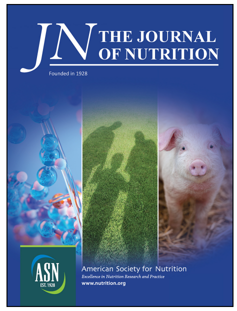


The effect of three daily servings of full-fat dairy for 12 weeks on body weight, body composition, energy metabolism, blood lipids, and dietary intake of adults with overweight and obesity

G.Harvey Anderson, Corrina Zi Chen Zhou, Shirley Vien, Marisa Soo, Shekoufeh Salamat, Maryam Akbarifakhrabadi, Larissa Chomka, Priya Kathirvel, Ferhan Siddiqi, Hrvoje Fabek, Bohdan Luhovyy

PII: S0022-3166(26)00022-2

DOI: https://doi.org/10.1016/j.tjnut.2026.101373

Reference: TJNUT 101373

To appear in: *The Journal of Nutrition*

Received Date: 11 July 2025

Revised Date: 24 September 2025

Accepted Date: 15 January 2026

The effect of three daily servings of full-fat dairy for 12 weeks on body weight, body composition, energy metabolism, blood lipids, and dietary intake of adults with overweight and obesity

G. Harvey Anderson[1], Corrina Zi Chen Zhou[1], Shirley Vien[1], Marisa Soo[1], Shekoufeh Salamat[1], Maryam Akbarifakhrabadi[2], Larissa Chomka[1], Priya Kathirvel[2], Ferhan Siddiqi[3], Hrvoje Fabek[1] and Bohdan Luhovyy[2].

[1]Department of Nutritional Sciences, Temerty Faculty of Medicine, University of Toronto, Toronto, ON, M5R 0A3, Canada

[2]Department of Applied Human Nutrition, Mount Saint Vincent University, Halifax, NS, B3M 2J6, Canada

[3]Department of Medicine, Dalhousie University, Halifax, NS, B3H 2Y9, Canada

Correspondence: G. Harvey Anderson; Medical Sciences Building, Room 5253A, 1 King's College Circle, Toronto, ON M5S 1A8, CA; 416-978-1832; harvey.anderson@utoronto.ca

ABSTRACT

Background: Habitual dairy consumption reduces risk factors for obesity and its associated characteristics of the metabolic syndrome.

Abbreviations

3D-AL: 3-dairy *ad libitum*
3D-EN: 3-dairy energy neutral
BG: Blood glucose
BMI: Body mass index
BW: Body weight
CFG: Canada's Food Guide
DBP: Diastolic blood pressure
DHQ: Dietary History Questionnaire
FFM: Fat free mass
FM: Fat mass
HC: Hip circumference
HDL-C: HDL cholesterol
KAP: Knowledge, Attitudes, and Practices Questionnaire
LD-ER: Low dairy energy restriction
LDL-C: LDL cholesterol
MSVU: Mount Saint Vincent University
Non-HDL-C: Non-HDL cholesterol
PIUR: Protein intake-urea excretion ratio
RMR: Resting metabolic rate
SBP: Systolic blood pressure
TC: Total cholesterol
TG: Triglycerides
UCR: Urea-creatinine ratio
UofT: University of Toronto
WC: Waist circumference
WHR: Waist-hip ratio
WHtR: Waist-height ratio

Objective: To describe the effect of adding three daily servings of full-fat dairy to the diet of adults with overweight and obesity, counselled to follow Canada's Food Guide (CFG).

Methods: A 12-week single-blinded, parallel, randomized study was conducted in 74 participants (age: 36.55 ± 1.04 years; body mass index (BMI): 29.34 ± 0.43 kg/m^2) assigned to 1 of 3 groups: 1) Low Dairy Energy Restriction (LD-ER): 500kcal restriction with ≤1 serving of low-fat dairy, 2) 3 Dairy Energy Neutral (3D-EN): 500kcal restriction replaced by 3 servings of full-fat dairy, and 3) 3 Dairy *Ad libitum* (3D-AL): no energy restriction with 3 servings of full-fat dairy. Changes in physiological outcomes and dietary intakes were measured over 12 weeks.

Results: Body weight and BMI were reduced by treatment ($p<0.05$) in LD-ER over the 12 weeks ($p>0.05$). In 3D-AL, a decrease (0.25 ± 0.34 cm) in hip circumference ($p<0.05$) and in systolic blood pressure (2.72 ± 2.18; $p<0.05$; SBP) was found at week 12. SBP also decreased in LD-ER ($p<0.05$). Triglycerides increased in all groups at week 4 ($p<0.05$) but returned to baseline by week 12. Neither treatment nor time affected waist circumference, fat and fat-free mass, resting metabolic rate, fasting blood cholesterol, and urine creatinine and urea ($p>0.05$). Protein and calcium ($p<0.04$) intakes were increased with time in 3D-EN and 3D-AL but not in LD-ER. Compliance with CFG, assessed by a food tracker, increased with time (77% by week 12).

Conclusions: Frequent and daily consumption of full-fat dairy as part of a healthy diet is consistent with CFG.

Clinical Trials Registry: This study was registered on ClinicalTrials.gov as NCT04399460 on May 22, 2020, and can be accessed at https://www.clinicaltrials.gov/study/NCT04399460

Keywords: Full-fat dairy, body weight, body composition, energy metabolism, dietary intake, Canada's Food Guide, dietary counselling, dietary intervention, obesity

INTRODUCTION

Obesity and cardiometabolic disorders are prevalent within the Canadian population, with over 2.6 million adults diagnosed with cardiovascular disease and more than a third considered obese. Collectively, this poses an annual burden of $35 billion on the healthcare system [1], [2], [3]. These conditions are closely linked with weight and adiposity as excess body fat [4].

Body weight (BW) and composition are strongly influenced by diet [5], [6]. Dairy is the second largest agricultural industry in Canada and provides a rich source of macro- and micro-nutrients [7], [8]. It has been widely documented in many observational and randomized controlled trials, including low-fat and high-fat dairy, to be positively associated with lower BW, reduced waist circumference (WC), and more favorable blood lipid markers [9], [10], [11], [12]. However, there has been a decrease in dairy milk consumption amongst Canadian consumers from 70.2% in 2004 to 56.1% in 2015, with consumers choosing partly skimmed milk (1% to 2%) over full-fat dairy (3.25%) [13], [14]. A primary reason given for this shift is the association of animal-based foods with negative cardiometabolic outcomes, and the promotion of plant-based diets and alternatives [15]. As well, most nutrition recommendations advise against consuming full-fat dairy products, saturated fats, and food products from animal sources [9], [16], [17]. In contrast, a recent expert panel concluded that there is little evidence to support the differentiation between regular-fat and low-fat dairy foods in dietary guidelines for both adults and children [18].

The 2019 Canada's Food Guide (CFG) moved away from its previous nutrient-based guidance with a goal to reduce intake of foods associated with chronic diseases. It encourages the consumption of plant-based foods and proteins and provides no quantitative recommendations for dairy intake [19]. In contrast, the Dietary Guidelines for Americans explicitly recommend 3 servings of low- or no-fat dairy a day for adults and specify that plant-based dairy alternatives (e.g., almond, rice, coconut, oat, and hemp) are not included in the dairy group, except for fortified soy products [20]. However, neither recognizes recent evidence that full-fat dairy may be beneficial. Full-fat dairy was inversely associated with central obesity compared to low-fat dairy in a 12-year follow-up study within a male cohort [11]. Another 12-week study in individuals with metabolic syndrome found that 3-daily servings of either low-fat or high-fat dairy did not increase fasting serum cholesterol and triglycerides (TG) compared to a low dairy diet [12]. A 30-year study of the risk of dairy fats on type 2 diabetes in a cohort of Swedish adults reported that cream and butter intake were inversely related to the disease [21]. However, studies investigating the effects of long-term consumption of full-fat dairy on cardiometabolic health measures in metabolically healthy overweight and obese adults remain limited.

Therefore, the objective of this study was to describe the effect of regular consumption of three servings of full-fat dairy for 12 weeks in an energy-neutral and *ad libitum* diet compared to an energy-restricted diet by healthy overweight and obese adults while counselled to follow CFG. We hypothesized that adding three servings of full-fat dairy combined with counselling to follow the CFG would not adversely affect cardiometabolic biomarkers but would increase intake of limiting nutrients and decrease intake of food and beverages associated with chronic diseases.

METHODS

Study Design

A single-blinded, randomized, parallel, multi-site study was conducted at the University of Toronto (UofT) and Mount Saint Vincent University (MSVU). Block randomization was performed prior to recruitment on SAS version 9.4 (SAS Institute Inc., Cary, North Carolina, USA) by the study dietitian to generate a random allocation sequence stratified by sex with a block size of 12. Recruited participants were blinded of the dietary interventions and assigned to the next treatment group allocation in the sequence. Male and female participants (n=74 total) were randomized to one of the three diet intervention groups for 12 weeks: low-dairy energy restriction diet (LD-ER), 3-dairy energy neutral diet (3D-EN), and 3-dairy *ad libitum* diet (3D-AL). A registered dietitian counseled participants in the LD-ER to reduce their daily caloric intake by 500 kcal and to limit their consumption of dairy products to less than one serving per day, choosing low-fat dairy options or plant-based alternatives. Participants in the 3D-EN arm were counselled to add three servings of full-fat dairy to their daily diet, which was reduced by 500 kcal to be energy neutral. The 3D-AL group consumed three daily servings of full-fat dairy and received no advice about their caloric intake. The novelty of the design rested with the concurrent counselling of participants to adjust their diet to align with the 2019 CFG.

Participants attended biweekly study visits. At weeks 0 (baseline) and 12, all measures were taken including baseline and physical activity questionnaires, blood pressure, BW, height, WC, hip circumference (HC), body composition, blood sample, urine sample, resting metabolic rate (RMR), dietary history, food record, Knowledge, Attitudes and Practices (KAP) Questionnaire, and dairy log. At weeks 2, 6, and 10, baseline questionnaires, weight measurement, and dairy logs were completed. At weeks 4 and 8, physical activity questionnaire and blood and urine samples were collected. Three-day food records were completed at weeks 0, 4, and 8, while the Food Tracker was completed at weeks 2, 6, 10, and 12. Dietary counselling was provided at each visit with more in-depth sessions at weeks 0, 4, and 8 (**Table 1**). The experimental procedures were reviewed and approved by the Human Subject Review Committee at the UofT Ethics Review Office and the University Research Ethics Board at MSVU in Halifax. This study is registered on ClinicalTrials.gov as NCT04399460.

Participants

Healthy overweight to obese male and female adults between 25 to 60 years old with a body mass index (BMI) between 25 to 34.9 kg/m^2 were recruited through advertisements placed on the UofT and MSVU campuses, the Toronto Transit Commission subway, and online platforms including Reddit, Kijiji, and Facebook. Exclusion criteria included WC <88 cm for women or <102 cm for men, blood pressure >140/90 mmHg, fasting blood glucose >7 mmol/L, self-reported gastrointestinal symptoms to dairy, history of chronic illness or cardiometabolic disease, pregnant or lactating, menopausal or post-menopausal women, taking medications or supplements that would affect outcome measures, smokers, marijuana use more frequent than one to two times a month, and a history of consistent dieting.

The original sample size for this study, based on BW as the primary dependent measure, was 153 participants. This sample size was calculated with 124 participants being required to detect a difference of 2 kg change in BW between treatment groups with an estimated power level of 0.80 and an $\alpha = 0.05$, and accounting for a 15-20% dropout rate. Unfortunately, delays due to the COVID-19 pandemic allowed only 107 participants to be recruited and 74 to be completed for this study. Participant follow-up was conducted on an ongoing basis during in-person study sessions and between the weeks via email to ensure study compliance and their well-being. Participants were withdrawn from the study if they reported discomfort or distress with components of the study protocol.

Treatments

The dairy products used in the study were Neilson TruTaste Microfiltered Homogenized Milk (3.25% MF, Saputo Inc., Montréal, Quebec, Canada), Danone Oikos Greek Yogurt in assorted flavours (2% MF, Danone, Boucherville, Quebec, Canada), and Armstrong Cheese Sticks in assorted flavours (31% MF, Saputo Inc., Montréal, Quebec, Canada). Nutritional facts for the products are shown in **Table 2**. These products were selected based on fat content and availability in the marketplace. The initial yogurt selected for this study, Liberté Greek Yogurt with 35% Less Sugar (3% MF, Liberté Inc., Montréal, Quebec, Canada), was discontinued due to COVID-19. Three participants completed the remainder of the study with the Danone yogurt, which was similar in nutrient content. All dairy was purchased from the marketplace and provided to the participants during their study visits.

Participants were instructed to consume 250 mL of milk at breakfast with a serving of carbohydrates, one 100 g container of yogurt at lunch, and two 21 g cheese sticks, totalling 42 g of cheese, at dinner. They were advised to consume yogurt and cheese 7 to 10 minutes before a meal so that the first-phase insulin response would be present at the beginning of the meal. The dairy serving sizes were based on Health Canada's Reference Amounts of 250 mL for milk, 125 g for yogurt, and 30 g for cheese [22]. Two packages of cheese sticks provide similar protein (10 g) to the servings of milk and yogurt at 8 g. Participants were allowed to switch the order of yogurt and cheese consumption.

Experimental protocol

Participants arrived for their on-site visits between 8 and 10 AM following a 12-hour overnight fast with water allowed up to 1 hour before the visit. No strenuous physical activity or alcohol consumption was allowed 24 hours before. Upon arrival, participants completed questionnaires to assess the consistency of their activities for the past 24 hours and over the past month, including sleep, stress, alcohol consumption, and the previous day's food intake. The CSEP-PATH Physical Activity and Sedentary Behaviour Questionnaire was used to assess physical activity [23], [24]. During the COVID-19 pandemic, virtual sessions were held when in-person visits were not possible.

