

Changes in Lunch-period Nutrient Intake and Nutrient Density Following the Implementation of a Universal School Lunch Program: A Quasi-experimental Study in Saskatchewan, Canada

Natalia Alaniz-Salinas

University of Saskatchewan

Hassan Vatanparast

University of Saskatchewan

Jessica Liefers

University of Saskatchewan

Rachel Engler-Stringer

rachel.engler-stringer@usask.ca

University of Saskatchewan

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Abstract

Background

Universal school meal programs are expanding in Canada, but evidence remains limited on how they affect lunch-period consumption. We assessed whether changes in lunch-period energy and nutrient intake, contributions to Dietary Reference Intakes (DRIs), and nutrient density differed between intervention and control schools after implementation of a universal school lunch program.

Methods

This quasi-experimental controlled before-and-after study used repeated cross-sectional samples from four elementary schools in Saskatoon, Canada. Two schools implemented a universal free lunch program and two served as controls. Lunch intake was assessed in May–June 2021 and May–June 2023 using a photography-assisted weighed plate-waste protocol. For each student, intake was based on one observed lunch or the average of two lunches within each study period. School-period means were analysed using a DiD linear regression with equal weighting of schools. Sensitivity analyses included covariate-adjusted student-period DiD models and longitudinal mixed-effects models among students observed at both periods, with a random intercept for participant. With four schools and one pre-intervention measurement, estimates were interpreted descriptively. Nutrient density was assessed using the Nutrient Rich Food Index 9.3 (NRF 9.3).

Results

There were 980 student-period observations (379 baseline; 601 follow-up). In intervention schools, school-provided lunches increased from 43.0% to 61.9%. Mean energy intake declined by 76.8 kcal in intervention schools and 167.9 kcal in controls (DiD, + 91.1 kcal). Most nutrient intakes declined in both groups. Folate and vitamin C increased in intervention schools while declining in controls, whereas saturated fat and sodium declined in both groups but less in intervention schools. Other nutrient and DRI outcomes showed no consistent differential pattern. NRF 9.3 increased in controls and declined in intervention schools (DiD, – 47.2 points). Covariate-adjusted estimates were similar to the primary estimates. Longitudinal estimates (n = 136) were generally similar in direction for individual nutrients, although NRF 9.3 differed (+ 10.7 points).

Conclusions

Implementation substantially changed lunch provision and was accompanied by some favourable nutrient-specific changes, although improvements were not consistent across outcomes. Interpretation

should account for baseline exposure to school-provided food, variable participation, and evolving implementation.

BACKGROUND

School food has become an increasingly prominent area of nutrition policy and research in Canada, reflecting concerns about child nutrition, food insecurity, and inequities in access to nutritious foods [1]. This attention has increased with the recent federal commitments, including the introduction of Canada's National School Food Policy in 2024 [2], within a broader landscape of school food programs that has historically varied across provinces and territories [3]. Children in Canada consume approximately one-third of their daily energy during school hours [4], with lunch alone contributing about one-quarter of daily energy on school days [5]. However, Canadian studies have identified nutritional gaps in school-time intake, including lower school-hour densities of several nutrients compared with intake outside school hours [4], and modest contributions of school lunches to several nutrients [6]. Lunch has also been shown to contribute proportionally less whole fruit, whole grains, and milk, and proportionally more sodium, than would be expected based on its contribution to daily energy intake [5].

Adequate nutrient intake is important during childhood and adolescence [7]. Diet quality during childhood has also been associated with academic performance [8] and with cardiometabolic health later in life [9]. Despite the potential for school food programs to influence these outcomes, evidence on how such programs change what students actually consume remains limited. Most evaluations focus on program availability, participation, menu offerings, or overall diet quality rather than quantifying energy and nutrient intake during lunch, and few controlled studies have examined observed lunch consumption under real-world implementation conditions [1, 10]. In our baseline assessment of the four schools included in this study, school-provided lunches were more nutrient-dense than home-packed lunches. However, their absolute contributions to several nutrients remained modest [6]. That cross-sectional analysis described lunch-period dietary intake by lunch provenance before program implementation but could not assess changes following universal provision. The present study therefore examined all foods and beverages consumed at lunch, regardless of provenance, and assessed whether baseline-to-follow-up changes in energy and nutrient intake, contributions to Dietary Reference Intakes (DRIs), and nutrient density differed between intervention and control schools following implementation of a universal school lunch program.

METHODS

Study Design and Setting

This quasi-experimental controlled before-and-after study was conducted in the same four elementary schools (Kindergarten to Grade 8) at baseline and approximately two years after implementation of a universal school lunch program. At each study period, dietary data were collected from a cross-sectional sample of students; some students contributed observations at both periods. The primary analysis used

a difference-in-differences (DiD) design to compare school-population-level changes in lunch-period dietary outcomes between intervention and control schools. A longitudinal sensitivity analysis examined within-student changes among students observed at both periods who remained in the same school.

The overall study protocol has been published [11]. The study was conducted in four public elementary schools in Saskatoon, Saskatchewan, located in neighbourhoods with lower mean household income than the city average, based on neighbourhood-level census data [12]. The schools were purposively selected in collaboration with the school division from schools with existing small lunch programs and infrastructure that could support expanded lunch provision. Two schools implemented the Good Food for Learning program and two served as controls.

Data were collected at baseline (May–June 2021), before program implementation, and at follow-up (May–June 2023), near the end of the second school year of implementation. Intervention status was not randomly assigned. Reporting was guided by the STROBE statement and its extension for nutritional epidemiology (STROBE-nut) [13].

The University of Saskatchewan Behavioural Research Ethics Board approved the study (BEH-509). Parents and caregivers received written study information and could decline their child's participation, and students provided verbal assent before dietary data collection. Permission to conduct the study was also obtained from Saskatoon Public Schools.

Participants

All students enrolled in Kindergarten through Grade 6 at participating schools were eligible for dietary assessment. Students with at least one usable lunch observation at baseline and/or follow-up were included in the primary analysis. Schools provided students' age and reported gender from school records.

For the primary analysis, the analytic unit was the student-period, defined as one student's dietary intake value at either baseline or follow-up. When two usable lunch observations from the same student were available at either baseline or follow-up, intake was averaged across the two days; when only one usable observation was available, intake from that lunch was used as the student-period value. The primary analysis used all eligible student-period observations at each study period and did not require the same students to be observed at baseline and follow-up. No separate sample-size calculation was conducted for the present analysis; the analytic sample included all eligible dietary observations from the four schools participating in the study. Unique participant identifiers were used to identify students observed at both study periods for the longitudinal sensitivity analysis.

