.42(0.01) | 1.48 (0.03) | 1.45 (0.02) | 1.41 (0.03) | 1.35 (0.02) | **< 0.0001** |
| TC: HDL (mmol/mmol) *n* = 6345 | 3.70(0.09) | 3.61 (0.09) | 3.61 (0.05) | 3.77 (0.08) | 3.82 (0.04) | **< 0.0001** |
| TC (mmol/L) *n* = 6346 | 4.85(0.02) | 4.90 (0.05) | 4.89 (0.04) | 4.88 (0.04) | 4.72 (0.05) | **< 0.0001** |
| WBC (10^9/L) *n* = 6244 | 6.59(0.06) | 6.31 (0.09) | 6.37 (0.07) | 6.62 (0.10) | 7.12 (0.13) | **< 0.0001** |
| CRP (mg/L) *n* = 5982 | 2.41(0.11) | 2.05 (0.22) | 2.48 (0.21) | 2.45 (0.13) | 2.73 (0.15) | **< 0.0001** |
| INS (pmol/L) *n* = 3158 | 71.94(1.75) | 66.39 (4.52) | 70.70 (2.96) | 75.02 (3.62) | 76.80 (4.12) | **< 0.0001** |
| TG (mmol/L) *n* = 3223 | 1.37(0.05) | 1.24 (0.06) | 1.30 (0.06) | 1.38 (0.03) | 1.61 (0.12) | **< 0.0001** |
| LDL (mmol/L) *n* = 3183 | 2.78(0.03) | 2.80 (0.06) | 2.74 (0.05) | 2.88 (0.04) | 2.67 (0.07) | 0.1463 |

BMI, body mass index; WC, waist circumference; dBP, diastolic blood pressure; sBP, systolic blood pressure; GLUS, glucose; HbA1C, hemoglobin A1c; HDL, high-density lipoprotein; TC: HDL, total cholesterol to high-density lipoprotein ratio; TC, total cholesterol; WBC, white blood cells; CRP, high-sensitivity c-reactive protein; INS, fasted insulin; TG, fasted triglycerides; LDL, low-density lipoprotein

[a] Threshold values for quartiles of ultra-processed food intake were as follows: quartile 1: ≤ 1.9 servings per day; quartile 2: 2.0–2.9 servings per day; quartile 3: 3.0–4.2 servings per day; quartile 4: ≥ 4.3 servings per day servings per day

[b] *P*-values were generated by ANOVA for continuous and $X^2$ tests for categorical variables. Significant associations at the $p < 0.05$ level are presented in bold

10.24; SE 4.66), and TG (quartile 1 *v*. 4; β 0.31; SE 0.06), and a significant negative relationship with HDL (quartile 1 *v*. 4; β -0.08; SE 0.03). The relationships between UPF and SBP (quartile 1 *v*. 4; β 1.83; SE 8.90), GLUS (quartile 1 *v*. 4; β 0.13; SE 0.10), TC: HDL (quartile 1 *v*. 4; β 0.12; SE 0.09) and CHOL (quartile 1 *v*. 4; β -0.09; SE 0.06) were not statistically significant. Significant associations remained for most outcomes after the adjustment for lifestyle factors. The only exception to this was HDL, for which final adjustment for PA rendered the relationship between UPF and HDL non-significant (quartile 1 *v*. 4; β -0.06; SE 0.03). Similarly, each 1-SD increment increase of UPF consumption was associated with significantly higher BMI (quartile 1 *v*. 4; β 0.76; SE 0.24), DBP (quartile 1 *v*. 4; β 0.35; SE 0.12), GLUS (quartile 1 *v*. 4; β 0.05; SE 0.02), HbA1C (quartile 1 *v*. 4; β 0.00048; SE 0.00014), TC: HDL (quartile 1 *v*. 4; β 0.06; SE 0.02), WBC (quartile 1 *v*. 4; β 0.08; SE 0.03), CRP (quartile 1 *v*. 4; β 0.16; SE 0.06), INS (quartile 1 *v*. 4; β 3.01; SE 1.00), and TG (quartile 1 *v*. 4; β 0.06; SE 0.02), and lower HDL (quartile 1 *v*. 4; β -0.02; SE 0.01) in the final adjusted model.