Blood glucose (BG) was measured on arrival through a finger prick sample using a handheld glucometer (Accu-Chek Aviva; Roche Diagnostics Canada, Laval, Quebec, Canada) to ensure that the participant was fasted. Intravenous blood samples were collected into 4 mL BD Vacutainer® K_2EDTA tubes (BD Diagnostics, Franklin Lakes, New Jersey, USA) at weeks 0 and 12 for HbA1c analysis, as well as 5 mL BD Vacutainer® SST™ II *Advance* tubes (BD Diagnostics, Franklin Lakes, New Jersey, USA) at weeks 0, 4, 8, and 12. The SST tube sample was allowed to clot before being centrifuged at 3600 RPM for 10 minutes at 4°C (Thermo Electron Corporation, Massachusetts, USA). A 500 μL serum sample was aliquoted into Eppendorf tubes for analysis of total cholesterol (TC), HDL cholesterol (HDL-C), non-HDL cholesterol (non-HDL-C), LDL cholesterol (LDL-C), and TG and stored at −80°C. A spot urine sample was also collected during the week 0, 4, 8, and 12 study visits with 1500 μL aliquoted into an Eppendorf tube for analysis of creatinine, urea, and a measure of protein intake. Samples collected at MSVU were frozen at −80°C and sent to UofT for storage and analysis. The blood and urine samples were analyzed by the Pathology and Laboratory Medicine Department at Mount Sinai Hospital (Toronto, Ontario, Canada) via clinical analyzer (Roche Diagnostics Canada, Laval, Quebec, Canada).

WC was measured at the top of the iliac crest and HC was measured at the maximum extension of the buttocks. Densitometry was measured via BOD POD (COSMED USA Inc., Chicago, Illinois, USA). Body composition values including percent fat mass (FM) and fat-free mass (FFM) were calculated using the Siri equation in the BOD POD program. RMR was measured via a metabolic cart (ParvoMedics Inc., Salt Lake City, Utah, USA). The measurement was 30 minutes long, with participants kept awake in a quiet, sedentary state for the duration. The first

10 minutes of the measurement were excluded from the analysis to allow for stabilization of the measures.

Participants completed the Dietary History Questionnaire (DHQ) II created by the US National Cancer Institute to indicate their past month's diet. A modified version was used, based on the Canadian DHQ-II and updates from the American DHQ-III of 2018 [25], [26]. The KAP questionnaire, designed following guidelines of the Food and Agriculture Organization, was used to obtain understanding and thoughts towards nutrition and the CFG [27]. Participants in the 3D-EN and 3D-AL groups also completed a dairy log every two weeks in which they documented the product flavour, time of consumption, and time of lunch and dinner to assess adherence with the dairy intervention.

Nutrition counseling was provided for 30 minutes at weeks 4 and 8, and for 10 minutes at weeks 2, 6, and 10. An explicit goal of the counseling was to encourage participants to utilize the CFG as their dietary guidance. Participants also completed three-day food records and food trackers over the 12-weeks and were taught how to use these tools by the study dietitian. These assessment tools provided information about the participants' eating patterns and adherence to the CFG recommendations [28]. The dietitian provided tailored guidance to adjust their diets to the study protocol.

Three-day food records were completed on weeks 0, 4, and 8 to assess nutrient intake. The participants recorded the amounts of all foods, snacks, and beverages consumed over 3 days, which included two non-consecutive weekdays and one weekend. Participants were instructed to be specific when recording the type of foods or beverage consumed and to include all parts of what was eaten including sauces and seasoning. Measuring cups and spoons were provided, and guidance to use a scale or the hand serving size guide was provided to help with estimating food amount [29]. Participants were also instructed to use standard measurement units (g, mL, cups, tbsp, etc.) and specify cooking method such as whether the food was raw, grilled, or fried. For products purchased or foods prepared at a restaurant, information about brand name, product type (e.g. “low fat”, “low sodium”, “sugar free”), restaurant name, and menu item were to be included.

The food trackers were collected on weeks 2, 6, 10, and 12 to assess food intake. These were simplified food records that documented participant intake by serving size for food categories determined based on the Healthy Eating Food Index and recommendations of the CFG[19], [30], [31]. All foods and drinks consumed were tracked for at least 7 days which did not have to be consecutive but included at least 2 weekend days. Participants recorded the number of servings in the appropriate category on the tracker. If a food item fit into multiple categories, it was listed in all of them. For example, a serving of salmon was recorded as a healthy fat and an animal-based protein. Complex foods were broken down into their main ingredients, such that a bowl of chicken noodle soup would be vegetables, chicken, white pasta, and butter. Seasonings and sauces were not tracked unless used in large quantities. Food skills including reading food labels, cooking at home, and using healthy cooking methods, were tracked, as well as the participant’s frequency of dining out. A table categorizing various foods and a hand serving size guide were provided to help participants [29].

Data analysis

Statistical analysis was conducted using SAS version 9.4. Three-way ANOVA was used to determine treatment, week, and sex effects on the dependent measures. Including sex as a factor ensured that potential variability due to sex was accounted for, while interpretation focused on treatment, week, and their interaction. Two-way ANOVA was used to determine treatment and sex differences in mean values. When sex was not a factor, it was removed from the statistical models. For assessing changes in outcome measures from weeks 0 to 12, a paired or one-sample t-test was used to determine the change within each treatment group. This was followed by a one-way ANOVA to compare the effect of treatment on the changes from baseline among the groups. KAP questionnaire responses provided on a scale of 0 (least) to 10 (most) were averaged for mean values, while Yes/No answers were tallied for qualitative questions. A paired t-test was used to compare week 0 and week 12 responses. Dairy logs were analyzed for treatment group and sex effects on compliance using two-way ANOVA. Food intake and weekly food skills usage were assessed based on data tabulated from the food trackers. Nutrient intake was calculated based on analysis of the 3-day food records obtained at baseline and weeks 4 and 8 using Cronometer (Cronometer Software Inc., Revelstoke, BC, CA). Nutrient intakes were calculated for protein, fat, calcium, magnesium, potassium, vitamins A, B2, B12, D, and total energy. Reported dietary intake was analyzed using three-way ANOVA to determine the effects of treatment, time, and sex. Two-way ANOVA was used to determine treatment and sex differences in averaged dietary intakes. Tukey-Kramer *post hoc* test was used to identify pairwise differences, with p-value <0.05 used to determine statistical significance.

RESULTS

Participant characteristics

Data collection was conducted from September 2020 to February 2023. Overall, 746 individuals were screened for eligibility. A total of 107 participants were enrolled, of which 74 participants completed the study from UofT (n=43) and from MSVU (n=31). The remaining 33 participants could not complete the entire study due to reasons including losses to follow-up, scheduling conflicts, discomfort with bloodwork, health issues, and non-compliance. However, data collected from the withdrawn participants were included if baseline data were available for the assessment of change. Missing data also required adjustments in the sample size of analysis for some outcome measures, outlined in **Figure 1**. The number of males and females was not evenly distributed.

Participants were 36.55 ± 1.04 years old with a BMI of 29.34 ± 0.43 kg/m^2. At baseline, glycemia (blood glucose: 5.43 ± 0.07 mmol/L; HbA1C: 5.33 ± 0.04%), cholesterol (total: 5.07 ± 0.11 mmol/L; LDL: 3.10 ± 0.10 mmol/L; HDL: 1.37 ± 0.04 mmol/L; non-HDL: 3.71 ± 0.11 mmol/L), TG (1.34 ± 0.08 mmol/L), and blood pressure (systolic: 118.77 ± 1.23 mmHg; diastolic: 72.55 ± 1.17 mmHg) were within clinically normal ranges. The baseline measurements were similar among treatment groups (p>0.20), but a sex difference was found. Males had higher baseline BW, height, BMI, blood pressure, waist-hip-ratio (WHR), FFM, RMR, and non-HDL-C. Females had higher baseline HDL-C and FM. Results are presented as means ± standard error of the mean (**Table 3**).

Anthropometric measures

There was a treatment effect found for BW (p=0.0064) but not time (p=0.92) or treatment-by-time interaction (p=0.07) effects over the 12 weeks (**Table 4**). The interaction approached statistical significance because there was a 0.35 ± 0.25 kg increase in the 3D-EN compared to a 0.69 ± 0.37 kg decrease in LD-ER (p<0.04) group with a 95% CI [-2.1, -0.06], regardless of time. The change in 3D-AL was a 0.14 ± 0.27 kg increase, which was not significantly different from the other treatment groups (Table 4**; Figure 2**). A treatment effect (p=0.0061) was found for BMI, but no week (p=0.93) or treatment-by-week interaction effects (p=0.09) were detected. Over 12 weeks, the decrease in BMI by -0.22 ± 0.12 kg/m^2 in LD-ER was different from the increase of 0.10 ± 0.08 kg/m^2 in 3D-EN (p=0.047; 95% CI [-0.7, -0.004]), but not from the 0.03

± 0.09 kg/m^2 increase in 3D-AL (p=0.18; 95% CI [-0.6, 0.09]), regardless of time (Table 4). Week 0 and 12 measures of BW and BMI were not different between the treatment groups (p>0.40). No differences between treatment groups (p>0.60) or change from week 0 to 12 (p>0.20) were found for WC, WHR, and waist-height ratio (WHtR; **Table 5**). However, HC was reduced from baseline by 0.25 ± 1.64 cm (p=0.048; 95% CI [0.008, 1.4]) and systolic blood pressure (SBP) by 2.72 ± 2.18 mmHg (p=0.04; 95% CI [0.2, 7.3]) in 3D-AL participants. In the LD-ER group, SBP was also reduced from baseline by 4.25 ± 2.20 mmHg (p=0.049; 95% CI [0.01, 7.6]). No treatment group differences were observed for the changes in HC (p=0.59) and SBP (p=0.09). There were no time (p>0.10) or treatment (p=0.99) effects for diastolic blood pressure (DBP) (Table 5). Males had higher WHR by 0.04 ± 0.14 (p<0.006), SBP by 9.58 ± 1.74 mmHg (p<0.0001), and DBP by 5.31 ± 1.76 mmHg (p<0.02) than females at week 12.

Body composition and metabolic rate

There was no treatment (p>0.40) or week 0 and 12 (p>0.10) differences in FM, FFM, and RMR (Table 5). Males had higher FFM and lower FM at week 12 than females by 8.31 ± 1.58 %, and higher RMR by 472.72 ± 10.85 kcal/day (p<0.0001).

Blood measures

There were no treatment group differences (p>0.50), changes from baseline (p>0.30), or treatment-by-week effects (p>0.30) for BG, LDL-C, HDL-C, non-HDL-C, and TC (Table 4**; Figure 3**). No treatment group (p=0.94) or week 0 and 12 differences (p>0.20) were found for HbA1C (Table 5). TG changes from baseline (p=0.01) existed, but no treatment group differences (p=0.40) or interaction effects (p=0.56) were found (Table 4; Figure 3). TG concentration increased from baseline at week 4 by 0.16 ± 0.06 mmol/L (p=0.049; 95% CI [-0.3,

-0.0004]). This change was different from the 0.01 ± 0.05 mmol/L decrease from baseline at week 12 (p=0.047; 95% CI [-0.3, -0.0001]). In 3D-EN, males had 0.26 ± 0.35 mmol/L greater increase in TG (p=0.018) and 0.08 ± 0.17 mmol/L greater decrease in HDL-C (p=0.030) than females. Mean TC in 3D-EN was also 0.69 ± 0.52 mmol/L higher for males than females (p=0.018).

No treatment (p>0.06), week (p>0.10), or treatment-by-week (p>0.06) differences were found for the changes from baseline in urinary creatinine, urea, urea-creatinine ratio (UCR) and protein intake-urea excretion ratio (PIUR). The mean changes from baseline in each treatment group are presented in Table 4.

Food intake

Data for the participants' food and beverage intake are presented in **Table 6**. There were no treatment (p=0.59), week (p=0.96), or treatment-by-week (p=0.53) effects in the changes from baseline in fruit and vegetable intake, but males had higher intakes than females by a mean of 0.35 ± 0.53 servings (p=0.044). Increased whole grain and decreased white and whole wheat intake occurred with time (p<0.0001), but there were no treatment group differences (p>0.90) or treatment-by-week effects (p>0.10). Whole grain consumption increased at all weeks in comparison to baseline by a mean of 0.38 ± 0.14 servings per day (p<0.001), except at weeks 3-4 and 7-8. White and whole wheat food consumption decreased (p<0.0001) by 2.7 ± 0.37 servings from baseline at the same weeks. Grain food intakes at weeks 3-4 and 7-8 were similar to week 0 and different from the other weeks (p<0.008).

Animal protein (p<0.0001) and ruminant meat (p=0.0043) intake decreased from baseline, but no treatment group (p>0.50) or treatment-by-week effects (p>0.10) existed. Daily consumption of animal protein foods decreased from week 0 by a mean of 1.68 ± 0.31 servings per day at weeks 1-2, 5-6, 9-10, and 11-12 (p<0.0005). Ruminant meat intake was lowered by 0.53 ± 0.18 servings at week 1-2 (p=0.0091) and by 0.43 ± 0.20 servings at week 11-12 (p=0.044). No treatment (p=0.36), week (p=0.055), or treatment-by-week (p=0.57) effects were observed for plant protein food consumption, but males had higher intake than females by 0.29 ± 0.28 servings (p=0.029).

Dairy intake was affected by treatment (p=0.0061), week (p<0.0001), and treatment-by-week (p=0.025) effects. There was a smaller average increase in dairy consumption in LD-ER (0.44 ±0.25 servings) than in 3D-EN (1.60 ± 0.26 servings; p<0.0001) and 3D-AL (1.51 ± 0.33 servings; p<0.001), which were similar. Overall, lower (p<0.0001) amounts of dairy foods were consumed in LD-ER (1.20 ± 0.08 servings) than 3D-EN (2.78 ± 0.09 servings) and 3D-AL (2.64 ± 0.11 servings). Consumption of dairy foods increased at all weeks in 3D-EN (p<0.005) and 3D-AL (p<0.002). There was a higher increase from baseline in 3D-EN than LD-ER at weeks 3-4, 5-6, 9-10, and 11-12 by a mean of 1.39 ± 0.80 servings (p<0.04). The change from baseline was also higher by 0.97 ± 0.74 servings at week 5+6 in 3D-AL than LD-ER (p=0.035).