Intervention

Before implementation, all four schools operated small, targeted school food programs that were inconsistently funded and primarily intended for students requiring food assistance. Food provided through these programs consisted mainly of sandwiches and pre-packaged snack items rather than a daily prepared lunch available to the full student population. Beginning in October 2021, the two intervention schools shifted from this targeted approach to a universal model in which a free lunch was available each school day to all enrolled students. Participation remained voluntary, and students could eat the school-provided lunch, bring food from home, or consume foods from both sources. Control schools continued their existing food programs, although the nature and extent of food provision also changed during the study period. Further details on pre-existing food programming, intervention implementation, and changes in control-school food provision are reported in the accompanying process evaluation (Alaniz-Salinas et al., manuscript submitted for publication).

A six-week rotating menu was developed as the initial guide for the program [11] and was informed by Canada's Dietary Guidelines [14]. Lunches were generally planned around a hot main dish, with vegetables and/or fruit, and milk or water. The menu was intended to include nutrient-dense foods such as vegetables and fruit, whole grains, and protein foods, including plant-based options when feasible.

The intervention also included grade-specific food and nutrition education activities, described in the published protocol [11]. In practice, these activities were delivered intermittently and were not systematically tracked; daily meal provision was implemented more consistently (Alaniz-Salinas et al., manuscript submitted for publication). The present analysis evaluated the intervention as implemented and did not estimate the independent contribution of the educational component.

Meals were prepared and served within the participating schools, not through a centralized food service system. As implementation progressed, menus, food sourcing, staffing, and daily routines changed in response to school capacity, purchasing issues, food donations, staffing constraints, and student uptake (Alaniz-Salinas et al., manuscript submitted for publication). Foods therefore varied across observation days, and the reported outcomes reflect routine program delivery rather than a fixed menu.

Dietary Assessment and Nutrient Coding

Lunch intake was measured using photography-assisted weighed plate waste. The protocol targeted two observation days per student within each study period. Observation dates were selected in advance without reference to the foods or menus being served and were coordinated with participating schools for feasibility. The specific classrooms to be observed were generally confirmed on the day before or the day of data collection. At baseline, dietary data were collected over four school days at each school. At follow-up, data collection was conducted over a longer period, generally six to eight school days depending on the school, to obtain the required observations and accommodate school schedules and student availability. A second usable observation was not available for all students because some students were absent, left school for lunch, were participating in other school activities, or did not participate in dietary assessment on a given observation day. Observation dates were not disclosed to

students or families beforehand [11]. Each student was assigned a unique identification number used to link dietary observations and demographic information.

On each observation day, trained research staff weighed foods and beverages immediately before consumption and reweighed remaining items after lunch using calibrated digital scales. Consumed amounts were calculated by subtracting the weight remaining after lunch from the pre-lunch weight. Photographs and field notes were used during coding to confirm food identity, portions, and any circumstances affecting the measurement. The identification number assigned to each student was used to link foods and beverages measured before lunch with the corresponding leftovers after consumption. Full details of the dietary assessment procedures have been published in a baseline dietary assessment study [6].

Lunch provenance was first classified for each observed lunch as school-provided, home-packed, or mixed using direct observation and food-source documentation. School-provided lunches consisted entirely of foods and beverages supplied through the school food program, whereas home-packed lunches consisted entirely of foods and beverages brought from home or obtained elsewhere. Mixed lunches contained foods from both sources, regardless of the relative proportion contributed by each.

A student-period provenance category was then assigned using all available lunch observations within that period. Students with one observed lunch retained the classification of that lunch. For students with two observed lunches, provenance was classified as school-provided when both lunches were school-provided, home-packed when both were home-packed, and mixed when either lunch contained foods from both sources or when provenance differed between the two observation days.

Energy and nutrient intake were estimated using Food Processor Nutrition and Fitness Software (version 11.6.522; ESHA Research, Salem, OR, USA) [15]. The Canadian Nutrient File (CNF), 2015 version [16], was prioritized when matching foods to nutrient profiles. For each candidate match, the nutrient and source information available in Food Processor were reviewed. When a CNF entry relied on older United States Department of Agriculture (USDA) food-composition data, a more current USDA FoodData Central profile was used when it represented the same or a more appropriate food match [6, 17]. This approach was used particularly for fruits, vegetables, and meats, for which more current USDA profiles were available. Final food-code selection also considered the closest match to the observed food type, form, and preparation.

Brand-specific products were not routinely coded; instead, nutritionally comparable generic food items were selected. For school-provided meals, recipes were entered into the software using ingredient lists, preparation methods, and quantity information obtained from school nutrition staff. Energy and nutrient intake were calculated for all measured foods and beverages consumed during lunch; plain water intake was not quantified.

Outcome Measures

Energy and Nutrient Intake

Primary outcomes were lunch energy intake (kcal) and selected nutrients of public health relevance: protein, total fat, carbohydrates, dietary fibre, total sugars, saturated fat, calcium, folate, iron, magnesium, phosphorus, potassium, sodium, zinc, and vitamins A, C, D, and E. All outcomes reflect intake during the lunch period only and were not extrapolated to total daily intake.

Contribution to Dietary Reference Intakes

For descriptive context, nutrient intakes were expressed as the percentage contribution to age- and, where applicable, sex-specific DRIs established by Health Canada [18]. The Estimated Average Requirement (EAR) was used when available, the Adequate Intake (AI) was used for nutrients without an established EAR, and the Chronic Disease Risk Reduction Intake (CDRR) was used for sodium [18]. These percentages were used to describe the contribution of lunch-period intake to daily reference values and were not interpreted as indicators of overall dietary adequacy.

Because biological sex was not available, reported gender was used as a proxy when assigning sex-specific DRI values for participants aged 9–13 years; the DRI reference values used for participants aged 5–8 years were not sex-specific. DRI contribution analyses were limited to nutrients for which an applicable EAR, AI, or CDRR could be assigned. Reference values are provided in Additional file 1: Table S1.

Nutrient Density

Nutrient density was assessed using the Nutrient Rich Food Index 9.3 (NRF 9.3), based on the validated Nutrient Rich Food nutrient-profiling framework [19–21]. For each student-period intake profile, the score was calculated as the sum of percentage Daily Values (%DV) for nine nutrients to encourage minus the sum of percentage Maximum Recommended Values (%MRV) for three nutrients to limit, standardized per 2000 kcal. Higher scores indicate greater nutrient density.