When including daily servings of fruits and vegetables to model 4, the relationship between UPF intake and DBP (β 0.33; SE 0.28; $p = 0.23$), HBA1C (β 0.00044; SE 0.00024; $p = 0.068$), CRP (β 0.14; SE 0.08; $p = 0.092$)), and INS (β 2.62; SE 3.10; $p = 0.397$) became non-significant, whereas the relationship with BMI (β 1.19; SE 0.34; $p = 0.0006$), WC (β 6.37; SE 3.00; $p = 0.034$), WBC (β 0.16; SE 0.07; $p = 0.018$) and fasting TG (β 0.12; SE 0.03; $p = 0.0006$) remained significant. The interaction between each cardiometabolic measure and fruit and vegetable servings was not significant for any variable.

**Table 3** Associations between UPF consumption and cardiometabolic Outcomes[a]

| Variable | UPF Quartile[b] | | | | | UPF (serv/day) | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | Per 1-unit increase in UPF servings | |
| | Reference | Beta (95% CI) | Beta (95% CI) | Beta (95% CI) | *p*-value for trend | Beta (95% CI) | *p*-value |
| **BMI (kg/m$^2$)** | | | | | | | |
| unadjusted | 0 | 1.01 (0.15, 1.87) | 2.69 (1.22, 4.16) | 3.11 (1.40, 4.82) | **< 0.0001** | 0.69 (0.34, 1.04) | **0.0001** |
| model 1 | 0 | 0.96 (0.04, 1.88) | 2.66 (1.15, 4.17) | 3.08 (1.39, 4.77) | **< 0.0001** | 0.70 (0.37, 1.03) | **< 0.0001** |
| model 2 | 0 | 1.06 (0.20, 1.92) | 2.71 (0.97, 4.45) | 3.00 (1.08, 4.92) | **0.0005** | 0.79 (0.34, 1.24) | **0.0007** |
| model 3 | 0 | 1.08 (0.20, 1.96) | 2.71 (1.00, 4.42) | 2.91 (2.87, 2.95) | **0.001** | 0.76 (0.29, 1.23) | **0.0018** |
| **WC (cm)** | | | | | | | |
| unadjusted | 0 | 8.45 (1.08, 15.82) | 21.58 (4.03, 39.13) | 18.21 (9.12, 27.30) | **< 0.0001** | 4.31 (1.72, 6.90) | **0.0012** |
| model 1 | 0 | 7.70 (0.14, 15.26) | 20.94 (3.33, 38.55) | 17.33 (1.87, 32.79) | **0.0003** | 4.31 (1.57, 7.05) | **0.0023** |
| model 2 | 0 | 7.97 (0.26, 15.68) | 19.86 (0.62, 39.10) | 15.56 (− 3.71, 34.83) | **< 0.0001** | 4.53 (0.08, 8.98) | **0.0468** |
| model 3 | 0 | 8.01 (0.43, 15.59) | 19.73 (0.75, 39.71) | 14.66 (14.54, 14.78) | **0.0255** | 4.26 (− 0.34, 8.86) | 0.0708 |
| **SBP (mmHg)** | | | | | | | |
| unadjusted | 0 | 1.82 (− 0.37, 4.03) | 0.37 (− 2.26, 3.00) | 1.91 (− 14.28, 18.30) | 0.3397 | 0.29 (− 0.20, 0.78) | 0.2383 |
| model 1 | 0 | 1.80 (0.31, 3.29) | 0.19 (− 1.81, 2.19) | 1.83 (− 15.63, 19.29) | 0.825 | 0.28 (− 0.11, 0.67) | 0.1641 |
| model 2 | 0 | 1.96 (0.45, 3.47) | 0.23 (− 1.87, 2.33) | 2.09 (− 17.31, 21.49) | 0.2374 | 0.38 (− 0.01, 0.77) | 0.0589 |
| model 3 | 0 | 1.97 (0.46, 3.48) | 0.24 (− 1.88, 2.36) | 2.12 (− 17.28, 21.52) | 0.232 | 0.39 (− 0.02, 0.80) | 0.061 |
| **DBP (mmHg)** | | | | | | | |
| unadjusted | 0 | 1.52 (0.36, 2.68) | 0.90 (− 0.28, 2.08) | 1.36 (− 9.60, 12.32) | 0.1008 | 0.19 (− 0.05, 0.43) | 0.097 |