Healthy fat foods decreased from week 0 by a mean of 0.82 ± 0.31 servings (p=0.0006) and intake of saturated fat foods decreased by 0.91 ± 0.38 servings (p<0.0001) at all weeks except week 3-4. No treatment group (p>0.50) or treatment-by-week (p>0.80) differences existed. Processed foods and confectionery and baked goods decreased by week (p=0.0041; p=0.014), but no treatment (p>0.20) or treatment-by-week interaction (p>0.10) effects were found. For processed foods, there was a decrease in daily intake at week 9-10 by 0.42 ± 0.15 servings (p=0.021) and week 11-12 by 0.39 ± 0.14 servings (p=0.031) compared to week 0. For confectionery foods and baked goods, consumption was lowered at week 9-10 by 0.54 ± 0.27 servings (p=0.04) and week 11-12 by 0.56 ± 0.27 servings (p=0.025) compared to baseline.

Change in water, sweetened beverage, and unsweetened plant-based beverage consumption was not affected by treatment ($p>0.10$), week ($p>0.05$) or treatment-by-week interactions ($p>0.40$). Unsweetened beverage intake decreased from week 0 at week 9-10 by 0.59 ± 0.23 servings per day ($p=0.019$) and week 11-12 by 0.55 ± 0.26 servings per day ($p=0.037$). There were significant changes from baseline ($p=0.0041$) in unsweetened beverage intake, but no treatment group ($p=0.24$) or treatment-by-week ($p=0.099$) differences. Alcohol consumption decreased by 0.26 ± 0.12 servings per day from baseline ($p=0.0079$) at week 7-8. In 3D-EN, the increase in consumption by 0.15 ± 0.23 servings at week 3-4 was significantly different from the decrease at week 7-8 by 0.37 ± 0.30 servings ($p=0.044$). There were no treatment effects ($p=0.79$) on the changes in alcohol intake, but significant week ($p=0.013$) and treatment-by-week ($p<0.04$) differences were found.

Weekly food skills

Treatment group differences ($p>0.10$), changes over time ($p>0.10$), and treatment-by-week interaction effects ($p>0.09$) were not found for the usage of food skills. On average, participants reported reading food labels 2.79 ± 0.33 times, eating out 2.46 ± 0.18 times, eating home-cooked meals 12.04 ± 0.49 times, and utilizing healthy cooking methods 9.22 ± 0.49 times each week (**Table 7**). There was a sex difference ($p=0.043$) in the reading of food labels over the 12 weeks, with males using them 0.48 ± 0.35 times fewer than at first assessment (week 1-2) and females using them 0.98 ± 0.36 times more.

Daily nutrient intake

Mean daily intake of nutrients is presented in **Table 8** ($n=72$). For energy, treatment ($p=0.0033$) and treatment-by-week ($p=0.014$) but not week ($p=0.36$) differences were found for the changes from baseline. The change in energy intake was different between LD-ER and 3D-EN, with a mean 212.52 ± 82.96 kcal decrease in LD-ER compared to a 293.96 ± 97.19 kcal increase in 3D-EN (p=0.0024). The mean change in 3D-AL by 86.17 ± 137.32 kcal was not different from the other groups. At week 8, energy intake decreased (p=0.04) in LD-ER by 249.65 ± 116.56 kcal from baseline compared to 3D-EN, which increased (p=0.0037) by 432.16 ± 131.69 kcal (p=0.013). No differences were found at week 4. Average total daily energy intake was lower in LD-ER (1939.95 ± 64.36 kcal) than 3D-EN (2246.27 ± 78.87 kcal; p<0.001) and 3D-AL (2162.41 ± 100.24 kcal; p=0.016), which were similar. Males consumed 571.8 ± 10.95 kcal more calories each day than females (p=0.0012).

Protein intake was affected by week (p=0.0018) and treatment-by-week (p=0.032) interaction, but not by treatment (p=0.059). Mean total protein intake was higher (p=0.017) in 3D-EN (102.98 ± 4.77 g) than LD-ER (93.13 ± 3.86 g). Average intake in 3D-AL was 103.41 ± 7.58 g but not statistically different from the other groups (p=0.083). Females had 30.55 ± 2.69 g lower intake than males (p=0.0056). The interaction between treatment and time is explained by the following. The change at week 8 (+18.29 ± 7.01 g) was different from baseline (p=0.0012) and the change at week 4 (+6.44 ± 4.45 g; p=0.041). In 3D-AL, intake increased by 10.29 ± 4.18 g at week 4 compared to week 0 (p=0.036). In 3D-EN, there was a significant increase by 35.04 ± 8.18 g at week 8 from baseline (p=0.012). There was also a significant difference in the change at week 8 between LD-ER which decreased by 2.14 ± 9.42 g and 3D-EN (p=0.017).

Fat intake was not impacted by treatment (p=0.084) and week (p=0.087) effects, but there were treatment-by-week interactions (p=0.037). At week 8, there was a significant increase in fat intake by 31.14 ± 6.14 g from baseline (p<0.001) in 3D-EN, but no significant changes from baseline were found in other treatment groups. This week 8 increase in 3D-EN was different from the decrease by 4.84 ± 10.60 g in LD-ER (p=0.0079). The average daily fat intake in LD-ER (91.13 ± 5.84 g) was lower (p<0.03) than 3D-EN (97.63 ± 4.55 g) but not different from 3D-AL (89.43 ± 4.80 g).

Calcium intake was significantly affected by treatment (p=0.0009), week (p=0.0013), and treatment-by-week (p=0.014) effects. There was a mean increase by 506.59 ± 176.52 mg in 3D-AL which was different from the 20.32 ± 57.91 mg decrease observed in LD-ER (p=0.0013). The mean increase in 3D-EN by 284.96 ± 59.94 mg was intermediate. The mean increase in calcium intake at week 4 by 180.49 ± 41.39 mg was not significantly different from baseline (p=0.056), but the increase by 236.66 ± 70.41 mg in 3D-EN (p=0.0028) and by 371.74 ± 60.37 mg in 3D-AL (p<0.0001) were significant and were different (p=0.0006) from the change in LD-ER. A significant increase from baseline in calcium intake by 276.79 ± 120.46 mg was observed at week 8 (p=0.001). This week 8 change was significantly different (p=0.0002) between the LD-ER and 3D-AL groups, with a 47.67 ± 77.62 mg decrease in LD-ER and a 758.59 ± 417.01 mg increase in 3D-AL. Overall, daily calcium intake was significantly higher in 3D-EN (1100.10 ± 45.20 mg; p=0.045) and 3D-AL (1120.50 ± 137.53; p=0.0004) than LD-ER (760.28 ± 40.57 mg).

No treatment group differences (p>0.08), changes from baseline (p>0.06), or treatment-by-week interaction effects (p>0.20) were found for the changes from baseline in vitamin A, B2, B12 and D, as well as magnesium and potassium intakes. However, single-factor analyses presented in table 8 showed significant increases in vitamin D intake in 3D-EN by 91.60 ± 32.51 IU at week 4 (p=0.01) and by 117.10 ± 51.58 IU at week 8 (p=0.034). The increase at week 8 in 3D-EN by 117.10 ± 51.58 IU was different from the decrease by 79.81 ± 106.92 IU in LD-ER (p=0.0021). Magnesium intake increased by 66.04 ± 27.07 mg at week 4 (p=0.023) while potassium intake increased by 643.71 ± 252.21 mg at week 8 (p=0.019) in 3D-EN. There was a greater increase in potassium intake in 3D-EN by 561.73 ± 406.74 mg during week 4 than in LD-ER and 3D-AL, which had comparable intakes (p=0.0025). Figure 4 shows the mean changes in daily energy and selected nutrient intakes (protein, fat, calcium, and vitamin D) from baseline to week 8 by treatment group.

Dietary compliance and nutrition knowledge

The mean compliance with dairy consumption over the 12 weeks was 79.9 ± 3.2%, with 58.5 ± 4.7% consumed within the correct 7-10 min time window (n=49). The compliance was 78.8 ± 1.8% for milk and 70.3 ± 1.7% for cheese and yogurt. There were no significant differences in compliance between the dairy treatment groups (p>0.60) or sexes (p>0.50). Adherence to dairy servings remained consistent across the 12-week intervention, with no significant effect of week (p = 0.67). In contrast to week 0 (rating of 3.36 ± 0.39 on a 10-point scale), participants at week 12 reported greater understanding of the CFG (6.83 ± 0.23; p<0.0001) and how to apply it in their daily lives. The reported level of knowledge of the food guide was 7.54 ± 0.19 at week 12. While only 32% of the participants were aware of the release of the new 2019 food guide at the start of the study, 92% believed it was essential to learn about it at the end. At week 12, there was a 77% compliance rate with the dietary recommendations provided (5.4 ± 0.12 days a week), and 94% were willing to continue the dietary recommendations they received beyond the study (n=67; **Table 9**).

DISCUSSION

The results support our hypothesis that adding three servings of full-fat dairy combined with counselling to follow the CFG would not adversely affect the blood biomarkers of chronic disease but would increase intake of limiting nutrients and decrease intake of food and beverages associated with chronic diseases. They provide evidence that three servings of full-fat dairy can be accommodated in the diet of Canadians, within the context of the Canadian Food Guide. Three daily servings of full-fat dairy did not increase BMI, weight, body fat, HbA1C, blood glucose, or lipids over 12 weeks, when compared with an energy-restricted diet with low dairy consumption. Reductions in systolic blood pressure and HC, as well as higher limiting nutrient intakes were found in the dairy consuming groups, while all participants made dietary changes in accordance with CFG over the 12 weeks.

Adherence to the treatments and dietary guidance was shown by several lines of evidence. The overall adherence to dairy intake was high (79%), meeting our target of 3 servings in the high dairy groups and 1 serving in the low dairy group. Adherence to dietary counselling was indicated by increases and decreases in intake of foods and beverages as recommended by CFG and dietary guidance. The LD-ER group achieved an average decrease of 213 kcals rather than the intended 500 kcals. BW and BMI decreased in the LD-ER group when compared with the 3D-EN group.

In the 3D-EN group, energy neutrality was not achieved and was reflected in the small weight increase compared to the LD-ER group. HC was lower than baseline at week 12 in 3D-AL and BW and BMI did not change, indicating that appetite regulation adjusted for the additions. The functionality of the dairy matrix with complex binding of fat, protein, lactose, calcium and other nutrients may explain why participants did not gain weight despite a marked increase in full-fat dairy consumption [32]. Dairy protein, fats and calcium have unique metabolic and physiological properties. In a comparison of the effects of individual macro-components of dairy with whole milk on metabolic hormone responses, the effects of the whole were proven to be more than simply a sum of its components [33]. As well, the extra fats and proteins provided by dairy may lead to a satiating effect as those on the *ad libitum* diet did not have substantially higher energy intake than those on the energy-neutral diet despite their caloric freedom. Previous studies have also demonstrated the role of dairy in reducing hunger and food intake [34], [35], [36].

Body composition was not different among the treatment groups. Consistent with no effect on FFM was the absence of change over time in RMR or creatinine excretion [37], [38]. Similarly, a crossover study involving a 6-month intervention of a high (≥4 servings/day) and low (≤1 serving/day) dairy diet in overweight and obese adults found an increase in weight during the high dairy phase consistent with an initial higher energy intake, but overall, no final group differences in body weight, fat, BMI, WC, HC, body composition and RMR [39]. In contrast, a meta-analysis of randomized control trials showed that adding 2-4 daily servings of dairy to the diets of overweight/obese adults resulted in greater fat mass loss and 75% higher lean mass retention in comparison to low dairy control diets, possibly explained by higher protein, calcium, and medium-chain triglycerides intakes which have roles in regulating energy metabolism and satiety [9].

The lower SBP in LD-ER and 3D-AL groups at the end of the study is also consistent with other reports, suggesting that further exploration of the effect of dairy fat and full-fat dairy on blood pressure regulation is merited [40], [41]. Furthermore, although the Dietary Approaches to Stop Hypertension diet recommends 2 servings of low-fat dairy each day, a 12-week study of adults with metabolic syndrome found a SBP reduction in the group with 3 daily servings of low-fat dairy [12], [42].

Dietary counselling to encourage the participants to follow CFG was effective. Over the course of 12 weeks, the participants received a total of 120 minutes of nutrition counselling. It led to a doubling in the understanding and application of the CFG by the end of the study, whereby 94%

of participants expressed willingness to continue the recommended eating pattern in the future. The dietary shifts aligned with the CFG, including an increase in whole grains and a decrease in animal proteins, ruminant meats, fats, processed and confectionery foods, unsweetened beverages, and alcohol. The CFG recommends consuming half of grain foods as whole grains, reducing animal-based foods, limiting fat intake to 2-3 tbs of unsaturated fats, eliminating processed and confectionery foods, and selecting water as the drink of choice [19], [31]. However, participants did not increase their fruit and vegetable intake, nor their intake of plant proteins. Overall, participants consumed fewer than 4 servings of fruits and vegetables and plant protein foods instead of the recommended 7-10 servings per day, comparable to the national average of 4.5 servings per day [31], [43]. Males consumed more servings of fruits and vegetables and plant proteins in this study than females, which may be associated with their overall higher energy intake rather than choice. In addition, there were no improvements in food skills [19]. Although participants reported eating home-cooked meals an average of 83% of the time, they need encouragement to improve cooking methods and to read food labels.

During the first 8 weeks of the study, increases in the intakes of energy, protein, fat, calcium, vitamin D, potassium, and magnesium were seen amongst the dairy consuming participants but not in the LD-EN group. However, differences in protein intake were not reflected in urea excretion, which was similar for all groups. This can be explained by the use of single spot-check samples of urine collected from fasted participants attending the research center. Urinary nitrogen output reflects up to 80% of dietary protein intake, based on 24-hour urine nitrogen output over several days [44]. Fat accounted for 42% of daily calories in the low dairy group and 38% in the high dairy groups, above the recommended 20-35% [45].

The dairy groups increased their average intake of calcium above the recommended target of 1000mg, whereas the LD-ER each day averaged only 760 mg per day [46]. Calcium consumption was 1120 mg in 3D-AL and averaged 1110 mg per day in the high dairy consuming groups. There were no significant changes in vitamin A, B2, and B12 intakes over the timeframe of the study. Despite the mandatory fortification of milk with vitamin D in Canada, intakes were below the Recommended Dietary Allowance of 600 IU. However, as of 2022, the fortification requirement of vitamin D in milk has been doubled to 2 μg per 100 ml, and voluntary fortification of yogurt and kefir has also been permitted. When applied by 2025, this will increase the effectiveness of dairy to meet vitamin D requirements [47]. Magnesium and potassium intakes were below the daily dietary allowance before the study, but intake increased to meet the requirement for females in the 3D-EN and 3D-AL groups, respectively [48].