Consistent with our published baseline analysis [6], the calculation used vitamin D in place of vitamin E among nutrients to encourage and total sugars in place of added sugars. The specific Daily Values and Maximum Recommended Values used in this study are provided in Additional file 1: Table S2. Individual nutrient contributions were capped at 100% before summation [20]. For students with two observed lunches within a study period, nutrient intakes were averaged across days before calculating the NRF 9.3 score; students with one observation contributed the score based on that lunch.

Statistical Analysis

Descriptive statistics were calculated by study group and period. Continuous variables are presented as means and standard deviations, and categorical variables as counts and percentages. As an exploratory

assessment of sample composition, mean age and the distributions of age group and reported gender were examined descriptively across study groups and periods.

The primary DiD analysis compared baseline-to-follow-up changes in lunch-period dietary outcomes between intervention and control schools [22, 23]. All foods and beverages consumed during the observed lunch period were included, whether school-provided, home-packed, or mixed. The estimand therefore represents change in lunch-period consumption across the participating school populations rather than the effect of consuming a school-provided lunch among program participants only.

For each outcome, student-period values were averaged within each school and study period. This produced eight school-period means (four schools × two periods), which were analysed using a linear regression including study period, study group, and their interaction. Each school-period contributed equally to the model:

$$Y_{st} = \beta_0 + \beta_1 \text{Post}_t + \beta_2 \text{Intervention}_s + \beta_3 (\text{Post}_t \times \text{Intervention}_s) + \epsilon_{st}$$

where Y_{st} is the mean outcome for school s at period t ; Post_t indicates follow-up versus baseline; Intervention_s indicates intervention versus control school; and ϵ_{st} is the error term. The period-by-group interaction coefficient β_3 was the DiD estimate.

The model was fitted separately for each energy, nutrient, DRI-contribution, and NRF 9.3 outcome. Because each school-period contributed equally, each of the four schools had equal weight regardless of the number of students observed. Baseline group means may therefore differ from those reported in our previous baseline study [6], which pooled participant-level values across schools. Given the small number of schools, DiD estimates were interpreted descriptively.

As a sensitivity analysis, covariate-adjusted DiD models were fitted using student-period data. To retain the equal school-period weighting of the primary analysis, each student-period was weighted by the inverse of the number of observations in its school-period, so that the summed weight within each school-period was equal. Weights were recalculated separately for each outcome after observations with missing model variables were excluded. Models included school fixed effects, study period, the period-by-group interaction, age at the corresponding study period, and reported gender. A second model additionally adjusted for the number of lunch observations contributing to each student-period value. Because study group did not vary within schools, its main effect was absorbed by the school fixed effects and was omitted. Lunch provenance was not included because it could change following intervention implementation. These models were treated as sensitivity analyses rather than replacements for the primary school-level analysis.

To examine whether the primary estimates were sensitive to the number of lunch observations contributing to each student-period value, the same school-level DiD regression was repeated separately

for student-periods based on one observed lunch and those based on two observed lunches. These analyses were descriptive; no formal test comparing the two strata was conducted.

A longitudinal sensitivity analysis was conducted among students with valid participant identifiers who were observed at both baseline and follow-up. Because the intervention was assigned and delivered at the school level, the longitudinal analysis was restricted to students who remained in the same participating school at baseline and follow-up. Students with undefined reported gender at either study period were excluded so that all longitudinal models used the same analytic sample. Repeated student-period observations were analyzed using linear mixed-effects models fitted with the *lme()* function in the *nlme* package. A random intercept for each participant was included to account for correlation between baseline and follow-up measurements from the same student. Each energy, nutrient, DRI-contribution, and NRF 9.3 outcome was modeled separately using restricted maximum likelihood estimation.

The principal longitudinal model included study period (baseline/follow-up), study group (control/intervention), and their interaction as fixed effects, with a random intercept for each participant. The period-by-group interaction represented the difference in baseline-to-follow-up change between students in intervention and control schools. Additional sensitivity models sequentially adjusted for baseline age and reported gender, the number of lunch observations contributing to each student-period value, and school fixed effects. Full model specifications are provided in Additional file 1: Table S5. Lunch provenance was not included as a covariate because it could itself change following intervention implementation.

The longitudinal analysis was treated as a sensitivity analysis rather than an alternative primary analysis because only a subset of baseline students was observed at follow-up. Model-based 95% confidence intervals and p-values are reported for the longitudinal sensitivity models.

For nutrient fields in which Food Processor returned no value, the value was coded as zero according to the predefined data-processing rule. No statistical imputation was otherwise performed.

All analyses were conducted using R version 4.5.0 (R Foundation for Statistical Computing, Vienna, Austria) [24].

RESULTS

Sample Characteristics

Four schools contributed 980 student-period observations: 379 at baseline and 601 at follow-up (Table 1). Mean age was similar at baseline and follow-up in both control schools (8.5 and 8.3 years, respectively) and intervention schools (8.5 and 8.4 years, respectively), and the distributions of age group and reported gender were also similar across periods within both study groups. Overall, 627 of 980 student-period observations (64.0%) were based on two observed lunches.

Of the 379 baseline student-period observations, 373 had usable participant identifiers. Among these students, 141 (37.8%) were also observed at follow-up. Of the 141 linked students, 137 remained in the same participating school. One of these 137 students had an undefined reported gender at one or both study periods and was excluded from the longitudinal mixed-effects analysis, resulting in a final analytic sample of 136 students contributing 272 student-period observations.

Lunch Provenance

Lunch provenance shifted over time (Table 1). In intervention schools, the proportion of student-period observations classified as school-provided increased from 43.0% at baseline to 61.9% at follow-up, while mixed lunches decreased from 35.5% to 16.5%. In comparison, the proportion of school-provided lunches remained nearly unchanged in control schools, increasing from 33.2% to 34.2%.

Table 1
Sample characteristics and lunch provenance by study group and period

Category	Characteristic	Control Baseline, n (%)	Control Follow-up, n (%)	Intervention Baseline, n (%)	Intervention Follow-up, n (%)
Total	Student-period observations	193 (100)	310 (100)	186 (100)	291 (100)
Reported gender	Female	89 (46.1)	157 (50.6)	92 (49.5)	135 (46.4)
	Male	103 (53.4)	153 (49.4)	93 (50.0)	156 (53.6)
	Unknown/missing	1 (0.5)	0 (0.0)	1 (0.5)	0 (0.0)
Age group	5–8 years	99 (51.3)	168 (54.2)	93 (50.0)	156 (53.6)
	9–13 years	94 (48.7)	142 (45.8)	93 (50.0)	135 (46.4)
Lunch provenance	Home-packed	84 (43.5)	159 (51.3)	40 (21.5)	63 (21.6)
	Mixed	45 (23.3)	45 (14.5)	66 (35.5)	48 (16.5)
	School-provided	64 (33.2)	106 (34.2)	80 (43.0)	180 (61.9)
Number of lunch observations	One	56 (29.0)	135 (43.5)	65 (34.9)	97 (33.3)
	Two	137 (71.0)	175 (56.5)	121 (65.1)	194 (66.7)
Note. Values are student-period observations and are presented as n (%). Percentages are calculated within each study group and period. Reported gender information was provided by participating schools from school records and was used as a proxy for biological sex when assigning sex-specific Dietary Reference Intake values for participants aged 9–13 years. Students contributed one or two observed lunches within each study period.					