| model 1 | 0 | 1.49 (0.41, 2.57) | 0.86 (− 0.26, 2.00) | 1.39 (− 7.42, 10.81) | **0.0464** | 0.18 (− 0.04, 0.40) | 0.0981 |
| model 2 | 0 | 1.74 (0.74, 2.74) | 1.20 (0.10, 2.30) | 2.06 (− 12.68, 18.80) | **0.0045** | 0.36 (0.14, 0.58) | **0.0015** |
| model 3 | 0 | 1.75 (0.75, 2.75) | 1.21 (0.11, 2.31) | 2.04 (− 12.70, 16.78) | **0.0384** | 0.35 (0.11, 0.59) | **0.0024** |
| **GLUS (mmol/L)** | | | | | | | |
| unadjusted | 0 | -0.05 (− 0.23, 0.13) | -0.07 (− 0.23, 0.09) | 0.13 (− 0.05, 0.31) | 0.2117 | 0.03 (− 0.01, 0.07) | 0.0781 |
| model 1 | 0 | -0.05 (− 0.21, 0.11) | -0.08 (− 0.24, 0.08) | 0.13 (− 0.07, 0.33) | 0.3586 | 0.03 (− 0.01, 0.07) | 0.1339 |
| model 2 | 0 | -0.03 (− 0.19, 0.13) | -0.06 (− 0.24, 0.12) | 0.17 (− 0.03, 0.37) | 0.1827 | 0.05 (0.01, 0.09) | **0.0178** |
| model 3 | 0 | -0.03 (− 0.19, 0.13) | -0.06 (− 0.24, 0.12) | 0.17 (− 0.03, 0.37) | 0.1935 | 0.05 (0.01, 0.09) | **0.0222** |
| **HbA1C** | | | | | | | |
| unadjusted | 0 | -0.00025 (− 0.00115, 0.00065) | 0.00031 (− 0.00098,0.00160) | 0.0012 (− 0.00029,0.00269) | 0.1171 | 0.00029 (0.00002,0.00056) | **0.0455** |
| model 1 | 0 | -0.00004 (− 0.00078, 0.00070) | 0.00053 (− 0.00076,0.00182) | 0.0015 (0.00001,0.00299) | **0.0238** | 0.00035 (0.00010,0.00060) | **0.0072** |
| model 2 | 0 | 0.00013 (− 0.00058, 0.00084) | 0.00065 (− 0.00064,0.00194) | 0.0018 (0.00031,0.00329) | **0.0085** | 0.00048 (0.00021,0.00075) | **0.0006** |
| model 3 | 0 | 0.00013 (− 0.00058, 0.00084) | 0.00065 (− 0.00064,0.00194) | 0.0018 (0.00031,0.00329) | **0.0093** | 0.00048 (0.00021,0.00075) | **0.0007** |
| **HDL (mmol/L)** | | | | | | | |
| unadjusted | 0 | -0.02 (− 0.10, 0.06) | -0.07 (− 0.15, 0.01) | -0.13 (− 0.21, − 0.05) | **0.0003** | -0.03 (− 0.05, − 0.01) | **< 0.0001** |
| model 1 | 0 | -0.02 (− 0.08, 0.04) | -0.06 (− 0.12, 0.00) | -0.08 (− 0.14, − 0.02) | **0.0147** | -0.02 (− 0.04, 0.00) | **0.0002** |
| model 2 | 0 | -0.02 (− 0.08, 0.04) | -0.04 (− 0.10, 0.02) | -0.06 (− 0.12, 0.00) | **0.0498** | -0.02 (− 0.04, 0.00) | **0.0005** |
| model 3 | 0 | -0.02 (− 0.08, 0.04) | -0.04 (− 0.10, 0.02) | -0.06 (− 0.12, 0.00) | 0.0746 | -0.02 (− 0.04, 0.00) | **0.0017** |
| **TC: HDL (mmol/mmol)** | | | | | | | |
| unadjusted | 0 | 0.01 (− 0.19, 0.21) | 0.17 (− 0.03, 0.37) | 0.21 (0.01, 0.41) | **0.0417** | 0.06 (0.02, 0.10) | **0.0066** |
| model 1 | 0 | -0.01 (− 0.19, 0.17) | 0.14 (− 0.04, 0.32) | 0.12 (− 0.06, 0.30) | 0.1525 | 0.05 (0.01, 0.09) | **0.0272** |
| model 2 | 0 | 0.02 (− 0.18, 0.22) | 0.12 (− 0.08, 0.32) | 0.14 (− 0.06, 0.34) | 0.0958 | 0.06 (0.02, 0.10) | **0.0065** |
| model 3 | 0 | 0.02 (− 0.18, 0.22) | 0.12 (− 0.08, 0.32) | 0.13 (− 0.07, 0.33) | 0.1127 | 0.06 (0.02, 0.10) | **0.0095** |
| **TC (mmol/L)** | | | | | | | |