The strength of the results of this study for application to Canadian dietary recommendations resides with the novel approach of adding three servings of dairy to the diets of obese and overweight participants who made adjustments in their diets that were consistent with CFG. The results align with the conclusion of an expert group that there is no evidence to support the avoidance of high-fat dairy in diets [18].

The weakness of this study was presented by the COVID-19 limitations on the recruitment of the targeted sample size of 50 participants per group, the carryout of the study length of 24 weeks, and the termination of funding due to government timelines. Nevertheless, the achieved sample size provides sufficient evidence to justify a repeat study of a larger sample size and duration. It was sufficiently powered to detect changes in fasting BG, lipids, and HbA1c over 12 weeks [49], [50]. However, the short duration of the study may have masked longer-term changes in these measures and in BMI and body composition as well.

Another limitation of the present study is that circulating fatty acid profiles were not assessed. Specific bioactive fatty acids found in dairy fat, including conjugated linoleic acid (CLA), vaccenic acid, and long-chain n-3 fatty acids such as DHA, have been shown in controlled interventions to influence lipid metabolism beneficially [51], [52]. Future studies that include detailed fatty acid profiling may provide mechanistic insights into the cardiometabolic effects of dairy consumption.

SUMMARY. This study examined the long-term metabolic and nutritional impacts of regular consumption of full-fat dairy accompanied by dietary counselling to follow Canada's Food Guide. We found that consuming 3 daily servings of full-fat dairy did not lead to increases in weight, body fat, HbA1C, blood glucose or lipids when compared with an energy-restricted diet with low dairy consumption. Improvements in systolic blood pressure, hip circumference, BMI, and potentially limiting nutrient intakes were found in the dairy consuming groups, while all participants made dietary changes in accordance with the food guide over the 12 weeks.

CONCLUSION

Three daily servings of full-fat dairy can be accommodated by Canada's Food Guide 2019 and play a supportive role in meeting dietary recommendations and requirements.

ACKNOLWEDGEMENTS

We would like to thank our UofT research assistants Jake Seo, Emily Yang, Jasmine Wong, and Jacqueline Wong, as well as members from MSVU including Erik VanDenboer, Megan Churchill, Duygu Gunaydin, and Gowshigga Thamotharampillai for their endless support in the completion of this study. We would also like to thank Homa Bondar and Sandy Soufivand at the Mount Sinai Hospital and Dr. Camilla Parzanini from UofT for conducting the blood analysis.

We declare the following contributions of authors: GHA, HF, and BL designed research; MS, LC, and MA conducted research; SV, PK, and FS provided support and oversight for data collection; CZZ, MS, and SV analyzed data; GHA, CZZ, SV, and MS wrote paper; SS edited paper; GHA had primary responsibility for final content. All authors have read and approved the final manuscript.

Author Disclosures: The authors disclose no conflicts of interests.

Data Availability: Data described in the manuscript, code book, and analytic code will be made available upon request pending (e.g. application and approval, payment, other).

Funding: This research was supported by Dairy Research Cluster 3 (Dairy Farmers of Canada and Agriculture and Agri-Food Canada) under the Canadian Agricultural Partnership AgriScience Program, and the Mitacs Accelerate program. The supporting sources were not involved and presented no restrictions in the publication of this research.

REFERENCES

[1] Public Health Agency Canada, “Heart Disease in Canada.” Accessed: Feb. 27, 2025. [Online]. Available: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/heart-disease-canada.html

[2] Obesity Canada, “Cost of Inaction on Obesity,” Obesity Canada. Accessed: Feb. 27, 2025. [Online]. Available: https://obesitycanada.ca/understanding-obesity/cost-of-inaction/

[3] E. Lytvyak, S. Straube, R. Modi, and K. K. Lee, “Trends in obesity across Canada from 2005 to 2018: a consecutive cross-sectional population-based study,” *Can. Med. Assoc. Open Access J.*, vol. 10, no. 2, pp. E439–E449, Apr. 2022, doi: 10.9778/cmajo.20210205.

[4] F. Lopez-Jimenez *et al.*, “Obesity and cardiovascular disease: mechanistic insights and management strategies. A joint position paper by the World Heart Federation and World Obesity Federation,” *Eur. J. Prev. Cardiol.*, vol. 29, no. 17, pp. 2218–2237, Nov. 2022, doi: 10.1093/eurjpc/zwac187.

[5] S. Wharton *et al.*, “Obesity in adults: a clinical practice guideline,” *Can. Med. Assoc. J.*, vol. 192, no. 31, pp. E875–E891, Aug. 2020, doi: 10.1503/cmaj.191707.

[6] J.-P. Després, “Body fat distribution and risk of cardiovascular disease,” *Circulation*, vol. 126, no. 10, pp. 1301–1313, Sept. 2012, doi: 10.1161/CIRCULATIONAHA.111.067264.

[7] Agriculture and Agri-Food Canada, “Canada’s dairy industry at a glance.” Accessed: Feb. 27, 2025. [Online]. Available: https://agriculture.canada.ca/en/sector/animal-industry/canadian-dairy-information-centre/dairy-industry
[8] C. J. Cifelli, “Looking beyond traditional nutrients: the role of bioactives and the food matrix on health,” *Nutr. Rev.*, vol. 79, no. Suppl 2, pp. 1–3, Dec. 2021, doi: 10.1093/nutrit/nuab100.
[9] W. Stonehouse, T. Wycherley, N. Luscombe-Marsh, P. Taylor, G. Brinkworth, and M. Riley, “Dairy Intake Enhances Body Weight and Composition Changes during Energy Restriction in 18–50-Year-Old Adults—A Meta-Analysis of Randomized Controlled Trials,” *Nutrients*, vol. 8, no. 7, p. 394, July 2016, doi: 10.3390/nu8070394.
[10] A. R. Josse, S. A. Atkinson, M. A. Tarnopolsky, and S. M. Phillips, “Increased Consumption of Dairy Foods and Protein during Diet- and Exercise-Induced Weight Loss Promotes Fat Mass Loss and Lean Mass Gain in Overweight and Obese Premenopausal Women1234,” *J. Nutr.*, vol. 141, no. 9, pp. 1626–1634, Sept. 2011, doi: 10.3945/jn.111.141028.
[11] S. Holmberg and A. Thelin, “High dairy fat intake related to less central obesity: A male cohort study with 12 years’ follow-up,” *Scand. J. Prim. Health Care*, vol. 31, no. 2, pp. 89–94, June 2013, doi: 10.3109/02813432.2012.757070.
[12] K. A. Schmidt *et al.*, “Impact of low-fat and full-fat dairy foods on fasting lipid profile and blood pressure: exploratory endpoints of a randomized controlled trial,” *Am. J. Clin. Nutr.*, vol. 114, no. 3, pp. 882–892, July 2021, doi: 10.1093/ajcn/nqab131.
[13] N. Islam, M. Shafiee, and H. Vatanparast, “Trends in the consumption of conventional dairy milk and plant-based beverages and their contribution to nutrient intake among Canadians,” *J. Hum. Nutr. Diet. Off. J. Br. Diet. Assoc.*, vol. 34, no. 6, pp. 1022–1034, Dec. 2021, doi: 10.1111/jhn.12910.
[14] Statistics Canada, “Changes in Canadians’ preferences for milk and dairy products.” Accessed: Feb. 27, 2025. [Online]. Available: https://www150.statcan.gc.ca/n1/pub/21-004-x/2017001/article/14786-eng.htm
[15] Agri-Food Innovation Council, “Plant protein industry market analysis summary,” Mar. 2019. Accessed: Feb. 27, 2025. [Online]. Available: https://nrc.canada.ca/sites/default/files/2019-10/Plant_protein_industry_market_analysis_summary.pdf
[16] G.-C. Chen *et al.*, “Dairy products consumption and metabolic syndrome in adults: systematic review and meta-analysis of observational studies,” *Sci. Rep.*, vol. 5, no. 1, p. 14606, Sept. 2015, doi: 10.1038/srep14606.
[17] K. B. Comerford, G. D. Miller, A. C. Boileau, S. N. Masiello Schuette, J. C. Giddens, and K. A. Brown, “Global Review of Dairy Recommendations in Food-Based Dietary Guidelines,” *Front. Nutr.*, vol. 8, May 2021, doi: 10.3389/fnut.2021.671999.
[18] B. Lamarche *et al.*, “Regular-fat and low-fat dairy foods and cardiovascular diseases: perspectives for future dietary recommendations,” *Am. J. Clin. Nutr.*, vol. 121, no. 5, pp. 956–964, May 2025, doi: 10.1016/j.ajcnut.2025.03.009.
[19] Health Canada, “Canada’s Dietary Guidelines for Health Professionals and Policy Makers,” Health Canada, Jan. 2019.
[20] USDA, “Dietary Guidelines for Americans, 2020-2025,” Dec. 2020.
[21] S. Zhang *et al.*, “Dairy intake, plasma metabolome, and risk of type 2 diabetes in a population-based cohort,” *Am. J. Clin. Nutr.*, vol. 121, no. 5, pp. 1137–1148, May 2025, doi: 10.1016/j.ajcnut.2025.02.023.

[22] Health Canada, “Nutrition Labelling - Table of Reference Amounts for Food.” Accessed: July 19, 2023. [Online]. Available: https://www.canada.ca/en/health-canada/services/technical-documents-labelling-requirements/table-reference-amounts-food/nutrition-labelling.html
[23] CSEP, “CSEP-PATH: Physical activity and seedentary behaviour questionnaire (PASB-Q).” Accessed: Feb. 27, 2025. [Online]. Available: https://fitnessandhealthpromotion.ca/wp-content/uploads/2016/01/Phyiscal-Activity-and-Sedentary-Behaviour-Questionnaire-Adult.pdf
[24] J. R. Fowles, M. W. O’Brien, W. R. Wojcik, L. d’Entremont, and C. A. Shields, “A pilot study: Validity and reliability of the CSEP-PATH PASB-Q and a new leisure time physical activity questionnaire to assess physical activity and sedentary behaviours,” *Appl. Physiol. Nutr. Metab. Physiol. Appl. Nutr. Metab.*, vol. 42, no. 6, pp. 677–680, June 2017, doi: 10.1139/apnm-2016-0412.
[25] National Cancer Institute, “Diet History Questionnaire II (DHQ II) for U.S. and Canada.” Accessed: Feb. 27, 2025. [Online]. Available: https://epi.grants.cancer.gov/dhq2/
[26] National Cancer Institute, “Diet History Questionnaire III (DHQ III).” Accessed: Feb. 27, 2025. [Online]. Available: https://epi.grants.cancer.gov/dhq3/
[27] Y. Fautsch Macías and P. Glasauer, *Guidelines for assessing nutrition-related knowledge, attitudes and practices: KAP manual*. Rome: FAO, 2014.
[28] Health Canada, “Canada’s Dietary Guidelines,” Canada Food Guide. Accessed: Feb. 27, 2025. [Online]. Available: https://food-guide.canada.ca/en/guidelines/
[29] Unlock Food, “Handy guide to servings sizes.” Accessed: Feb. 27, 2025. [Online]. Available: https://www.unlockfood.ca/EatRightOntario/media/PDFs-new-website/Portions%20Toolkit/Handy-Servings-Guide-EN-v04a-July-2018.pdf
[30] D. Brassard *et al.*, “Development of the Healthy Eating Food Index (HEFI)-2019 measuring adherence to Canada’s Food Guide 2019 recommendations on healthy food choices,” *Appl. Physiol. Nutr. Metab.*, vol. 47, no. 5, pp. 595–610, May 2022, doi: 10.1139/apnm-2021-0415.
[31] Health Canada, “Eating well with Canada’s food guide: A resource for educators and communicators.” Accessed: Feb. 27, 2025. [Online]. Available: https://publications.gc.ca/collections/collection_2012/sc-hc/H164-38-2-2011-eng.pdf
[32] E. L. Feeney and M. C. McKinley, “The dairy food matrix: what it is and what it does,” in *Milk and dairy foods: their functionality in human health and disease*, I. Givens, Ed., Academic Press, 2020, pp. 205–225. doi: 10.1016/B978-0-12-815603-2.00008-5.
[33] S. Panahi *et al.*, “Mechanism of action of whole milk and its components on glycemic control in healthy young men,” *J. Nutr. Biochem.*, vol. 25, no. 11, pp. 1124–1131, Nov. 2014, doi: 10.1016/j.jnutbio.2014.07.002.
[34] S. Vien, S. Fard, D. El Khoury, B. Luhovyy, H. Fabek, and G. H. Anderson, “Age and Sex Interact to Determine the Effects of Commonly Consumed Dairy Products on Postmeal Glycemia, Satiety, and Later Meal Food Intake in Adults,” *J. Nutr.*, vol. 151, no. 8, pp. 2161–2174, Aug. 2021, doi: 10.1093/jn/nxab122.
[35] S. Onvani, F. Haghighatdoost, P. J. Surkan, and L. Azadbakht, “Dairy products, satiety and food intake: A meta-analysis of clinical trials,” *Clin. Nutr. Edinb. Scotl.*, vol. 36, no. 2, pp. 389–398, Apr. 2017, doi: 10.1016/j.clnu.2016.01.017.