Energy and Nutrient Intake

Mean lunch energy intake declined in both groups (Table 2), from 462.0 to 294.1 kcal in control schools and from 422.2 to 345.4 kcal in intervention schools. The DiD estimate was 91.1 kcal, indicating that the decline was smaller in intervention schools.

Across the 19 outcomes presented in Table 2, mean intakes declined in both groups for 17 outcomes. Folate and vitamin C were the exceptions: both increased in intervention schools while declining in control schools, yielding DiD estimates of 23.97 µg DFE and 5.42 mg, respectively. Saturated fat and sodium also declined in both groups, but the reductions were smaller in intervention schools, resulting in

positive DiD estimates of 2.61 g and 161.35 mg. For these nutrients to limit, the positive estimates represent less favourable differential changes rather than improvements. The remaining estimates primarily reflected differences in the magnitude of declines and did not show a consistent pattern of differential change.

Table 2

Lunch energy and nutrient intake at baseline and follow-up, by study group, and difference-in-differences estimates

Outcome	Control Baseline Mean (SD)	Control Follow-up Mean (SD)	Intervention Baseline Mean (SD)	Intervention Follow-up Mean (SD)	DiD Estimate
Energy (kcal)	462.0 (78.2)	294.1 (51.7)	422.2 (20.1)	345.4 (24.4)	91.10
Protein (g)	15.6 (0.5)	10.1 (0.0)	14.6 (1.3)	11.8 (0.3)	2.73
Total fat (g)	18.4 (2.5)	11.0 (2.1)	16.2 (2.1)	15.0 (0.4)	6.22
Carbohydrates (g)	59.9 (14.9)	39.2 (8.5)	55.9 (1.3)	42.2 (8.0)	6.97
Dietary fibre (g)	3.7 (0.9)	2.5 (0.0)	4.5 (0.0)	3.1 (0.6)	-0.18
Total sugars (g)	24.6 (4.2)	13.7 (2.6)	24.0 (3.1)	15.6 (2.6)	2.50
Saturated fat (g)	6.4 (0.4)	3.4 (0.7)	5.8 (0.9)	5.4 (0.0)	2.61
Calcium (mg)	201.8 (19.8)	117.1 (31.8)	206.1 (27.2)	160.0 (24.0)	38.66
Folate, DFE (µg)	82.3 (26.5)	76.0 (3.1)	69.7 (0.6)	87.4 (6.4)	23.97
Iron (mg)	2.7 (0.7)	1.8 (0.2)	2.3 (0.2)	2.0 (0.2)	0.67
Magnesium (mg)	55.4 (2.9)	34.2 (3.3)	59.8 (1.6)	39.4 (4.8)	0.89
Phosphorus (mg)	289.2 (7.3)	194.2 (34.2)	289.4 (4.5)	206.6 (16.7)	12.20
Potassium (mg)	505.6 (0.8)	311.6 (0.8)	539.8 (13.9)	422.6 (65.7)	76.88
Sodium (mg)	915.3 (49.1)	527.6 (15.6)	777.2 (86.9)	550.9 (63.3)	161.35
Vitamin A, RAE (µg)	114.2 (3.1)	92.9 (29.4)	149.1 (16.0)	140.1 (6.5)	12.30
Vitamin C (mg)	23.7 (9.9)	18.8 (4.2)	25.0 (2.3)	25.6 (6.2)	5.42
Vitamin D (µg)	0.9 (0.8)	0.6 (0.3)	1.2 (0.2)	0.7 (0.0)	-0.18
Vitamin E (mg)	1.6 (0.5)	1.1 (0.1)	1.6 (0.1)	1.1 (0.1)	0.15

Note. Values are unweighted means of the two school-level means within each study group and period, with standard deviations calculated across the two schools. Each school contributed equally regardless of the number of student-period observations. The DiD estimate is the period-by-group interaction coefficient from the school-level linear regression and represents the baseline-to-follow-up change in intervention schools relative to the corresponding change in control schools. Estimates are interpreted descriptively because only four schools were included. DiD, difference-in-differences; DFE, dietary folate equivalents; RAE, retinol activity equivalents; SD, standard deviation.

Outcome	Control Baseline Mean (SD)	Control Follow-up Mean (SD)	Intervention Baseline Mean (SD)	Intervention Follow-up Mean (SD)	DiD Estimate
Zinc (mg)	2.0 (0.1)	1.1 (0.1)	1.9 (0.1)	1.5 (0.1)	0.52
Note. Values are unweighted means of the two school-level means within each study group and period, with standard deviations calculated across the two schools. Each school contributed equally regardless of the number of student-period observations. The DiD estimate is the period-by-group interaction coefficient from the school-level linear regression and represents the baseline-to-follow-up change in intervention schools relative to the corresponding change in control schools. Estimates are interpreted descriptively because only four schools were included. DiD, difference-in-differences; DFE, dietary folate equivalents; RAE, retinol activity equivalents; SD, standard deviation.					

Contribution to Dietary Reference Intakes

For 12 of the 13 nutrients examined, mean percentage contributions to DRI reference values declined from baseline to follow-up in both groups (Table 3). Folate was the exception, decreasing in control schools and increasing in intervention schools. Positive DiD estimates for several other nutrients largely reflected smaller declines in intervention schools rather than increases from baseline. Sodium had a positive DiD estimate of 9.38 percentage points of the CDRR, indicating that the contribution of lunch-period sodium intake declined less in intervention schools than in control schools and therefore represented a less favourable differential change. Overall, the DRI contribution outcomes did not show a consistent pattern of improvement in intervention schools.

