

Manuscript Title: Healthy Dietary Patterns with and without Meat Improved Cardiometabolic Disease Risk Factors in Adults: A Randomized Crossover Controlled Feeding Trial

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Study Headline: Overweight or obese individuals who choose to follow a U.S.-style healthy dietary pattern, either lacto-ovo-vegetarian or omnivorous including two daily 3-oz servings of lean beef, may have improvements in multiple cardiometabolic disease risk factors. These study findings support the importance of overall diet quality in defining a healthful dietary pattern that supports cardiometabolic health, not the absence or presence of individual foods

Background:

Cardiometabolic disease risk is complex and diet is one of the key modifiable risk factors that can influence its development and progression. Reductions in the concentrations of TC, LDL-C, triglycerides, and total apolipoprotein B, and an increase in the concentration of HDL are common markers for improved cardiometabolic health.

The traditional Western-style dietary pattern, which is often characterized by higher intake of red and processed meat, along with other dietary components, has been associated with increased risk for cardiometabolic disease in observational studies. However, randomized clinical trials assessing the role of red meat consumption, specifically unprocessed beef, within healthy dietary patterns (e.g., Mediterranean-style and DASH-style patterns) have shown that beef can have a beneficial effect on blood lipid profiles and other markers of cardiovascular health.^{1,2,3,4} Beef is a nutrient-dense source of high-quality protein and numerous essential vitamins and minerals, including heme iron, zinc and vitamins B6 and B12. Over the past decade, diet quality and micronutrient intake in the United States (U.S.) have declined or remained below recommended levels, with many Americans failing to meet key nutritional guidelines. Combined with dietary recommendations to decrease the consumption of nutrient-dense animal source-foods, like beef, these declines in diet quality and micronutrient intakes may have unintended health consequences. With a focus on improving nutrient intakes and overall health of Americans, the U.S. Departments of Agriculture and Human and Health Services developed the U.S.-style healthy dietary pattern (HDP), presented in the 2020 *Dietary Guidelines for Americans*, to encourage a

¹ Roussell MA, et al. Beef in an Optimal Lean Diet study: effects on lipids, lipoproteins, and apolipoproteins. *Am J Clin Nutr.* 2012;95(1):9-16.

² Roussell MA, et al. Effects of a DASH-like diet containing lean beef on vascular health. *J Hum Hypertens.* 2014;28(10):600-5.

³ Fleming JA, et al. Effect of varying quantities of lean beef as part of a Mediterranean-style dietary pattern on lipids and lipoproteins: a randomized crossover controlled feeding trial. *Am J Clin Nutr.* 2021;113(5):1126-36.

⁴ Fleming JA, et al. A Mediterranean-style diet with lean beef lowers blood pressure and improves vascular function: secondary outcomes from a randomized crossover trial. *Curr Dev Nutr.* 2025;9(4):104573.

flexible approach to enjoy a variety of nutrient-dense foods. Several previous studies have examined the effects of varying amounts of animal-source proteins within the U.S.-style HDP on markers of cardiometabolic health, yet fewer studies have been conducted to compare healthy omnivorous to healthy “plant-forward” lacto-ovo or vegetarian dietary patterns.

Objective: To assess the effects of a omnivorous U.S-style HDP including two daily servings of lean, unprocessed beef (about 6 ounces) as compared to a lacto-ovo vegetarian U.S.-style HDP (no meat) on short-term changes in cardiometabolic disease risk factors in adults with overweight or obesity.

Study Design:

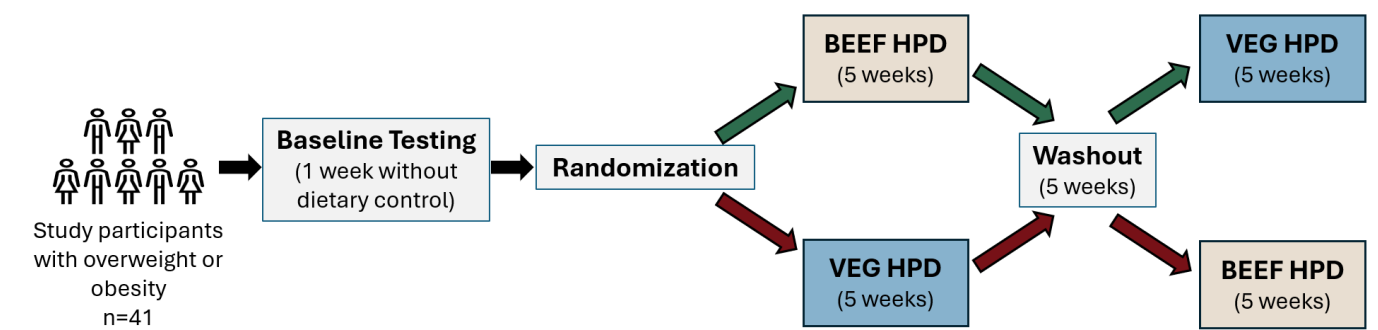
In a 16-week randomized, crossover-controlled feeding trial, 41 adult study participants with overweight or obesity, started with one week of baseline testing (without dietary control), followed by two five-week long controlled feeding periods (either VEG HDP or BEEF HDP in random order), separated by washout period (unrestricted self-selected (i.e., habitual) dietary pattern for five weeks. All meals were provided for study participants for the BEEF HDP or VEG HDP and no food or beverages were provided during the washout period. The BEEF HDP contained two, 3-oz cooked servings of lean, unprocessed beef per day (about 168 g or 6 oz/d) while the VEG HDP substituted the two servings of lean beef for predominantly starchy vegetables and refined grains, such as white potatoes, corn, green peas, green lima beans, plantains, and cassava. Adjustments were primarily made in the dairy and fat intake to match the energy and fat content in both dietary patterns. The researchers chose this approach because refined grains and starchy vegetables, similar to red meat, are generally recommended to be consumed less frequently as part of a HDP.

Both BEEF HDP or VEG HDP provided similar total calories, total fat, potassium, and added sugars. VEG HDP was higher in total carbohydrate, total dietary fiber, vegetable protein, polyunsaturated fatty acids, and sodium, while BEEF HDP was higher in total protein, animal protein, cholesterol, saturated fatty acids, and monounsaturated fatty acids (*See Table 1 in publication*).

Participants came to the lab a total of 8 times for standardized testing visits: two visits in the week before each intervention (total of 4 visits for the study) and two visits during the last week of each intervention (total of 4 visits for the study).. Participants were weighed weekly to monitor weight maintenance. Dietary adherence was assessed by documenting any deviations from the prescribed dietary intervention based on the self-reported menu check-off lists.

Participants completed a dietary satisfaction questionnaire after completing each 5-week dietary intervention. There were 23 questions using a Likert scale, with responses ranging from ‘Strongly Disagree’ to ‘Strongly Agree’ (*See Supplementary Table S2 in publication*).

Schematic of Randomized, Crossover-Controlled Feeding Trial Study Design



Intervention Details:

Study Arm	Intervention	Predominant Protein Source	Length of Intervention
BEEF HDP (Omnivore HDP)	Two, 3-oz cooked servings of lean, unprocessed beef/day (168 g/day) *Beef was the ONLY source of meat	>85% lean ground beef, top sirloin, top round Also included dairy, eggs, and variety of starchy vegetables and refined grains	5 weeks
VEG HDP (Lacto-Ovo Vegetarian HDP)	No meat or beef. Replaced two servings of beef with starchy vegetables	Dairy, eggs and a variety of starchy vegetables and refined grains (white potatoes, corn green peas, green lima beans, plantains, and cassava) and refined grains (any grain product that is not whole grain)	5 weeks

Key Findings:

- Adopting an omnivorous U.S.-style dietary pattern, with two daily servings of lean beef (BEEF HDP), or a lacto-ovo vegetarian U.S.-style dietary pattern (void of meat, VEG HDP), resulted in a wide variety of improvements in markers of cardiometabolic health in adults who were overweight or obese.
- Both dietary patterns (BEEF HDP and VEG HDP) reduced total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), total LDL particles, dense LDL IV, high-density lipoprotein-cholesterol (HDL), total HDL particles, buoyant HDL2b, apolipoprotein A1, and systolic blood pressure from baseline to the end of the intervention.
 - The VEG HDP decreased LDL, glucose, and insulin significantly greater than the BEEF HDP.
- There were no differences between diets or over time for dense LDL III, apolipoprotein B, triglycerides, HOMA-IR, or diastolic blood pressure.

Additional Results:

- Dietary adherence was high for both HDPs and averaged 89% with no significant difference between the BEEF HDP and VEG HDP.
- The participants' total diet satisfaction did not differ after consuming the BEEF or VEG HDP interventions.
- Blood urea nitrogen was higher, yet still well within normal range, following BEEF HDP compared to VEG HDP, which is consistent with the higher protein intake by the BEEF HDP group.

Study Implications:

- The overall diet quality is important in defining the healthfulness of a dietary pattern that supports cardiometabolic health, rather than the absence or presence of individual foods.
- This study demonstrates the inclusion of two servings of lean beef as part of a healthy omnivorous diet can support cardiometabolic health, such as reduced total cholesterol, dense LDL and systolic blood pressure.

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