[36] J.-A. Gilbert *et al.*, “Milk supplementation facilitates appetite control in obese women during weight loss: a randomised, single-blind, placebo-controlled trial,” *Br. J. Nutr.*, vol. 105, no. 1, pp. 133–143, Jan. 2011, doi: 10.1017/S0007114510003119.
[37] E. Gitsi, A. Kokkinos, S. K. Konstantinidou, S. Livadas, and G. Argyrakopoulou, “The Relationship between Resting Metabolic Rate and Body Composition in People Living with Overweight and Obesity,” *J. Clin. Med.*, vol. 13, no. 19, p. 5862, Oct. 2024, doi: 10.3390/jcm13195862.
[38] G. Forbes and G. Bruining, “Urinary creatinine excretion and lean body mass,” *Am. J. Clin. Nutr.*, vol. 29, no. 12, pp. 1359–1366, Dec. 1976, doi: 10.1093/ajcn/29.12.1359.
[39] G. E. Crichton, P. R. C Howe, J. D. Buckley, A. M. Coates, and K. J. Murphy, “Dairy consumption and cardiometabolic health: outcomes of a 12-month crossover trial,” *Nutr. Metab.*, vol. 9, no. 1, p. 19, Mar. 2012, doi: 10.1186/1743-7075-9-19.
[40] M. M. McGrane *et al.*, “Dairy Consumption, Blood Pressure, and Risk of Hypertension: An Evidence-Based Review of Recent Literature,” *Curr. Cardiovasc. Risk Rep.*, vol. 5, no. 4, pp. 287–298, Aug. 2011, doi: 10.1007/s12170-011-0181-5.
[41] A. A. Al Attar *et al.*, “Mechanisms underlying the effects of caloric restriction on hypertension,” *Biochem. Pharmacol.*, vol. 200, p. 115035, June 2022, doi: 10.1016/j.bcp.2022.115035.
[42] H. J. Challa, M. A. Ameer, and K. R. Uppaluri, “DASH Diet To Stop Hypertension,” in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2025. Accessed: Feb. 28, 2025. [Online]. Available: http://www.ncbi.nlm.nih.gov/books/NBK482514/
[43] J. Y. Polsky and D. Garriguet, “Change in vegetable and fruit consumption in Canada between 2004 and 2015,” *Health Rep.*, vol. 31, no. 4, pp. 3–12, June 2020, doi: 10.25318/82-003-x202000400001-eng.
[44] S. A. Bingham, “Urine Nitrogen as a Biomarker for the Validation of Dietary Protein Intake,” *J. Nutr.*, vol. 133, no. 3, pp. 921S-924S, Mar. 2003, doi: 10.1093/jn/133.3.921S.
[45] Health Canada, “Dietary reference intakes tables: Reference values for macronutrients.” Accessed: Mar. 26, 2025. [Online]. Available: https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/dietary-reference-intakes/tables/reference-values-macronutrients.html
[46] Health Canada, “Dietary reference intakes tables: Reference values for elements.” Accessed: Apr. 02, 2025. [Online]. Available: https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/dietary-reference-intakes/tables/reference-values-elements.html
[47] Canadian Food Inspection Agency, “Fortification of food.” Accessed: Mar. 25, 2025. [Online]. Available: http://inspection.canada.ca/en/food-labels/labelling/industry/fortification
[48] Health Canada, “Dietary reference intakes tables: Reference values for vitamins.” Accessed: Apr. 02, 2025. [Online]. Available: https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/dietary-reference-intakes/tables/reference-values-vitamins.html
[49] Y. J. Lee *et al.*, “Effects of low-fat milk consumption on metabolic and atherogenic biomarkers in Korean adults with the metabolic syndrome: a randomised controlled trial,” *J. Hum. Nutr. Diet. Off. J. Br. Diet. Assoc.*, vol. 29, no. 4, pp. 477–486, Aug. 2016, doi: 10.1111/jhn.12349.

[50] L. Agerholm-Larsen, A. Raben, N. Haulrik, A. S. Hansen, M. Manders, and A. Astrup, “Effect of 8 week intake of probiotic milk products on risk factors for cardiovascular diseases,” *Eur. J. Clin. Nutr.*, vol. 54, no. 4, pp. 288–297, Apr. 2000, doi: 10.1038/sj.ejcn.1600937.
[51] S. Pintus *et al.*, “Sheep cheese naturally enriched in α-linolenic, conjugated linoleic and vaccenic acids improves the lipid profile and reduces anandamide in the plasma of hypercholesterolaemic subjects,” *Br. J. Nutr.*, vol. 109, no. 8, pp. 1453–1462, Apr. 2013, doi: 10.1017/S0007114512003224.
[52] E. Murru *et al.*, “Dietary Conjugated Linoleic Acid-Enriched Cheeses Influence the Levels of Circulating n-3 Highly Unsaturated Fatty Acids in Humans,” *Int. J. Mol. Sci.*, vol. 19, no. 6, p. 1730, June 2018, doi: 10.3390/ijms19061730.

TABLES

Table 1. Study protocol completion timepoints.

	Week						
	0	2	4	6	8	10	12
Completed During Study Sessions							
Baseline Questionnaire	•	•	•	•	•	•	•
Physical Activity Questionnaire	•		•		•		•
Blood Pressure	•						•
Weight	•	•	•	•	•	•	•
Height	•						•
Finger Prick Blood Glucose Sample	•		•		•		•
Venous Blood Sample	•		•		•		•
Spot Urine Sample	•		•		•		•
Waist and Hip Circumference	•						•
BOD POD	•						•
Metabolic Cart	•						•
Dietary History Questionnaire II	•						•

Knowledge, Attitudes, Practices Questionnaire	•						•
Nutrition Counselling							
30 to 40 minutes	•		•		•		
10 minutes		•		•		•	
Completed Between Study Sessions							
3-Day Food Record	•		•		•		
Food Tracker		•		•		•	•
Dairy Log[1]	•	•	•	•	•	•	•

[1]Only completed by participants in the 3D-EN and 3D-AL groups.

Table 2. Nutrient composition of dairy treatments.

	Treatments[1]													
	Milk[2]	Cheese Sticks[4]		Previous Yogurt[5]	Yogurt[6]									
		A	B		A	B	C	D	E	F	G	H	I	J
Weight (g)	258[3]	21	21	100	100	100	100	100	100	100	100	100	100	100
Energy (kcal)	160	80	80	80	70	80	90	90	90	90	90	90	90	90
Total Fat (g)	8	7	7	2.5	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Saturated Fat (g)	5	4.5	4.5	1.5	1.5	1	1	1	1	1	1	1	1	1
Trans Fat (g)	0.2	0.2	0.2	0.1	0	0	0	0	0	0	0	0	0	0
Cholesterol (mg)	30	20	20	10	10	10	10	10	10	10	10	10	10	10
Sodium (mg)	125	130	150	35	30	25	25	30	25	30	35	30	40	50
Carbohydrates (g)	12	1	1	7	4	9	11	11	11	11	11	12	12	12
Fibre (g)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sugars (g)	12	0	0	6	3	7	9	9	10	10	10	10	10	10
Protein (g)	8	5	5	8	9	8	8	8	8	8	8	8	8	8
Calcium (mg)	330	110	110	88	100	75	75	75	75	75	75	75	75	75

[1]Data provided by manufacturer from nutrition facts table on packaging.

[2]Neilson TruTaste Microfiltered Homogenized Milk (3.25% MF), Saputo Inc., Montréal, Quebec, Canada.

[3]Weight based on 250ml of milk.

[4]Armstrong Cheese Sticks (31% MF), Saputo Inc., Montréal, Quebec, Canada.

A: Garden Herbs and Old Cheddar flavours

B: Marble Cheddar flavour

[5]Liberté Greek Yogurt at 35% Less Sugar (3% MF), Mango, Raspberry, and Vanilla flavour, Liberté Inc., Montréal, Quebec, Canada. Discontinued during the study, as of spring 2022.

[6]Danone Oîkos Greek Yogurt (2% MF), Danone, Boucherville, Quebec, Canada. Replacement yogurt used in the study, as of spring 2022.

A: Plain flavour

B: Blueberry flavour

C: Banana, Blackberry, and Vanilla flavour

D: Strawberry flavour

E: Strawberry Banana flavour

F: Honey, Pineapple, and Strawberry Raspberry flavour

G: Key Lime flavour

H: Raspberry Pomegranate flavour

I: Mandarin Orange flavour

J: Passion Fruit

Table 3. Baseline (week 0) characteristics of participants by sex.

Measure	LD-ER (*n* = 24) Male (*n* = 11)	LD-ER (*n* = 24) Female (*n* = 13)	3D-EN (*n* = 26) Male (*n* = 11)	3D-EN (*n* = 26) Female (*n* = 15)	3D-AL (*n* = 24) Male (*n* = 12)	3D-AL (*n* = 24) Female (*n* = 12)	*p* Treatment	*p* Sex	*p* Treatment x Sex
Age (years)	35.45 ± 3.22	40.62 ± 2.11	38.27 ± 3.17	35.00 ± 1.80	34.75 ± 2.53	35.33 ± 2.73	0.5151	0.6951	0.2621
Weight (kg)	103.05 ± 5.47 a	72.36 ± 1.78 b	91.35 ± 3.17 a	83.02 ± 2.86 b	91.16 ± 3.57 a	76.24 ± 2.79 b	0.4380	<0.0001	0.0044
Height (cm)	179.59 ± 1.70	162.16 ± 1.44	177.71 ± 2.43	165.43 ± 1.31	178.66 ± 1.81	162.16 ± 2.13	0.8079	<0.0001	0.3132
BMI (kg/m^2)	31.90 ± 1.72 a	27.52 ± 0.81 b	28.94 ± 0.88 ab	30.22 ± 0.84 ab	28.43 ± 0.73 ab	29.11 ± 0.98 ab	0.6133	0.3353	0.0131
WC (cm)	105.56 ± 3.56	94.26 ± 2.73	101.34 ± 2.65	100.46 ± 3.01	100.38 ± 2.41	98.18 ± 3.86	0.8692	0.0624	0.1976
HC (cm)	110.34 ± 3.20	106.14 ± 1.24	105.21 ± 1.17	111.36 ± 1.74	104.71 ± 1.74	105.61 ± 2.04	0.1896	0.5493	0.0323
WHR	0.96 ± 0.02	0.89 ± 0.02	0.96 ± 0.02	0.90 ± 0.02	0.96 ± 0.01	0.93 ± 0.02	0.5681	0.0011	0.5862
WHtR	0.59 ± 0.02	0.58 ± 0.02	0.57 ± 0.02	0.61 ± 0.02	0.56 ± 0.01	0.61 ± 0.03	0.9708	0.1138	0.3615
FFM (%)	68.67 ± 2.71	61.77 ± 1.71	69.51 ± 2.42	58.19 ± 1.22	69.18 ± 2.34	60.65 ± 1.83	0.7711	<0.0001	0.5389
FM (%)	31.33 ± 2.71	38.23 ± 1.71	30.49 ± 2.42	41.81 ± 1.22	30.83 ± 2.34	39.35 ± 1.83	0.7711	<0.0001	0.5389
RMR (kcal/day)	2098.88 ± 68.79	1356.39 ± 50.95	1886.34 ± 99.57	1494.11 ± 73.01	1930.36 ± 81.56	1365.98 ± 65.97	0.5798	<0.0001	0.0721
SBP (mmHg)	128.21 ± 2.58	112.36 ± 2.49	121.24 ± 2.44	114.53 ± 1.87	124.89 ± 2.80	113.94 ± 3.35	0.6451	<0.0001	0.2182
DBP (mmHg)	77.64 ± 3.37	68.21 ± 2.45	74.15 ± 2.80	70.87 ± 2.33	75.56 ± 2.42	70.19 ± 3.58	0.9872	0.0113	0.5467
BG (mmol/L)	5.50 ± 0.14	5.34 ± 0.17	5.45 ± 0.19	5.57 ± 0.16	5.24 ± 0.11	5.45 ± 0.19	0.6161	0.6621	0.4975
TC (mmol/L)	4.86 ± 0.32	4.94 ± 0.23	5.54 ± 0.32	4.80 ± 0.22	5.14 ± 0.21	5.26 ± 0.34	0.4997	0.4221	0.2185
HDL-C (mmol/L)	1.20 ± 0.09	1.61 ± 0.14	1.30 ± 0.07	1.38 ± 0.07	1.19 ± 0.08	1.49 ± 0.08	0.7379	0.0011	0.1867
Non-HDL-C (mmol/L)	3.66 ± 0.29	3.33 ± 0.28	4.25 ± 0.31	3.42 ± 0.22	3.96 ± 0.23	3.76 ± 0.32	0.3483	0.0464	0.4745
LDL-C (mmol/L)	3.08 ± 0.27	2.88 ± 0.25	3.53 ± 0.27	2.77 ± 0.18	3.23 ± 0.16	3.24 ± 0.30	0.5604	0.1116	0.2638
TG (mmol/L)	1.3 ± 0.13	0.99 ± 0.14	1.55 ± 0.28	1.44 ± 0.18	1.63 ± 0.24	1.18 ± 0.08	0.1585	0.0600	0.6403

HbA1c (%)	5.33 ± 0.10	5.31 ± 0.06	5.30 ± 0.11	5.32 ± 0.10	5.46 ± 0.07	5.28 ± 0.09	0.7883	0.4148	0.5147
Creatinine (mmol/L)	12.02 ± 2.05	11.98 ± 2.46	20.05 ± 3.88	11.23± 1.80	12.34 ± 2.17	19.24 ± 2.92	0.2603	0.7586	0.0118
Urea (mmol/L/kg)	2.78 ± 0.51 ab	2.97 ± 0.46 ab	3.34 ± 0.57 ab	3.03 ± 0.46 ab	2.47 ± 0.42 a	4.51 ± 0.49 b	0.4330	0.1032	0.0404
UCR (mmol/L/mmol/L)	23.40 ± 1.77	22.50 ± 2.41	18.07 ± 2.23	23.58 ± 1.42	19.53 ± 1.37	20.92 ± 2.48	0.3661	0.2225	0.2664
PIUR (g/mmol/L)[1]	0.72 ± 0.10	0.74 ± 0.20	0.54 ± 0.08	0.37 ± 0.05	0.66 ± 0.10	0.17 ± 0.01	0.3291	0.3087	0.5645

Data is presented as baseline means for each sex (means ± SEM; n=74). Two-way ANOVA analysis for baseline (week 0) measures with treatment (p>0.20) and sex (p<0.01) as independent factors. Statistical significance determined using Tukey–Kramer post hoc test (p<0.05). Different letters within each row denote values with significant differences. Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum*; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-hip ratio; WHtR, waist-height ratio; FFM, fat free mass; FM, fat mass; RMR, resting metabolic rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; BG, blood glucose; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; non-HDL-C, non-high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglyceride; HbA1c, hemoglobin A1c; UCR, urea-creatinine ratio; PIUR, protein intake-urea excretion ratio.