Table 3

Contribution of lunch intake to Dietary Reference Intakes at baseline and follow-up, by study group, and difference-in-differences estimates

Nutrient	Control Baseline Mean (SD)	Control Follow-up Mean (SD)	Intervention Baseline Mean (SD)	Intervention Follow-up Mean (SD)	DiD Estimate
Dietary fibre (% AI)	13.9 (3.3)	9.6 (0.1)	16.6 (0.0)	11.5 (2.2)	-0.77
Calcium (% EAR)	21.8 (2.6)	12.6 (3.7)	22.4 (2.6)	17.0 (2.4)	3.78
Folate, DFE (% EAR)	41.5 (12.6)	37.8 (3.2)	36.1 (0.2)	44.0 (2.8)	11.68
Iron (% EAR)	56.1 (14.2)	37.0 (3.3)	48.3 (3.9)	41.8 (2.9)	12.58
Magnesium (% EAR)	38.6 (0.1)	24.2 (0.2)	41.5 (1.7)	26.9 (2.2)	-0.14
Phosphorus (% EAR)	48.5 (2.0)	32.1 (7.5)	49.3 (2.3)	33.7 (0.8)	0.79
Potassium (% AI)	21.4 (0.1)	13.3 (0.1)	22.9 (0.6)	17.9 (2.7)	3.14
Sodium (% CDRR)	55.4 (3.3)	31.9 (1.4)	47.4 (5.3)	33.2 (3.1)	9.38
Vitamin A, RAE (% EAR)	33.3 (2.2)	27.4 (11.1)	43.9 (6.2)	41.2 (0.4)	3.09
Vitamin C (% EAR)	82.7 (28.1)	68.7 (20.3)	89.8 (10.7)	87.5 (19.3)	11.85
Vitamin D (% EAR)	9.1 (7.7)	5.5 (3.0)	12.3 (2.1)	7.0 (0.3)	-1.79
Vitamin E (% EAR)	22.4 (6.4)	14.5 (1.1)	21.2 (2.0)	15.3 (0.8)	1.96
Zinc (% EAR)	37.9 (3.8)	21.5 (0.4)	36.6 (3.1)	28.7 (2.7)	8.57

Note. Values are unweighted means of the two school-level means within each study group and period, with standard deviations calculated across the two schools. Each school contributed equally regardless of the number of student-period observations. Nutrient intake was expressed as a percentage of the applicable age- and sex-specific Estimated Average Requirement (EAR), Adequate Intake (AI), or Chronic Disease Risk Reduction Intake (CDRR). These percentages are presented for descriptive context and should not be interpreted as indicators of dietary adequacy. For sodium, a higher percentage of the CDRR represents greater intake relative to the recommended limit and should not be interpreted as more favourable. The DiD estimate is the period-by-group interaction coefficient from the school-level linear regression and represents the baseline-to-follow-up change in intervention schools relative to the corresponding change in control schools. Estimates are interpreted descriptively because only four schools were included. AI, Adequate Intake; CDRR, Chronic Disease Risk Reduction Intake; DFE, dietary folate equivalents; DiD, difference-in-differences; EAR, Estimated Average Requirement; RAE, retinol activity equivalents; SD, standard deviation.

Nutrient Density

NRF 9.3 scores were higher in intervention schools than in control schools at both periods (Table 4). Scores increased from 268.8 to 299.7 in control schools and decreased from 345.1 to 328.9 in intervention schools. The resulting DiD estimate was – 47.2 points, indicating a less favourable change in intervention schools.

Table 4
Lunch nutrient density (NRF 9.3) at baseline and follow-up, by study group, and difference-in-differences estimate

Outcome	Control Baseline Mean (SD)	Control Follow-up Mean (SD)	Intervention Baseline Mean (SD)	Intervention Follow-up Mean (SD)	DiD Estimate
NRF 9.3	268.8 (55.1)	299.7 (100.3)	345.1 (21.6)	328.9 (23.4)	–47.19

Note. Values are unweighted means of the two school-level means within each study group and period, with standard deviations calculated across the two schools. Each school contributed equally regardless of the number of student-period observations. Higher NRF 9.3 scores indicate greater nutrient density. The DiD estimate is the period-by-group interaction coefficient from the school-level linear regression and represents the baseline-to-follow-up change in intervention schools relative to the corresponding change in control schools. Estimates are interpreted descriptively because only four schools were included. DiD, difference-in-differences; NRF 9.3, Nutrient Rich Food Index 9.3; SD, standard deviation.

Covariate-adjusted Repeated Cross-sectional Sensitivity Analysis

Covariate adjustment did not materially change the direction or magnitude of the primary DiD estimates for the outcomes highlighted above (Additional file 1: Table S3). Estimates remained similar after adjustment for age and reported gender and after further adjustment for the number of lunch observations.

Sensitivity Analysis by Number of Lunch Observations

Restricting the analysis to student-periods with two observed lunches produced estimates in the same direction as the primary analysis for 27 of 33 outcomes (Additional file 1: Table S4). Among the outcomes emphasized in the primary results, folate, saturated fat, sodium, and NRF 9.3 retained the same direction. The energy estimate remained positive but was attenuated (+ 28.82 versus + 91.10 kcal), while vitamin C changed direction (– 2.73 versus + 5.42 mg). Estimates based on student-periods with one observed lunch were in the same direction as the primary estimates for 30 of 33 outcomes but tended to be larger in magnitude.

Longitudinal Sensitivity Analysis

In the principal longitudinal model, estimates were in the same direction as the primary DiD estimates for 17 of 19 energy and nutrient outcomes and 11 of 13 DRI contribution outcomes (Additional file 1: Table

S5). Dietary fibre and total sugars were the two nutrient outcomes for which the direction differed. NRF 9.3 showed the largest difference between analyses, with a primary DiD estimate of – 47.19 points and a longitudinal estimate of + 10.74 points. Estimates were generally similar across the additional models adjusting for baseline age and reported gender, number of lunch observations, and school fixed effects.

DISCUSSION

This study examined whether lunch-period dietary intake changed differently in intervention and control schools following implementation of a universal school lunch program. By including all foods consumed at lunch, whether school-provided, home-packed, or mixed, the analysis assessed change across the participating school populations rather than the effect of consuming a school-provided meal alone. We found that implementation was accompanied by several nutrient-specific differences in change, although the overall pattern across dietary outcomes was mixed. In the primary analysis, folate and vitamin C increased in intervention schools while declining in controls, whereas smaller reductions in saturated fat and sodium were less favourable. Covariate-adjusted repeated cross-sectional estimates were similar to the primary estimates, indicating that adjustment for age, reported gender, and number of lunch observations did not materially alter the principal findings. Folate remained in the same direction when analyses were restricted to student-periods based on two observed lunches, whereas vitamin C did not. Longitudinal findings were generally similar for individual nutrient and DRI outcomes, while NRF 9.3 varied by analytic sample.