**Table 3** (continued)

| Variable | UPF Quartile[b] | | | | | UPF (serv/day) | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | Per 1-unit increase in UPF servings | |
| | Reference | Beta (95% CI) | Beta (95% CI) | Beta (95% CI) | *p*-value for trend | Beta (95% CI) | *p*-value |
| unadjusted | 0 | -0.02 (−0.16, 0.12 | -0.02 (−0.16, 0.12) | -0.18 (−0.32, −0.04) | **0.0235** | -0.04 (−0.08, −0.00) | **0.0206** |
| model 1 | 0 | -0.01 (−0.13, 0.11) | 0.01(−0.11, 0.13) | -0.09 (−0.21, 0.03) | 0.1951 | -0.02 (−0.04, 0.00) | 0.1394 |
| model 2 | 0 | 0.01 (−0.13, 0.15) | 0.03 (−0.11, 0.17) | -0.05 (−0.19, 0.09) | 0.6773 | -0.01 (−0.05, 0.03) | 0.5659 |
| model 3 | 0 | 0.01 (−0.11, 0.13) | 0.03 (−0.09, 0.15) | -0.04 (−0.16, 0.08) | 0.6951 | -0.01 (−0.05, 0.03) | 0.5893 |
| **WBC (10^9/L)** | | | | | | | |
| unadjusted | 0 | 0.05 (−0.17, 0.27) | 0.31 (0.09, 0.53) | 0.80 (0.58, 1.02) | **<0.0001** | 0.15 (0.09, 0.21) | **<0.0001** |
| model 1 | 0 | 0.05 (−0.17, 0.27) | 0.32 (0.10, 0.54) | 0.78 (0.56, 0.99) | **<0.0001** | 0.15 (0.09, 0.21) | **<0.0001** |
| model 2 | 0 | 0.00 (−0.24, 0.24) | 0.13 (−0.11, 0.37) | 0.51 (0.28, 0.75) | **0.0086** | 0.08 (0.02, 0.14) | **0.0155** |
| model 3 | 0 | 0.00 (−0.24, 0.24) | 0.13 (−0.11, 0.37) | 0.50 (0.27, 0.74) | **0.0108** | 0.08 (0.02, 0.14) | **0.0279** |
| **CRP (mg/L)** | | | | | | | |
| unadjusted | 0 | 0.43 (−0.08, 0.94) | 0.39 (−0.12, 0.90) | 0.68 (0.17, 1.19) | **0.0125** | 0.14 (0.042, 0.238) | **0.0033** |
| model 1 | 0 | 0.43 (−0.06, 0.92) | 0.41 (−0.08, 0.90) | 0.75 (0.26, 1.24) | **0.0073** | 0.16 (0.062, 0.258) | **0.0014** |
| model 2 | 0 | 0.45 (0.0008, 0.90) | 0.32 (−0.13, 0.77) | 0.66 (0.21, 1.11) | **0.0377** | 0.16 (0.04, 0.28) | **0.0081** |
| model 3 | 0 | 0.45 (0.0008, 0.90) | 0.31 (−0.14, 0.76) | 0.64 (0.19, 1.09) | **0.0419** | 0.16 (0.04, 0.28) | **0.0097** |
| **INS (pmol/L)** | | | | | | | |
| unadjusted | 0 | 4.31 (−5.75, 14.37) | 8.63 (−1.43, 18.69) | 10.40 (0.34, 20.46) | 0.074 | 2.67 (0.34, 5.00) | **0.0256** |
| model 1 | 0 | 4.71 (−4.42, 13.83) | 9.14 (−0.00, 18.27) | 10.24 (1.11, 19.37) | **0.0411** | 2.61 (0.40, 4.82) | **0.0219** |
| model 2 | 0 | 4.75 (−3.08, 12.58) | 6.13 (−1.70, 13.96) | 10.76 (2.93, 18.59) | **0.0156** | 3.20 (1.24, 5.16) | **0.0014** |
| model 3 | 0 | 4.97 (−2.98, 12.92) | 6.19 (−1.76, 14.14) | 10.26 (2.31, 18.21) | **0.0185** | 3.01 (1.05, 4.97) | **0.0028** |
| **TG (mmol/L)** | | | | | | | |
| unadjusted | 0 | 0.06 (−0.08, 0.20) | 0.14 (0.00, 0.28) | 0.38 (0.24, 0.52) | **<0.0001** | 0.07 (0.03, 0.11) | **0.0004** |
| model 1 | 0 | 0.03 (−0.09, 0.15) | 0.12 (0.00, 0.24) | 0.31 (0.19, 0.43) | **0.0011** | 0.05 (0.01, 0.09) | **0.0021** |
| model 2 | 0 | 0.06 (−0.03, 0.15) | 0.13 (0.03, 0.23) | 0.38 (0.28, 0.48) | **0.0043** | 0.07 (0.03, 0.11) | **0.0024** |
| model 3 | 0 | 0.07 (−0.03, 0.17) | 0.13 (0.03, 0.23) | 0.37 (0.27, 0.47) | **0.0018** | 0.06 (0.02, 0.10) | **0.0025** |
| **LDL (mmol/L)** | | | | | | | |
| unadjusted | 0 | -0.05 (−0.19, 0.09) | 0.09 (−0.05, 0.23) | -0.13 (−0.27, 0.01) | 0.4083 | -0.02 (−0.06, 0.02) | 0.1189 |
| model 1 | 0 | -0.05 (−0.19, 0.09) | 0.11 (−0.03, 0.25) | -0.16 (−0.30, 0.01) | 0.2943 | -0.03 (−0.05, −0.01) | **0.0433** |
| model 2 | 0 | -0.01 (−0.14, 0.12) | 0.17 (0.03, 0.31) | -0.02 (−0.16, 0.12) | 0.4478 | 0.00 (−0.04, 0.04) | 0.9686 |
| model 3 | 0 | -0.01 (−0.14, 0.12) | 0.17 (0.03, 0.31) | -0.02 (−0.16, 0.12) | 0.3355 | 0.00 (−0.04, 0.04) | 0.9705 |