[1]PIUR was calculated for n=35.

Table 4. Baseline and change from baseline (week 0) over 12 weeks in physiological measurements.

Measure		Treatment Groups			*p*	Change from Baseline				
		LD-ER (*n* = 24)	3D-EN (*n* = 26)	3D-AL (*n* = 24)		*p* Treatment	Time	Sex	Treatment x Time	Treatment x Time x Sex
Weight (kg)	Baseline	86.43 ± 4.12	86.55 ± 2.24	83.70 ± 2.71	0.4380					
	Mean change	-0.69 ± 0.37 a	+0.35 ± 0.25 b	+0.14 ± 0.27 ab	0.0374	0.0064	0.9202	0.2641	0.0750	0.6580
	Week 12	85.77 ± 4.25	87.16 ± 2.36	83.74 ± 2.94	0.4204					
BMI (kg/m^2)	Baseline	29.53 ± 0.99	29.68 ± 0.62	28.77 ± 0.60	0.6133					
	Mean change	-0.22 ± 0.12 a	+0.10 ± 0.08 b	+0.03 ± 0.09 ab	0.0496	0.0061	0.9256	0.3336	0.0933	0.6909
	Week 12	29.26 ± 1.02	29.86 ± 0.64	28.81 ± 0.61	0.6629					
BG (mmol/L)	Baseline	5.38 ± 0.11	5.52 ± 0.12	5.35 ± 0.11	0.5851					
	Mean change	-0.04 ± 0.10	-0.08 ± 0.11	+0.03 ± 0.09	0.7805	0.7006	0.7757	0.5311	0.7844	0.3973
	Week 12	5.36 ± 0.10	5.45 ± 0.10	5.40 ± 0.14	0.8496					
TC (mmol/L)	Baseline	4.90 ± 0.20	5.11 ± 0.20	5.20 ± 0.20	0.4888					
	Mean change	-0.06 ± 0.11	-0.11 ± 0.08	-0.01 ± 0.09	0.7215	0.6731	0.4136	0.4469	0.9572	0.1344
	Week 12	4.77 ± 0.16	4.93 ± 0.22	5.08 ± 0.20	0.5387					
HDL-C (mmol/L)	Baseline	1.44 ± 0.10	1.35 ± 0.05	1.34 ± 0.06	0.6797					
	Mean change	-0.03 ± 0.03	-0.04 ± 0.02	-0.02 ± 0.03	0.7089	0.7458	0.3475	0.9253	0.3203	0.3867
	Week 12	1.42 ± 0.09	1.33 ± 0.06	1.28 ± 0.06	0.5273					
LDL-C (mmol/L)	Baseline	2.96 ± 0.19	3.09 ± 0.17	3.24 ± 0.17	0.5598					
	Mean change	-0.04 ± 0.08	-0.09 ± 0.06	-0.03 ± 0.08	0.7530	0.5352	0.6111	0.9147	0.9769	0.0304
	Week 12	2.85 ± 0.16	2.92 ± 0.17	3.17 ± 0.19	0.4664					
Non-HDL-C (mmol/L)	Baseline	3.46 ± 0.21	3.77 ± 0.19	3.86 ± 0.20	0.3220	0.7707	0.3992	0.4254	0.9837	0.0719

	Mean change	-0.03 ± 0.03	-0.06 ± 0.08	+0.02 ± 0.08	0.8469					
	Week 12	3.33 ± 0.18	3.60 ± 0.20	3.80 ± 0.21	0.3121					
TG (mmol/L)	Baseline	1.09 ± 0.10	1.48 ± 0.15	1.40 ± 0.13	0.1069					
	Mean change	+0.02 ± 0.06	+0.06 ± 0.10	+0.04 ± 0.06 *	0.7722	0.3987	0.0103	0.0326	0.5620	0.6510
	Week 12	1.09 ± 0.10	1.47 ± 0.19	1.39 ± 0.13	0.1202					
Creatinine (mmol/L)	Baseline	12.33 ± 1.63	14.96 ± 2.09	15.79 ± 1.92	0.3519					
	Mean change	+0.58 ± 1.22	+0.14 ± 1.66	-0.79 ± 1.43	0.7582	0.6710	0.5135	0.6681	0.5279	0.0876
	Week 12	11.72 ± 1.83	15.75 ± 1.69	14.37 ± 2.06	0.3431					
Urea (mmol/L/kg)	Baseline	2.98 ± 0.34	3.16 ± 0.35	3.52 ± 0.39	0.5554					
	Mean change	+0.08 ± 0.27	+0.52 ± 0.33	+0.25 ± 0.26	0.5978	0.7110	0.1311	0.9385	0.8550	0.6188
	Week 12	2.68 ± 0.28	3.71 ± 0.38	3.43 ± 0.46	0.1492					
UCR (mmol/L/mmol/L)	Baseline	23.08 ±1.57	21.25 ± 1.34	20.22 ± 1.39	0.3221					
	Mean change	-0.25 ± 1.10	+1.70 ± 1.21	+2.91 ± 1.04*	0.1130	0.0679	0.3545	0.2894	0.6650	0.8080
	Week 12	23.07 ± 1.76	22.75 ± 1.54	22.77 ± 1.94	0.9762					
PIUR (g/mmol/L)	Baseline	0.69 ± 0.24	0.43 ± 0.08	0.44 ± 0.13	0.5250					
	Mean change	-0.08 ± 0.24	+0.34 ± 0.17	+0.09 ± 0.10	0.2383	0.0850	0.1328	0.4329	0.0695	0.1842
	Week 8[1]	0.64 ± 0.18	1.06 ± 0.38	0.70 ± 0.19	0.2227					

Data is presented as the mean baseline, change from baseline over 12 weeks, and week 12 values (mean ± SEM; n=74). One-way ANOVA for determining treatment differences in baseline (p>0.10), mean change from baseline (p<0.05), and week 12 measures (p>0.10). Different letters within each row indicate means with significant treatment differences detected using Tukey–Kramer post hoc test, p<0.05. One-sample t-test comparing mean change from baseline over 12 weeks to the baseline of zero in each treatment group, with asterisks indicating a significant mean change from baseline (* p<0.05; ** p<0.001; *** p<0.0001). Two-tailed paired t-test comparing baseline and week 12 measurements within each treatment group, no significant differences were found (p>0.05). Three-way ANOVA to determine treatment (p>0.006), time (p>0.01), sex (p>0.08), and their interaction (p>0.03) effects on the changes from baseline, with Tukey-Kramer *post hoc* test to determine statistical differences (p<0.05).

Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum*; BMI, body mass index; BG, blood glucose; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; non-HDL-C, non-high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglyceride; UCR, urea-creatinine ratio; PIUR, protein intake-urea excretion ratio.

[1] Final PIUR was calculated at week 8.

Table 5. Comparison of physiological measures assessed at week 0 (baseline) and 12.

	Treatment Groups									Change from baseline		
	LD-ER (*n* = 24)			3D-EN (*n* = 26)			3D-AL (*n* = 24)			*p*		
Measure	Week 0	Week 12	*p*	Week 0	Week 12	*p*	Week 0	Week 12	*p*	Treatment	Sex	Treatment x Sex
WC (cm)	99.44 ± 2.45	98.24 ± 2.56	0.2649	100.83 ± 2.03	100.49 ± 1.96	0.6390	99.28 ± 2.24	99.33 ± 2.40	0.3350	0.8733	0.6538	0.6341
HC (cm)	108.06 ± 1.63	107.82 ± 1.81	0.7220	108.76 ± 1.26	108.22 ± 1.19	0.1641	105.16 ± 1.31	104.91 ± 1.38	0.0478	0.5928	0.2047	0.4095
WHR	0.92 ± 0.01	0.91 ± 0.01	0.3215	0.93 ± 0.02	0.93 ± 0.01	0.8647	0.94 ± 0.01	0.95 ± 0.01	0.9182	0.6142	0.2318	0.7270
WHtR	0.58 ± 0.01	0.58 ± 0.02	0.3084	0.59 ± 0.01	0.59 ± 0.01	0.6371	0.58 ± 0.01	0.58 ± 0.02	0.3336	0.8972	0.6757	0.6727
FFM (%)	64.77 ± 1.66	64.90 ± 1.64	0.8591	62.98 ± 1.65	62.83 ± 1.68	0.1423	64.91 ± 1.70	64.85 ± 1.89	0.9208	0.9484	0.0718	0.1812
FM (%)	35.23 ± 1.66	35.10 ± 1.64	0.8591	37.02 ± 1.65	37.17 ± 1.68	0.1423	35.09 ± 1.70	35.15 ± 1.89	0.9208	0.9484	0.0718	0.1812
RMR (kcal/day)	1707.57 ± 89.19	1692.38 ± 92.12	0.9536	1641.51 ± 64.87	1671.43 ± 67.17	0.5209	1571.86 ± 101.96	1612.11 ± 107.16	0.7394	0.4657	0.5606	0.8933
SBP (mmHg)	119.63 ± 2.41	115.38 ± 2.45	0.0494	117.37 ± 1.61	118.46 ± 1.60	0.4642	119.42 ± 2.42	116.70 ± 2.33	0.0400	0.0905	0.9535	0.9480
DBP (mmHg)	72.53 ± 2.22	70.67 ± 1.91	0.2153	72.26 ± 1.79	70.31 ± 1.92	0.1127	72.88 ± 2.19	71.86 ± 2.20	0.4624	0.9911	0.3542	0.3930
HbA1C (%)	5.32 ± 0.06	5.27 ± 0.06	0.2942	5.31 ± 0.07	5.30 ± 0.07	0.7114	5.37 ± 0.06	5.37 ± 0.07	0.8272	0.9795	0.3643	0.3958

Data is presented as the mean week 0 and week 12 values (means ± SEM; n=74). Two-tailed paired *t*-test analysis comparing week 0 and week 12 measurements within each treatment group, $p<0.05$ denoting significant differences. Two-way ANOVA to determine treatment ($p>0.09$), sex ($p>0.07$), and their interaction ($p>0.10$) effects on the change from baseline, and Tukey-Kramer *post hoc* test to determine statistical differences ($p<0.05$). Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum*; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-hip ratio; WHtR, waist-height ratio; FFM, fat-free mass; FM, fat mass; RMR, resting metabolic rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c.

Table 6. Baseline and change from baseline (week 1-2) over 12 weeks in daily dietary food and beverage intake by number of servings.

Category		Treatment Groups LD-ER (*n* = 25)	3D-EN (*n* = 24)	3D-AL (*n* = 25)	*p*	Change from Baseline *p* Treatment	Time	Sex	Treatment x Time	Treatment x Time x Sex
Fruits & vegetables	Baseline	3.56 ± 0.51	3.31 ± 0.39	3.19 ± 0.42	0.8358					
	Mean change	+0.26 ± 0.53	-0.21 ± 0.55	-0.46 ± 0.38	0.5729	0.5898	0.9624	0.0438	0.5287	0.1635
	Week 11-12	3.75 ± 0.31	3.40 ± 0.33	3.21 ± 0.35	0.5391					
Whole grains	Baseline	0.53 ± 0.15	0.54 ± 0.17	0.40 ± 0.19	0.7902					
	Mean change	+0.31 ± 0.11 *	+0.22 ± 0.21	+0.21 ± 0.21	0.9263	0.9054	<0.0001	0.5494	0.2536	0.9821
	Week 11-12	1.06 ± 0.13†	0.66 ± 0.10	0.96 ± 0.21	0.1469					
White & whole wheats	Baseline	4.24± 0.71	3.57 ± 0.32	4.48 ± 0.61	0.5108					
	Mean change	-2.11 ± 0.88 *	-1.64 ± 0.38 **	-2.13 ± 0.53 *	0.9263	0.9153	<0.0001	0.1736	0.1111	0.2175
	Week 11-12	1.26 ± 0.23†	1.37 ± 0.19†††	1.57 ± 0.22††	0.1469					
Plant proteins	Baseline	0.36 ± 0.14	0.23 ± 0.09	0.65 ± 0.22	0.1848					
	Mean change	+0.39 ± 0.13*	+0.28 ± 0.14	+0.03 ± 0.22	0.3130	0.3587	0.0550	0.6358	0.5698	0.0501
	Week 11-12	0.80 ± 0.15†	0.60 ± 0.13	0.59 ± 0.14	0.5000					
Animal proteins	Baseline	2.99 ± 0.65	3.16 ± 0.55	2.93 ± 0.54	0.9589					
	Mean change	-1.24 ± 0.43 *	-1.17 ± 0.47 *	-0.81 ± 0.46	0.7714	0.5677	<0.0001	0.1098	0.1208	0.2454
	Week 11-12	1.79 ± 0.35†	1.30 ± 0.14††	1.82 ± 0.31	0.3005					
Ruminant meats	Baseline	0.82 ± 0.48	0.48 ± 0.18	0.58 ± 0.21	0.7371					
	Mean change	-0.50 ± 0.38	-0.23 ± 0.15	-0.39 ± 0.20	0.7613	0.6327	0.0043	0.2793	0.8554	0.4209
	Week 11-12	0.32 ± 0.10	0.25 ± 0.07	0.29 ± 0.11	0.8777					