The change in lunch provenance provides important context for the mixed population-level findings. In intervention schools, exclusively school-provided lunches increased from 43.0% to 61.9%, but the proportion of observations involving any school-provided food remained about 78% because mixed lunches declined. Exposure to school food was therefore already common at baseline. Although school-provided lunches were more nutrient-dense than home-packed lunches in our baseline study [6], participation was also variable, as reflected by the continued presence of school-provided, home-packed, and mixed lunches at follow-up. The present analysis therefore reflects dietary change after universal availability under routine implementation rather than the effect of consistently consuming a complete school-provided lunch. Importantly, universal availability did not result in uniform exposure to the intervention meal, and the observed population-level effects reflect a setting in which students continued to obtain lunch foods from multiple sources.

Energy intake declined substantially in both groups, although the decline was smaller in intervention schools. The positive DiD estimate was substantially attenuated when the analysis was restricted to student-periods based on two observed lunches (+ 28.82 versus + 91.10 kcal in the primary analysis). Averaging intake across two observation days may reduce the influence of day-to-day variation and provide a more reliable representation of usual lunch-period intake than a single observation [25]. The attenuation in the two-lunch analysis therefore suggests that the magnitude of the primary energy estimate should be interpreted cautiously. However, because the two-lunch analysis also included a different subset of students, the difference between estimates cannot be attributed solely to reduced

within-student variability. Age and reported-gender distributions were similar across study periods, and the adjusted energy estimate was close to the primary estimate. However, because intake was assessed only during the lunch period and individual energy requirements and total daily intake were not measured, the nutritional significance of lower lunch-period energy intake cannot be determined.

Interpretation of the nutrient-specific DiDs depends on the direction of the underlying change. In the primary analysis, folate and vitamin C increased in intervention schools while declining in controls, although the vitamin C estimate changed direction in the two-observation sensitivity analysis. For several other nutrients, positive DiDs reflected smaller declines in intervention schools. This may be relatively favourable for nutrients such as protein and some vitamins and minerals but does not establish dietary adequacy. In contrast, smaller declines in saturated fat and sodium were less favourable. The DRI contribution analyses showed the same general pattern, including a positive sodium DiD for percentage of the CDRR, which represented a smaller reduction in sodium relative to the recommended limit rather than an improvement.

NRF 9.3 was more sensitive to analytic approach. The primary DiD was – 47.19 points and was attenuated to – 14.02 when restricted to student-periods based on two lunches, whereas the longitudinal estimate was + 10.74. The longitudinal analysis included a smaller, selected subset of students, and NRF 9.3 was already higher in intervention schools at baseline. With only two schools per group, the contrasting estimates are better interpreted as evidence of sensitivity to analytic sample and school-level variation than opposing intervention effects.

Previous Canadian research has generally reported favourable, although not uniform, effects of school food and nutrition programs on dietary outcomes. Colley et al. found that Canadian school food programs were positively associated with nutrition knowledge, dietary behaviour, and intake of healthy foods, but also identified intervention duration, intensity, and resource availability as factors that could limit program effects [26]. A more recent Canadian systematic review similarly characterized the literature as heterogeneous and largely focused on nutrition education interventions using subjective measures to infer changes in nutrition; relatively few evaluated no-cost food provision programs [1]. These findings are relevant to the present study because Good Food for Learning was a multicomponent intervention implemented within existing school systems rather than under tightly controlled feeding conditions.

More recent Canadian findings also illustrate why effects may differ across specific nutritional outcomes. Dabravolskaj et al. found that elementary-school students accessing school food programs consumed more vegetables and fruit and had better overall diet quality than students who did not access these programs [25]. However, in meal-specific analyses, school-provided lunches were associated with higher daily sodium intake. Implementation of mandatory school nutrition policies in Canada has also been associated with improved school-time diet quality [27]. Together, these findings suggest that improvements in overall dietary quality do not necessarily imply favourable changes in

every individual nutrient and provide relevant context for the less favourable sodium pattern observed in the present study.

Controlled and quasi-experimental studies from other settings provide further context. In a difference-in-differences evaluation of universal free school meals in England and Scotland, Parnham et al. found increased school-meal uptake and lower lunchtime total fat and sodium following universal provision, with weaker evidence of lower energy intake and no clear changes in several other dietary outcomes [28]. In the Danish OPUS School Meal Study, replacing usual packed lunches with nutritionally designed school meals changed the composition of dietary intake, including lower fat and higher protein and several micronutrients, without changing mean energy intake [29]. Sabinsky et al. likewise found improved lunch dietary quality when free school meals were offered instead of packed lunches; when meals were no longer provided free of charge, uptake was limited and the difference in dietary quality was no longer observed [30]. Together, these studies suggest that school meals can improve dietary intake, but the size and direction of effects depend both on the nutritional characteristics of the meals and on the extent to which students take them up and replace foods they would otherwise consume.

The importance of distinguishing universal availability from actual uptake is also supported by a recent natural experiment evaluating the expansion of universal free school meals among secondary-school students in England. Spence et al. found little evidence of differential change across most dietary outcomes, but only 19 students in intervention schools changed lunch type to take up the universal meal offer [31]. The authors emphasized that interpretation of dietary effectiveness needs to account for limited uptake, the possibility that uptake changes over time after implementation, and how the offer is communicated to students and families. They also identified food quality and availability and the dining environment as important considerations for maximizing the nutritional benefit of universal provision. Although the students were older and the intervention context differed from the present study, the underlying issue is directly relevant: making a meal universally available does not ensure that students consistently consume it.

In Good Food for Learning, these considerations extend beyond meal uptake. Menus, food sourcing, staffing, and service routines evolved throughout implementation, while food provision in control schools also changed over the same period (Alaniz-Salinas et al., manuscript submitted for publication). In addition, the planned food and nutrition education activities were delivered intermittently and were not systematically tracked, whereas daily meal provision was implemented more consistently. These implementation differences are relevant because both the foods made available and students' exposure to other intervention components could influence food choices and consumption. Together, variable participation, continued consumption of home-packed and mixed lunches, changes in control-school food provision, and evolving intervention delivery may have reduced the contrast between intervention and control schools and limited the magnitude of dietary changes detectable at the school-population level. Despite these implementation challenges, both intervention schools sustained daily lunch provision across the two-year intervention.