Model 1: adjusted for age, sex, income quartile, household education, race

Model 2: additionally adjusted for smoking, total servings, BMI, and sedentary time

Model 3: additionally adjusted for physical activity

[a] Analyses were performed using multi-variable linear regression analyses. Beta represents the change in cardiometabolic outcome among UPF quartile compared to the reference, quartile 1

[b] Threshold values for quartiles of ultra-processed food intake were as follows: quartile 1: ≤ 1.9 servings per day; quartile 2: 2.0–2.9 servings per day; quartile 3: 3.0–4.2 servings per day; quartile 4: >4.2 servings per day servings per day

*P*-value significant at the < 0.05 level and presented in bold

## Discussion

To the best of our knowledge, this study is the first to assess associations between UPF intake and a range of cardiometabolic risk factors using a nationally representative sample of Canadian adults. Our findings reveal that those in the highest UPF consumption quartile had significantly higher BMI, WC, DBP, HbA1c, CRP, WBC, INS, and TG, even after adjusting for sociodemographic and lifestyle factors. These results align with studies in other populations, such as the U.S. National Health and Nutrition Examination Survey and a Spanish Mediterranean diet cohort, both of which found that high UPF intake correlates with a range of unfavorable cardiometabolic outcomes, independent of obesity status and diet quality adjustments [28, 29].

We found consistent associations between UPF intake and markers of obesity (BMI and waist circumference), reinforcing evidence from studies linking UPF with rising overweight and obesity rates in Canada, the U.S., and other countries [12, 30, 31]. Additionally, diastolic, but

not systolic, blood pressure was elevated with higher UPF intake, consistent with longitudinal findings from Brazilian adults [32]. Increased levels of HbA1c and fasting insulin associated with high UPF consumption highlight a potential link to impaired glucose metabolism, echoing global findings that connect high UPF diets with type 2 diabetes risk [12, 33–37]. Our analyses however, did not reveal significant associations between UPF intake and blood glucose levels, potentially due to only half of participants providing fasting glucose (the others collected at random). As suggested by others, fasting insulin may be a better marker of glucose abnormalities and has been shown to be independently associated with insulin resistance, type 2 diabetes, obesity, and hypertension [38–43].