Dairy	Baseline	0.87 ± 0.18	1.36 ± 0.22	1.40 ± 0.36	0.3197					
	Mean change	+0.44 ± 0.25 a	+1.60 ± 0.26 b ***	+1.51 ± 0.33 b **	0.0107	0.0061	<0.0001	0.7656	0.0252	0.3619
	Week 11-12	1.25 ± 0.21 a	2.92 ± 0.11 b†††	2.76 ± 0.24 ab†	<0.0001					
Healthy fats	Baseline	2.00 ± 0.55	1.33 ± 0.31	1.68 ± 0.51	0.6170					
	Mean change	-1.01 ± 0.58	-0.52 ± 0.33	-0.98 ± 0.51	0.7299	0.7821	0.0006	0.5826	0.9699	0.8340
	Week 11-12	1.07 ± 0.17	0.83 ± 0.15	0.74 ± 0.18	0.3733					
Saturated fats	Baseline	2.12 ± 0.91	1.08 ± 0.31	1.48 ± 0.59	0.5286					
	Mean change	-1.53 ± 0.88	-0.47 ± 0.32	-1.01 ± 0.57	0.5058	0.5415	<0.0001	0.2932	0.8101	0.1834
	Week 11-12	0.92 ± 0.25	0.54 ± 0.11	0.42 ± 0.09	0.0787					
Processed foods	Baseline	0.92 ± 0.26	0.79 ± 0.15	0.85 ± 0.18	0.8981					
	Mean change	-0.48 ± 0.26	-0.29 ± 0.21	-0.23 ± 0.20	0.7247	0.6305	0.0041	0.8018	0.9649	0.5508
	Week 11-12	0.44 ± 0.12	0.39 ± 0.06	0.50 ± 0.15	0.7748					
Confectionary & baked goods	Baseline	0.87 ± 0.24	0.81 ± 0.31	1.33 ± 0.59	0.6269					
	Mean change	-0.24 ± 0.19	-0.11 ± 0.24	-0.87 ± 0.56	0.3211	0.2365	0.0139	0.6528	0.1486	0.0713
	Week 11-12	0.61 ± 0.17	0.59 ± 0.11	0.39 ± 0.09	0.3653					
Water	Baseline	3.20 ± 0.83	4.07 ± 1.02	3.68 ±1.09	0.8342					
	Mean change	+1.31 ± 1.23	-1.27 ± 1.00	-0.02 ± 1.00	0.2597	0.1876	0.9526	0.2643	0.4730	0.1856
	Week 11-12	5.91 ± 1.04 a	3.32 ± 0.58 b	4.37 ± 0.45 ab	0.0402					
Unsweetened beverages	Baseline	1.50 ± 0.36	1.96 ± 0.39	1.10 ± 0.28	0.2166					
	Mean change	-0.73 ± 0.23 **	-0.68 ± 0.40	+0.03 ± 0.28	0.1701	0.2430	0.0041	0.0807	0.0994	0.4554
	Week 11-12	0.67 ± 0.20	0.78 ± 0.22†	1.11 ± 0.26	0.3892					
Unsweetened plant-based beverages	Baseline	0.21 ± 0.15	0.13 ± 0.11	0.10 ± 0.07	0.7853					
	Mean change	+0.04 ± 0.11	+0.20 ± 0.23	+0.03 ± 0.05	0.6708	0.8651	0.7197	0.3977	0.7931	0.9335
	Week 11-12	0.31 ± 0.10	0.14 ±0.14	0.26 ± 0.17	0.6885					
Sweetened beverages	Baseline	0.68 ± 0.27	0.80 ± 0.30	0.79 ± 0.29	0.9477	0.6650	0.0350	0.0777	0.9600	0.7616

	Mean change	-0.13 ± 0.20	-0.27 ± 0.24	-0.43 ± 0.30	0.7030					
	Week 11-12	0.63 ± 0.17 a	0.31 ± 0.08 ab†	0.21 ± 0.06 b	0.0261					
Alcohol	Baseline	0.19 ± 0.11	0.38 ± 0.22	0.23 ± 0.12	0.6878					
	Mean change	-0.05 ± 0.08	-0.18 ± 0.18	-0.13 ± 0.10	0.7588	0.7916	0.0134	0.6362	0.0395	0.0996
	Week 11-12	0.28 ± 0.10	0.27 ± 0.08	0.17 ± 0.06	0.5915					

Data is presented as the mean baseline, change from baseline over 12 weeks, and week 11-12 values (mean ± SEM; n=74). One-way ANOVA for determining treatment differences in baseline (p>0.10), mean change from baseline (p<0.02), and week 12 measures (p<0.05). Different letters within each row indicate means with significant treatment differences detected using Tukey–Kramer post hoc test, p<0.05. One-sample t-test comparing mean change from baseline over 12 weeks to the baseline of zero in each treatment group, with asterisks indicating a significant mean change from baseline (* p<0.05; ** p<0.001; *** p<0.0001). Two-tailed paired t-test comparing baseline and week 12 measurements within each treatment group, with daggers indicating a significant difference between week 12 and baseline values († p<0.05; †† p<0.001; ††† p<0.0001). Three-way ANOVA to determine treatment (p>0.006), time (p<0.97), sex (p>0.04), and their interaction (p>0.02) effects on the changes from baseline, with Tukey-Kramer *post hoc* test to determine statistical differences (p<0.05). Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum*.

Table 7. Mean number of times of weekly food skills usage and change from baseline (week 1-2) over 12 weeks.

		Treatment Groups			*p*					
		LD-ER	3D-EN	3D-AL	Mean	Change from baseline				
Food Skills		(*n* = 25)	(*n* = 24)	(*n* = 25)	Treatment	Treatment	Time	Sex	Treatment x Time	Treatment x Time x Sex
Using food labels	Mean	3.38 ± 0.61	2.32 ± 0.35	2.71 ± 0.70	0.7295	0.1286	0.3011	0.0432	0.0939	0.8467
	Mean change	+0.31 ± 0.59	-0.55 ± 0.32	+1.12 ± 0.39						
Eating out/getting takeout	Mean	3.44 ± 0.42	1.94 ± 0.20	2.07 ± 0.27	0.0939	0.8525	0.9190	0.2191	0.9756	0.3672
	Mean change	-0.10 ± 0.54	-0.26 ± 0.21	+0.12 ± 0.20						
Eating homecooked meals	Mean	10.45 ± 0.77	13.75 ± 0.79	11.82 ± 0.96	0.2234	0.6291	0.7456	0.9491	0.9091	0.2071
	Mean change	+1.12 ± 0.75	-0.23 ± 0.66	+0.64 ± 0.90						
Using healthy cooking methods	Mean	7.01 ± 0.74	11.10 ± 0.83	9.41 ± 0.91	0.2018	0.2819	0.1707	0.9734	0.5292	0.4870
	Mean change	+1.84 ± 0.66	+0.05 ± 0.61	+0.60 ± 0.65						

Data is presented as the mean weekly usage and mean change from week 1-2 over 12 weeks (mean ± SEM; n=74). One-way ANOVA analysis with treatment (p>0.09) as independent factor to assess differences in mean weekly usage. Three-way ANOVA analysis to determine treatment (p>0.10), time (p>0.30), sex (p>0.04), and their interaction (p>0.09) effects on the changes from baseline. Tukey–Kramer post hoc test (*p*<0.05) to determine statistical significance. Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum*.

Table 8. Baseline and changes from baseline (week 0) at weeks 4 and 8 in intakes of nutrients.

		Treatment Groups				Change from baseline				
		LD-ER	3D-EN	3D-AL	***p***	***p***				
Category		(*n* = 28)	(*n* = 24)	(*n* = 20)		Treatment	Time	Sex	Treatment x Time	Treatment x Time x Sex
Energy (kcal)	Baseline	2060.21 ± 110.13	2068.03 ± 117.39	2138.23 ± 161.66	0.9011					
	Week 4 change	-169.78 ±104.83	+140.21 ± 100.47	+42.65 ± 104.73	0.0888	0.0033	0.3560	0.7514	0.0144	0.0400
	Week 8 change	-249.65 ± 116.56 a*	+432.16 ± 131.69 b*	+137.86 ± 278.46 ab	0.0132					
Protein (g)	Baseline	91.95 ± 5.90	91.39 ± 8.48	91.98 ± 10.75	0.9982					
	Week 4 change	+2.43 ± 9.38	+8.95 ± 5.01	+10.29 ± 4.18*	0.7389	0.0587	0.0018	0.8114	0.0318	0.5901
	Week 8 change	-2.14 ± 9.42 a	+35.04 ± 8.18 b*	+33.87 ± 20.79 ab	0.0284					
Fat (g)	Baseline	93.10 ± 10.27	87.09 ± 7.55	85.71 ± 8.30	0.8238					
	Week 4 change	-1.25 ± 7.65	+3.80 ± 7.89	+7.79 ± 5.60	0.6920	0.0844	0.0871	0.8478	0.0374	0.2412
	Week 8 change	-4.84 ± 10.60 a	+31.14 ± 6.14 b***	+9.45 ± 12.10 ab	0.0309					
Calcium (mg)	Baseline	766.54 ± 72.01	924.87 ± 73.98	765.93 ± 70.07	0.2141					
	Week 4 change	+4.59 ± 61.80 a	+236.66 ± 70.41 b*	+371.74 ± 60.37 b***	0.0006	0.0009	0.0013	0.8536	0.0144	0.2348
	Week 8 change	-47.67 ± 77.62 a	+295.97 ± 87.00 ab*	+758.59 ± 417.01 b	0.0265					
Magnesium (mg)	Baseline	266.73 ± 23.87	266.21 ± 25.92	259.38 ± 32.56	0.9792					
	Week 4 change	+0.16 ± 24.09	+66.04 ± 27.07*	+17.70 ± 20.01	0.1416	0.0808	0.1455	0.4392	0.2218	0.0300
	Week 8 change	+10.79 ± 35.11	+89.38 ± 43.84	+1.03 ± 36.22	0.2296					
Potassium (mg)	Baseline	2431.51 ± 152.90	2441.60 ± 191.57	2519.16 ± 209.18	0.9383					
	Week 4 change	+91.87 ± 196.16 a	+639.90 ± 359.20 b	+64.47 ± 183.37 a	0.0025	0.1067	0.0619	0.4976	0.2711	0.2619
	Week 8 change	-17.29 ± 192.16	+643.71 ± 252.21*	+562.55 ± 532.84	0.2340					
Vitamin A (IU)	Baseline	3911.58 ± 1128.66	5052.14 ± 971.19	7435.57 ± 2916.39	0.3478	0.7176	0.7600	0.7445	0.3711	0.0532

	Week 4 change	+1126.79 ± 1715.97	-760.03 ± 1191.62	-2431.32 ± 2897.47	0.5479					
	Week 8 change	-864.74 ± 1160.59	+709.88 ± 1690.50	-233.82 ± 1939.38	0.8715					
Vitamin B2 (mg)	Baseline	1.76 ± 0.18	1.67 ± 0.15	1.65 ± 0.16	0.8660					
	Week 4 change	-0.18 ± 0.19	+0.20 ± 0.17	+0.00 ± 0.21	0.3490	0.3373	0.9860	0.2909	0.6218	0.5104
	Week 8 change	-0.20 ± 0.20	+0.16 ± 0.19	-0.01 ± 0.28	0.4639					
Vitamin B12 (µg)	Baseline	5.23 ± 1.68	3.52 ± 0.42	4.27 ± 1.39	0.6422					
	Week 4 change	-0.87 ± 1.84	+0.91 ± 0.64	-0.00 ± 1.49	0.6855	0.9021	0.1509	0.6964	0.6289	0.6418
	Week 8 change	+3.95 ± 3.13	+1.38 ± 0.72	+1.27 ± 2.02	0.6540					
Vitamin D (IU)	Baseline	247.10 ± 89.67	131.65 ± 21.23	147.33 ± 32.08	0.3573					
	Week 4 change	-66.47 ± 97.48	+91.60 ± 32.51*	+56.00 ± 41.99	0.2498	0.1180	0.1954	0.5210	0.1747	0.3237
	Week 8 change	-79.81 ± 106.92 a	+117.10 ± 51.58 ab*	+280.68 ± 229.06 b	0.0013					

Data is presented as mean baseline and change from baseline values (mean ± SEM; n=72). One-way ANOVA for determining treatment differences in baseline values (*p*>0.20) and mean changes from baseline at week 4 (*p*<0.003) and week 8 (p<0.04). Different letters within each row indicate means with significant treatment differences detected using Tukey–Kramer post hoc test, *p*<0.05. One-sample *t*-test for comparing week 4 and week 8 mean change from baseline to the baseline of zero in each treatment group, with asterisks indicating a significant mean change from baseline (* *p*<0.05; ** *p*<0.001; *** *p*<0.0001). Three-way ANOVA to determine treatment (p>0.0008), time (p<0.001), sex (p>0.20), and their interaction (p>0.01) effects on the changes from baseline, with Tukey-Kramer *post hoc* test to determine statistical differences (p<0.05). Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum*.

Table 9. Knowledge, attitudes, and practices of Canada's Food Guide dietary recommendations.

Question	Unit of Response	Week 0	Week 12
Do you think you understand the CFG and know how to use it in your daily life?	Out of 10	3.36 ± 0.39	6.83 ±0.23 ***
Do you think you have enough knowledge of CFG to make/keep up changes to your eating habits in the future?	Out of 10	-	7.54 ± 0.19
Did you know that Health Canada released a new food guide in 2019?	Yes	32%	-
	No	68%	-
Do you feel it is essential to learn about CFG?	Yes	78%	92%
	No	22%	8%
Will you be continuing the eating plan or recommendation that were given to you?	Yes	-	94%
	No	-	6%
How often did you follow the dietary recommendation that were given?	Out of 7 days	-	5.40 ± 0.12

Data is presented as means ± SEM or as a percentage of total responses (n=67). Asterisks indicate a significant difference (p<0.05) from baseline determined through paired t-test (*** p<0.0001).