Several limitations should be considered. Only four schools were included, with two intervention and two control schools, and intervention status was not randomly assigned. Schools were purposively selected from a single urban school division and had pre-existing food programs, which may limit generalizability to schools with different populations, resources, or baseline food provision. Although 980 student-period observations were available, the intervention was implemented at the school level, leaving only four independent school units for estimating differences between intervention and control conditions. This small number of schools substantially limits the precision and strength of statistical inference at the intervention-assignment level; accordingly, the primary school-level DiD estimates were interpreted descriptively rather than as confirmatory evidence of program effectiveness. Although adjustment for age, reported gender, and number of lunch observations produced estimates similar to the primary estimates, covariate adjustment cannot eliminate confounding from unmeasured school-level differences or overcome the limited number of intervention-assignment units. In addition, only one pre-intervention measurement was available, so the parallel-trends assumption underlying DiD could not be empirically assessed [22, 23]. The longitudinal mixed-effects models generated model-based 95% confidence intervals and p-values, but these reflect analyses of repeated observations within students and should be interpreted as sensitivity results rather than confirmatory tests of the school-level intervention effect.

The primary analysis used repeated cross-sectional samples and therefore represents changes in the student populations observed at each study period rather than within-student changes. The longitudinal sensitivity analysis provided a complementary assessment of change within the same students but included only 136 students and represented a selected subset of the baseline sample. The longitudinal findings should therefore be considered complementary to, rather than a replacement for, the primary school-population-level analysis. Dietary intake was based on one or two observed lunches per student-period and may not fully represent usual intake or variation across the six-week menu cycle. Although the two-lunch sensitivity analysis reduced the influence of a single observation day, two lunches still capture only a limited portion of the menu cycle. Consumption may also have been influenced by the particular foods served and students' preferences on observation days. Finally, dietary assessment was restricted to the lunch period, so the study cannot determine whether changes observed at lunch were offset by intake at other times of day or how they affected total daily dietary intake.

Biological sex was unavailable, and reported gender from school records was used as a proxy when assigning sex-specific DRI reference values for participants aged 9–13 years. This may have resulted in some misclassification of DRI contributions, although it does not affect the analyses of absolute nutrient intake or NRF 9.3.

The study also has several strengths. Foods and beverages consumed during lunch were assessed objectively using a photography-assisted weighed plate-waste method rather than relying on self-reported intake. The analysis included school-provided, home-packed, and mixed lunches, allowing dietary change to be examined across the participating school populations rather than only among students who consumed a school-provided meal. Data were collected during the same months at

baseline and follow-up, reducing seasonal differences in measurement, and the primary analysis was conducted at the school level, consistent with the level at which the intervention was implemented. The inclusion of complementary covariate-adjusted, observation-number, and longitudinal sensitivity analyses also allowed the stability of the primary findings to be examined across different analytic assumptions and samples.

Overall, these findings reinforce that the nutritional effects of universal school lunch programs depend not only on whether meals are made available, but also on what is offered, who consumes it, how consistently it is consumed, and how the program is implemented within the school environment. Universal availability is therefore an important intervention characteristic but should not be treated as equivalent to universal exposure. Future evaluations should prospectively measure individual-level uptake and changes in lunch provenance over time, reasons for participation and non-participation, menu quality and adherence, exposure to educational components, and aspects of the dining environment that may influence students' willingness to consume school meals. Studies including more schools, multiple pre-intervention measurements, and repeated dietary observations across the menu cycle would also provide stronger evidence about the conditions under which universal school food provision produces sustained improvements in what students actually consume.

CONCLUSIONS

Implementation of the universal lunch program substantially changed lunch provision and was accompanied by some favourable nutrient-specific changes, although improvements were not consistent across dietary outcomes. Folate showed the most consistent favourable differential change, whereas findings for vitamin C and NRF 9.3 varied by analytic approach. Because school-provided food was already common at baseline and participation remained variable, the findings reflect universal availability under evolving real-world implementation rather than consistent consumption of a school-provided lunch. These findings highlight the importance of student uptake, meal quality, and implementation in determining the nutritional effects of universal school food programs.

Abbreviations

AI
Adequate Intake
CDRR
Chronic Disease Risk Reduction Intake
CNF
Canadian Nutrient File
DFE
Dietary Folate Equivalents
DiD
Difference-in-Differences

DRI
Dietary Reference Intake
EAR
Estimated Average Requirement
NRF 9.3
Nutrient Rich Food Index 9.3
RAE
retinol activity equivalents
USDA
United States Department of Agriculture

Declarations

Ethics approval and consent to participate

All methods were carried out in accordance with relevant guidelines and regulations and with the Declaration of Helsinki. The University of Saskatchewan Behavioural Research Ethics Board approved the study and the use of an informed opt-out parental/caregiver consent process (BEH 509; approved 15 January 2020). Parents and caregivers received written information describing the study and were given the opportunity to decline their child's participation. Under this REB-approved process, children whose parents or caregivers did not opt out were eligible to participate. Participating students provided verbal assent before dietary data collection. Permission to conduct the study was also obtained from Saskatoon Public Schools.

Clinical trial number: not applicable.

Consent for publication

Not applicable

Availability of data and materials

The dataset analyzed during the present study is not publicly available because it includes data collected from children in school settings and contextual information that could compromise participant or school confidentiality. De-identified data may be available from the corresponding author upon reasonable request and subject to ethics approval, school division approval, and applicable data-sharing agreements.

Competing interests

The authors declare no competing interests.

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Authors' contributions

Natalia Alaniz-Salinas: Conceptualization, methodology, investigation, data curation, formal analysis, validation, project administration, writing—original draft, and writing—review and editing.

Rachel Engler-Stringer: Conceptualization, methodology, supervision, project administration, funding acquisition, validation, and writing—review and editing.

Hassan Vatanparast: Methodology, supervision, and writing—review and editing.

Jessica Liefers: Methodology, supervision, and writing—review and editing.

All authors read and approved the final manuscript.

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References

1. Carducci B, Dominguez G, Kidd E, Oh C, Jain R, Khan A, et al. Promoting healthy school food environments and nutrition in Canada: a systematic review of interventions, policies, and programs. *Nutr Rev.* 2025;83:e356–91. doi:10.1093/nutrit/nuae030.
2. Employment and Social Development Canada. National School Food Policy. Gatineau (QC): Employment and Social Development Canada; 2024.
3. Ruetz AT, McKenna ML. Characteristics of Canadian school food programs funded by provinces and territories. *Can Food Stud.* 2021;8(3):70–106. doi:10.15353/cfs-rcea.v8i3.483.
4. Tugault-Lafleur CN, Black JL, Barr SI. Examining school-day dietary intakes among Canadian children. *Appl Physiol Nutr Metab.* 2017;42:1064–72. doi:10.1139/apnm-2017-0125.
5. Tugault-Lafleur CN, Black JL. Lunch on school days in Canada: examining contributions to nutrient and food group intake and differences across eating locations. *J Acad Nutr Diet.* 2020;120:1484–97. doi:10.1016/j.jand.2020.01.011.