Triglycerides but not TC, TC: HDL, HDL, or LDL were significantly positively associated with UPF consumption in fully adjusted analyses modelled here. Investigations of Iranian [44] and Spanish [45] adults revealed similar associations, with authors reporting a significant positive association between UPF intake and TG, and significant negative association with HDL, but no significant relationship with LDL or TC. Diets high in UPF are associated with higher intakes of saturated, unsaturated, and *trans* fatty acids, which may partially explain the associations observed [7, 46]. Indeed, among Spanish adults, associations between UPF and dyslipidemia was significant despite adjustments for free sugar, saturated fat, and *trans* fat, suggesting nutritional composition is not the only factor driving these health outcomes [45].

We found that lower HDL was significantly associated with being in the highest UPF quartile until final adjustment for PA, indicating that PA status may more strongly influence HDL than diet. This findings is in keeping with an intervention study examining the effects of diet versus exercise on lipid particle size which found that only the exercise intervention increased HDL particle size among adults with obesity [47]. Similarly, a supervised exercise training program was associated with higher HDL levels, regardless of adherence to the dietary guidelines set out by the American Heart Association among overweight, sedentary Americans [48]. These findings are consistent with previous studies demonstrating the effectiveness of exercise interventions on improving HDL status [49–52]. Despite adjustment, UPF consumption was consistently positively associated with markers of inflammation (CRP and WBC). In the only clinical trial of UPF consumption, conducted by Hall et al., participants on the unprocessed food diet observed lower CRP levels compared to baseline, highlighting the anti-inflammatory effect of whole, unprocessed foods [53]. These results are in agreement with various observational studies concluding positive associations between UPF consumption and both CRP and WBC [22, 54–57]. Elevated CRP and WBC are both associated with increased cardiovascular risk [58–62].

Our study importantly considered the effect of fruit and vegetable consumption on the relationship between UPF consumption and cardiometabolic risk factors. Interestingly, we observed that associations between UPF and DBP, HbA1c, and CRP became non-significant after controlling for fruit and vegetable intake. Higher total servings of food correlated with higher UPF but lower fruit and vegetable intake, suggesting the replacement of unprocessed/ minimally processed foods by highly processed foods in the diet of Canadian adults. This displacement may in part mediate the relationship observed between UPF intakes and cardiometabolic risk factors. High UPF consumption has been shown to associate with poorer diet quality [7, 46] including higher intakes of sodium, fat, and added sugars, and lower intakes of fibre and micronutrients, which are independently associated with worse health outcomes including cardiometabolic risk, morbidity, and mortality.

Our work adds to the limited body of evidence which has begun to consider the mediating role of diet quality in the relationship between UPF and health. In a population-based cohort study of Italian adults, UPF was associated with cardiovascular mortality and this relationship was only partially mediated by the high sugar content of the diet [63]. On the other hand, a longitudinal analysis of French adults revealed that neither fat, sodium, nor sugar content significantly mediated the relationship between UPF intake and cancer risk [23]. More work is needed to disentangle the effects of UPF consumption independent of their nutritional quality, considering the impact of other constituent factors inherent to UPFs on the observed outcomes.

There are other potential mechanisms, beyond nutrient composition, which have been proposed to explain the effect of UPF on health. For instance, processing methods induce structural changes to the food matrix, making UPF more palatable, consumed more quickly, and delaying the onset of satiation [11, 53, 64]. These processes also alter the nutrient bioavailability of UPF. UPF are hyperglycaemic [9, 65], leading to a rapid increase in blood sugar. In addition, research has begun to implicate the use of food additives in the disruption of the gut microbiota [66, 67], for which a number of negative health outcomes have been established [68, 69]. Phthalate and bisphenol-A exposure from food processing methods and packaging also may play a role in mediating some of the health outcomes observed. Higher UPF intake has been shown to correlate with higher urinary levels of phthalate metabolites [70–73], which are known to associate with a range of cardiometabolic diseases and risk factors [74–78].

There are a number of limitations that should be considered in the interpretation of our results. The cross-sectional design of the CHMS is not appropriate for