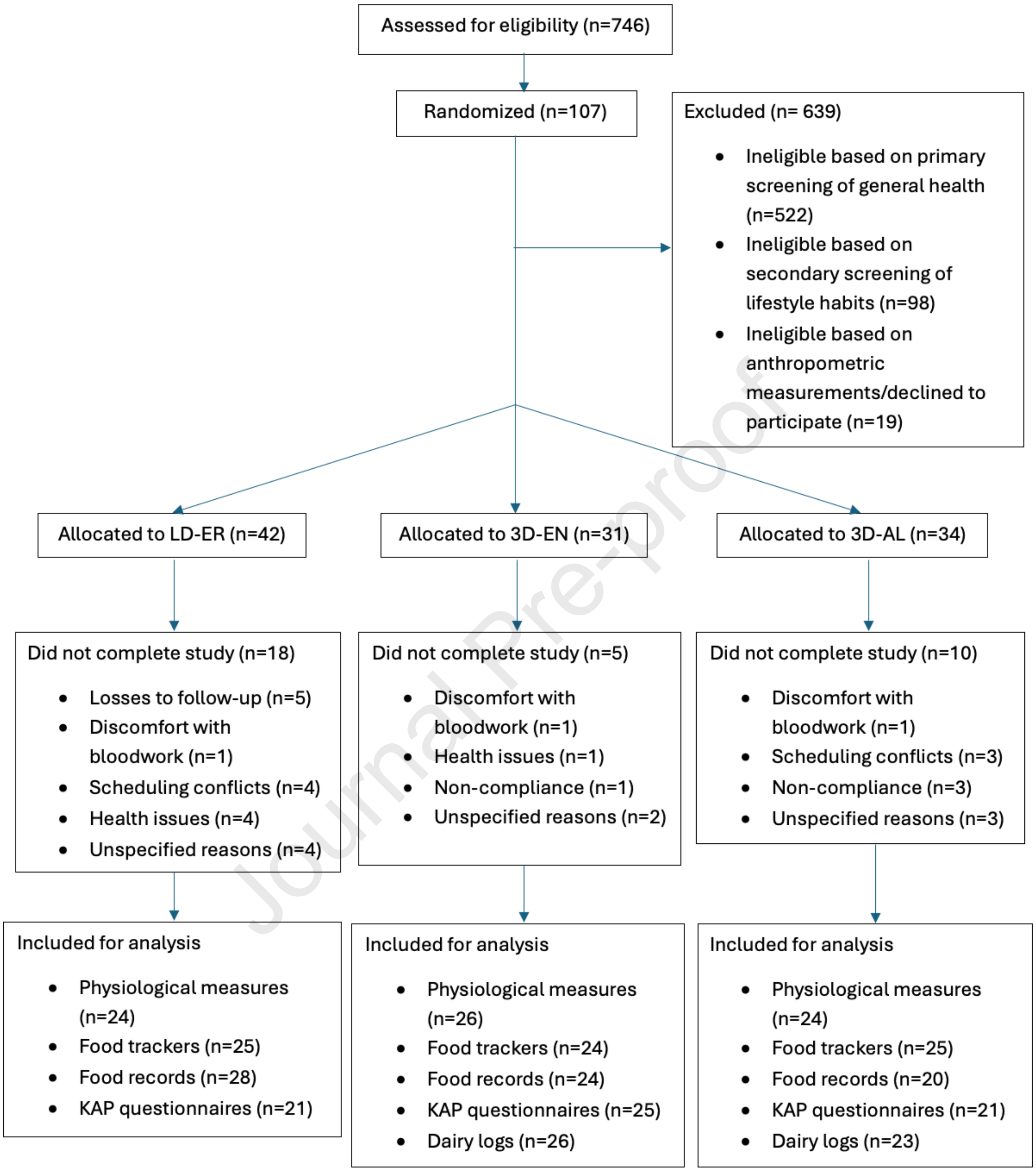
FIGURES

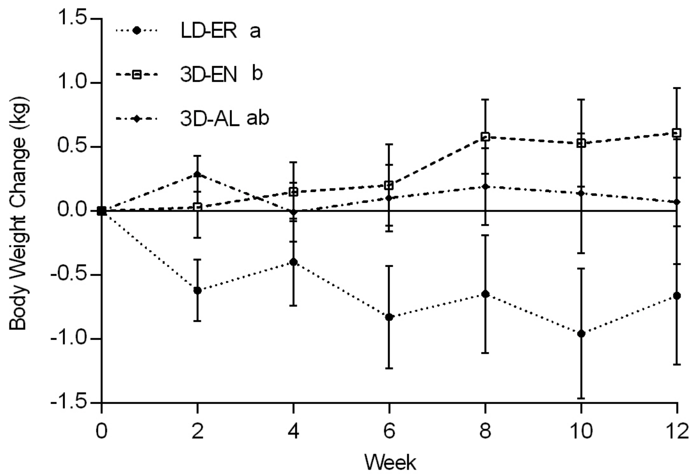
Figure 1. Flow diagram of study participants.

Figure 2. Change in body weight (kg) over 12 weeks. Data are means of change from baseline ± SEM (n=74). Three-way ANOVA with treatment, week, and sex as independent factors. Tukey–Kramer post hoc test ($p<0.05$) used to detect significant differences as shown by letter superscripts. Body weight was affected by treatment ($p=0.039$) but not week ($p=0.88$) or treatment-by-week interaction ($p=0.07$) over the 12 weeks. The interaction approached statistical significance because there was a 0.35 ± 0.25 kg increase in the 3D-EN compared to a 0.69 ± 0.37 kg decrease in LD-ER ($p<0.04$) group. The change in 3D-AL was a 0.14 ± 0.27 kg increase, which was not significantly different from the other treatment groups. Tukey–Kramer post hoc test, $p<0.05$. Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum.*

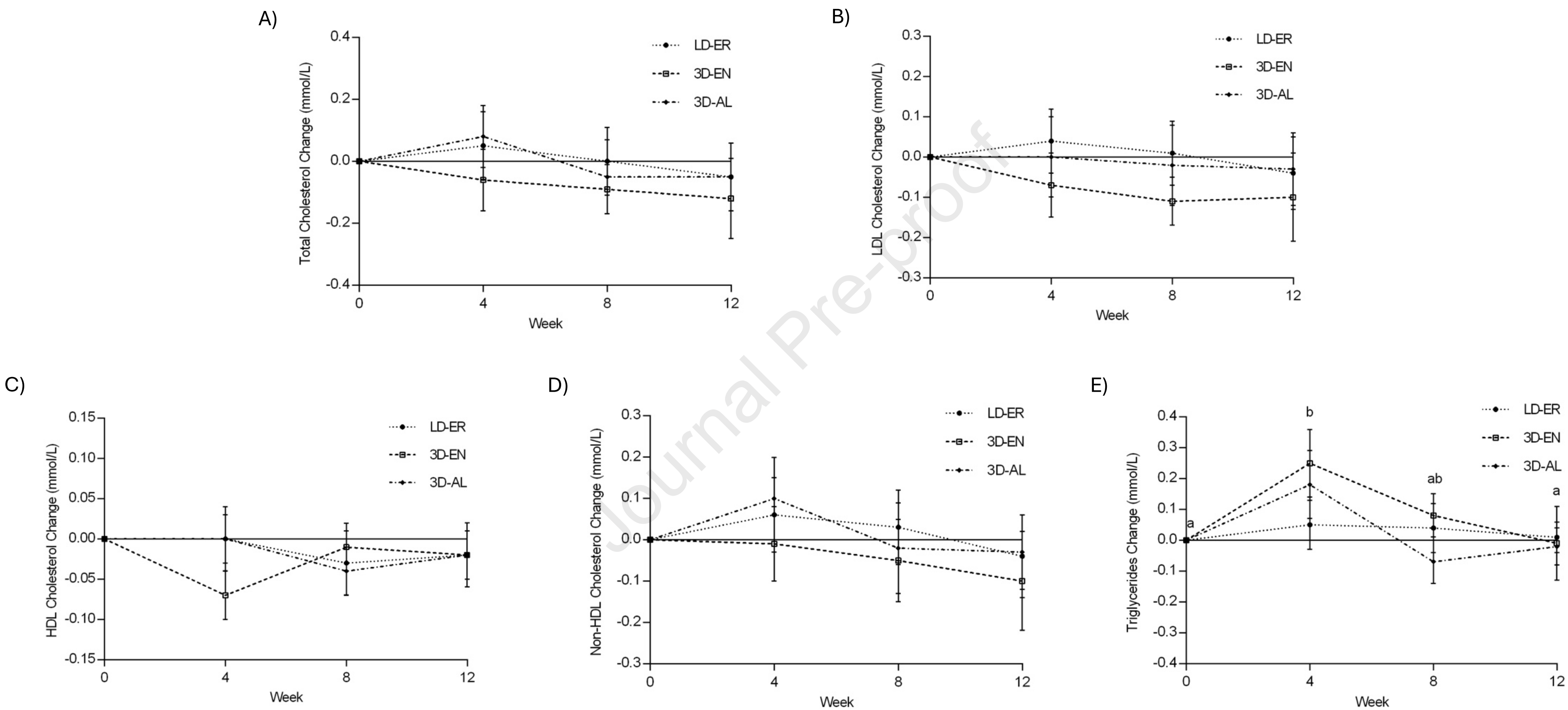
Figure 3. Change in blood lipids (mmol/L) over 12 weeks. A) total cholesterol, B) LDL cholesterol, C) HDL cholesterol, D) non-HDL cholesterol, E) triglycerides. Data are means of change from baseline ± SEM (n=74). Three-way ANOVA with treatment, week, and sex as independent factors. There were no treatment group differences ($p>0.20$), changes from baseline ($p>0.30$), or treatment-by-week effects ($p>0.30$) for total, LDL, HDL, and non-HDL cholesterols. There were triglyceride changes from baseline ($p=0.022$), but no treatment group differences ($p=0.38$) or interaction effects ($p=0.69$). Tukey–Kramer post hoc test ($p<0.05$) detected significant difference in changes from baseline as shown by letter superscripts. Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum.*

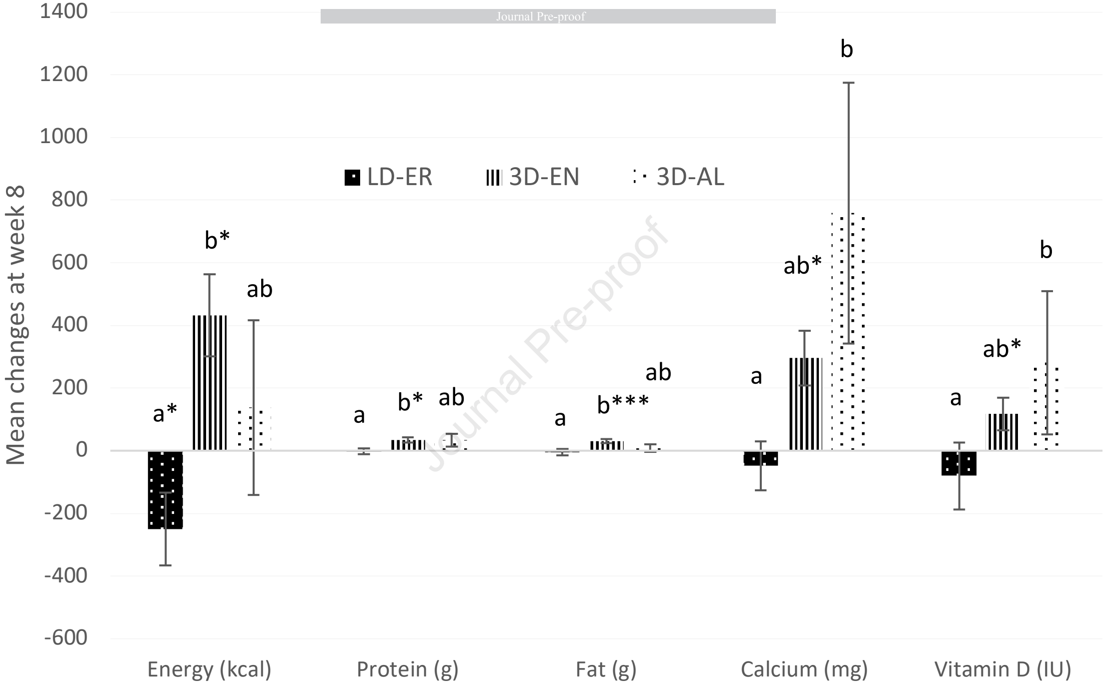
Figure 4. Changes in daily energy (kcal), protein (g), fat (g), calcium (mg), and vitamin D (IU) intake from baseline to week 8. Only outcomes with a significant treatment effect are illustrated; results for all other nutrients are presented in Table 8. Values are means ± SEM (n=72). Treatment, time, and treatment-by-time effects were assessed by three-way ANOVA with sex included as a factor. Tukey–Kramer post hoc test was used for pairwise comparisons as indicated by different letters ($p<0.05$). Asterisks indicate significant within-group changes from baseline (* $p<0.05$, *** $p<0.0001$). Abbreviations: LD-ER, low dairy energy restriction; 3D-EN, 3 dairy energy neutral; 3D-AL, 3 dairy *ad libitum*.


Assessed for eligibility (n=746)
Randomized (n=107)
Excluded (n= 639)
Ineligible based on primary screening of general health (n=522)
Ineligible based on secondary screening of lifestyle habits (n=98)
Ineligible based on anthropometric measurements/declined to participate (n=19)
Allocated to LD-ER (n=42)
Allocated to 3D-EN (n=31)
Allocated to 3D-AL (n=34)
Did not complete study (n=18)
Losses to follow-up (n=5)
Discomfort with bloodwork (n=1)
Scheduling conflicts (n=4)
Health issues (n=4)
Unspecified reasons (n=4)
Did not complete study (n=5)
Discomfort with bloodwork (n=1)
Health issues (n=1)
Non-compliance (n=1)
Unspecified reasons (n=2)
Did not complete study (n=10)
Discomfort with bloodwork (n=1)
Scheduling conflicts (n=3)
Non-compliance (n=3)
Unspecified reasons (n=3)
Included for analysis
Physiological measures (n=24)
Food trackers (n=25)
Food records (n=28)
KAP questionnaires (n=21)
Included for analysis
Physiological measures (n=26)
Food trackers (n=24)
Food records (n=24)
KAP questionnaires (n=25)
Dairy logs (n=26)
Included for analysis
Physiological measures (n=24)
Food trackers (n=25)
Food records (n=20)
KAP questionnaires (n=21)
Dairy logs (n=23)



LD-ER a
3D-EN b
3D-AL ab
Body Weight Change (kg)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0
2
4
6
8
10
12
Week


A)
Total Cholesterol Change (mmol/L)
Week
LD-ER
3D-EN
3D-AL
B)
LDL Cholesterol Change (mmol/L)
Week
LD-ER
3D-EN
3D-AL
C)
HDL Cholesterol Change (mmol/L)
Week
LD-ER
3D-EN
3D-AL
D)
Non-HDL Cholesterol Change (mmol/L)
Week
LD-ER
3D-EN
3D-AL
E)
Triglycerides Change (mmol/L)
Week
LD-ER
3D-EN
3D-AL
a
b
ab
a


1400
1200
1000
800
600
400
200
0
-200
-400
-600
Mean changes at week 8
LD-ER
3D-EN
3D-AL
a*
b*
ab
a
b*
ab
a
b***
ab
a
ab*
b
a
ab*
b
Energy (kcal)
Protein (g)
Fat (g)
Calcium (mg)
Vitamin D (IU)