6. Alaniz-Salinas N, Engler-Stringer R, Vatanparast H. Nutritional contribution and quality of lunches consumed during school lunch periods in Canadian elementary schools: a plate waste analysis. *Nutrients*. 2026;18:2065. doi:10.3390/nu18132065.
7. Health Canada. Applying Canada's Dietary Guidelines: nutrition considerations for children and adolescents [Internet]. Ottawa (ON): Health Canada; 2026 [cited 2026 Aug 18]. Available from: <https://www.canada.ca/en/health-canada/services/food-guide/explore/dietary-guidelines/applying/advice-nutrition-different-life-stages/considerations-children-adolescents.html>
8. Florence MD, Asbridge M, Veugelers PJ. Diet quality and academic performance. *J Sch Health*. 2008;78:209–15. doi:10.1111/j.1746-1561.2008.00288.x.
9. Jääskeläinen P, Magnussen CG, Pahkala K, Mikkilä V, Kähönen M, Sabin MA, et al. Childhood nutrition in predicting metabolic syndrome in adults. *Diabetes Care*. 2012;35:1937–43. doi:10.2337/dc12-0019.
10. Cohen JFW, Hecht AA, McLoughlin GM, Turner L, Schwartz MB. Universal school meals and associations with student participation, attendance, academic performance, diet quality, food security, and body mass index: a systematic review. *Nutrients*. 2021;13:911. doi:10.3390/nu13030911.
11. Engler-Stringer R, Black J, Muhajarine N, Martin W, Gilliland J, McVittie J, et al. The Good Food for Learning universal curriculum-integrated healthy school lunch intervention: protocol for a two-year matched control pre-post and case study. *JMIR Res Protoc*. 2021;10:e30899. doi:10.2196/30899.
12. City of Saskatoon Planning and Development. City of Saskatoon neighbourhood profiles. Saskatoon (SK): City of Saskatoon; 2019 [cited 2021 Aug 5].
13. Lachat C, Hawwash D, Ocké MC, Berg C, Forsum E, Hörnell A, et al. Strengthening the Reporting of Observational Studies in Epidemiology—Nutritional Epidemiology (STROBE-nut): an extension of the STROBE statement. *PLoS Med*. 2016;13:e1002036. doi:10.1371/journal.pmed.1002036.
14. Health Canada. Canada's dietary guidelines for health professionals and policy makers. Ottawa (ON): Health Canada; 2019.
15. ESHA Research. Food Processor Nutrition and Fitness Software, version 11.6.522. Salem (OR): ESHA Research; 2018.
16. Health Canada. Canadian Nutrient File (CNF), 2015 [Internet]. Ottawa (ON): Health Canada; 2015 [cited 2024 Feb 15]. Available from: <https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/nutrient-data/canadian-nutrient-file-2015-download-files.html>
17. U.S. Department of Agriculture, Agricultural Research Service. FoodData Central [Internet]. [cited 2024 Aug 28]. Available from: <https://www.ars.usda.gov/data-visualization/fooddata-central/>
18. Health Canada. Dietary reference intakes tables: overview [Internet]. Ottawa (ON): Health Canada [cited 2024 Sep 3]. Available from: <https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/dietary-reference-intakes/tables.html>

19. Drewnowski A. The Nutrient Rich Foods Index helps to identify healthy, affordable foods. *Am J Clin Nutr*. 2010;91:1095S–1101S. doi:10.3945/ajcn.2010.28450D.
20. Fulgoni VL, Keast DR, Drewnowski A. Development and validation of the Nutrient-Rich Foods Index: a tool to measure nutritional quality of foods. *J Nutr*. 2009;139:1549–54. doi:10.3945/jn.108.101360.
21. Drewnowski A, Fulgoni V. Nutrient profiling of foods: creating a nutrient-rich food index. *Nutr Rev*. 2008;66:23–39. doi:10.1111/j.1753-4887.2007.00003.x.
22. Feng S, Ganguli I, Lee Y, Poe J, Ryan A, Bilinski A. Difference-in-differences for health policy and practice: a review of modern methods. *Stat Med*. 2025;44(23–24):e70247. doi:10.1002/sim.70247.
23. Sutton M, Francetic I, O'Neill S, Hugh-Jones S, Munford L. Guide to recent advances in difference-in-differences methodology for population health studies. *J Epidemiol Community Health*. 2026 Jun 25;jech-2025-225449. doi:10.1136/jech-2025-225449.
24. R Core Team. R: a language and environment for statistical computing. Version 4.5.0. Vienna: R Foundation for Statistical Computing; 2025.
25. Dabravolskaj J, Grubic N, Veugelers PJ, Maximova K. Dietary intake and diet quality of Canadian elementary schoolchildren accessing school food programmes: a cross-sectional study. *Br J Nutr*. 2026;135(10):1102–9. doi:10.1017/S0007114526106394.
26. Colley P, Myer B, Seabrook J, Gilliland J. The impact of Canadian school food programs on children's nutrition and health: a systematic review. *Can J Diet Pract Res*. 2019;80:79–86. doi:10.3148/cjdpr-2018-037.
27. Gaudin V, Stranges S, Wilk P, Sarma S. School nutrition policy and diet quality of children and youth: a quasi-experimental study from Canada. *Can J Public Health*. 2023;114:613–28. doi:10.17269/s41997-023-00743-y.
28. Parnham JC, Chang K, Millett C, Lavery AA, von Hinke S, Pearson-Stuttard J, et al. The impact of the Universal Infant Free School Meal Policy on dietary quality in English and Scottish primary school children: evaluation of a natural experiment. *Nutrients*. 2022;14:1602. doi:10.3390/nu14081602.
29. Andersen R, Biloft-Jensen A, Christensen T, Andersen EW, Ege M, Thorsen AV, et al. Dietary effects of introducing school meals based on the New Nordic Diet—a randomised controlled trial in Danish children: the OPUS School Meal Study. *Br J Nutr*. 2014;111:1967–76. doi:10.1017/S0007114514000634.
30. Sabinsky MS, Toft U, Sommer HM, Tetens I. Effect of implementing school meals compared with packed lunches on quality of dietary intake among children aged 7–13 years. *J Nutr Sci*. 2019;8:e3. doi:10.1017/jns.2018.29.
31. Spence S, Matthews JNS, Woodside JV, Brownell R, Scammell K, Bradley J. An evaluation of the effects of universal free school meals on secondary school-aged pupils' dietary intakes in England: a natural experiment. *BMC Public Health*. 2026;26:299. doi:10.1186/s12889-025-25960-7.

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