causal inference due to lacking temporality. Nonetheless, the large sample size provided by the CHMS provides robust and contemporary estimation of UPF intakes at the population level, across key sociodemographic and cardiometabolic risk factors and consistently observed associations despite adjustment for a number of potential confounding factors. In addition, the FFQ used by the CHMS was not designed to evaluate food based on its level of processing as it provides limited information about the brand of food items and the mode of preparation. Nevertheless, our study was primarily concerned with products in the highest level of food processing compared to other foods and discernment of UPFs (i.e., chips, sodas, etc.) was relatively objective. For the few products for which identification as UPF was less clear we took a more conservative approach to our classification. For instance, in accordance with NOVA classifications, plain yogurt is considered Group 1 (unprocessed), while yogurt with added fruits and/or sweeteners is considered Group 4 (UPF). Given that yogurt products were aggregated in the CHMS, for the purpose of this study, we classified all "yogurt" reported as consumed as an UPF. This decision also aligns with Canadian purchasing data showing a higher prevalence of flavored yogurt purchasing compared to plain yogurt [79]. We also classified fruit and vegetable juices as UPF consistent with previous literature [80]. Follow-up investigations will aim to look at the sensitivity of the various UPF classifications we found to be ambiguous here. The 52-item FFQ used in the CHMS did not allow for detailed estimates of total energy or nutrient intake due to its limited item count and serving size information. To account for dietary quality and energy intake, we included measures such as total food servings and servings of fruits and vegetables in our analyses. We did not include alcohol intake in our analyses due to the limited information provided by the CHMS on alcohol consumption. Future studies with more detailed data on alcohol consumption should consider the potential role of alcohol products on this relationship. Finally, this analysis assumes a linear relationship between UPF consumption and the outcomes analyzed here and does not explicitly model potential nonlinearity. While nonlinear effects could exist, categorization and linear modeling remain widely used for their interpretability and alignment with clinical guidelines. Future research could explore alternative approaches to assess nonlinear dose-response relationships.

Our work adds to a growing body of research examining morbidities associated with UPF intake among Canadians. Canadian data on food purchasing, eating behaviour, and the respective health outcomes are required to adequately and precisely inform Canadian food policies, regulations, and guidelines. Thus far, these policies have focused on restricting single nutrients of public health concern. UPF are largely the targets for such interventions, creating opportunities for marketing nutrient and health claims, which can often be misleading to consumers who do not understand the detrimental effects associated with UPF more globally. While guidance to reduce UPF consumption has been included in the latest iteration of Canada's Food Guide [81], our work suggests more work is needed to reduce intakes. We found UPF intakes to be greatest amongst households with lower income and education. Targeted public health campaigns aimed at improving consumer awareness, particularly among these higher risk groups, standardized front-of-package labeling, restrictions on UPF marketing, and improving accessibility and affordability of more healthful, whole foods could help reduce UPF intake. Ongoing monitoring of UPF intake trends would also support data-driven policy adjustments, ensuring long-term improvements in Canadian diets.

## Conclusions

To conclude, this study leveraged robust population level biomarker data to investigate the association between UPF consumption and cardiometabolic health. It revealed that higher UPF intake was associated with unfavourable BMI, WC, DBP, HbA1c, CRP, WBC, fasting insulin, and fasting TG. This work adds to the limited body of literature which characterizes intakes of UPF among adults and association with cardiometabolic risk and importantly provided much needed information on Canadian diets and the associated risk of cardiometabolic outcomes to inform ongoing food policy discussions.

### Abbreviations

| | |
|---|---|
| CVD | Cardiovascular disease |
| UPF | Ultra-processed food |
| CHMS | Canadian health measures survey |
| FFQ | Food frequency questionnaire |
| MEC | Mobile examination clinic |
| BP | Blood pressure |
| BMI | Body mass index |
| WC | Waist circumference |
| SBP | Systolic blood pressure |
| DBP | Diastolic blood pressure |
| GLUS | Glucose |
| HbA1C | Hemoglobin A1C |
| HDL | High-density lipoprotein |
| TC | Total cholesterol |
| TC:HDL | Total cholesterol to high-density lipoprotein cholesterol ratio |
| WBC | White blood cells |
| CRP | High-sensitivity c-reactive protein |
| INS | Insulin |
| TG | Triglycerides |
| LDL | Low-density lipoprotein |
| ST | Sedentary time |
| PA | Physical activity |
| SD | Standard deviation |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12986-025-00935-y.

Supplementary Material 1

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Not applicable.

**Author contributions**
All authors contributed to the study conception and design. Material preparation and analysis were performed by AB and AC. AB wrote the first draft of the manuscript with input from AC and VSM. All authors read and approved the final manuscript. AC supervised the project.

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**Data availability**
The data that support the findings of this study are available from Statistics Canada Research Data Centre but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Statistics Canada.

## Declarations

**Ethics approval and consent to participate**
Not applicable.

**Consent for publication**
Not applicable.

**Competing interests**
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