Manuscript Title: The incorporation of red meat in higher-HEI diets supports brain-health critical nutritional adequacy, and gut microbial diversity

Author List: Samitinjaya Dhakal, Mosharraf Hossain, Sanam Parajuli

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Study Headline: Eating red meat, including beef, as part of a nutrient-dense, high-quality diet improves intake of micronutrients that are essential for cognitive and mental health, without adversely affecting body mass index (BMI) or gut health.

Background:

Red meat, a culturally significant food source of essential nutrients, such as iron, zinc, and vitamin B12, has faced scrutiny due to its associations with some chronic diseases like cardiovascular disease and cancer. Previous observational research has shown healthy, balanced diets are associated with a lower risk of mental health disorders (such as depression, anxiety, and cognitive decline) and improved gut microbial health. However, epidemiological studies often fail to distinguish between unprocessed and processed red meat and do not account for overall diet quality, despite evidence that food synergies rather than isolated nutrients drive health outcomes. There is preliminary research suggesting that an individual's gut microbiota may impact their mental health, with imbalances (dysbiosis) linked to conditions like anxiety and depression through the gut-brain axis.[1] The researchers involved in this study were interested in assessing the role of red meat in the context of healthy, balanced diets on nutrient adequacy, mental health, and gut microbiota.

The Healthy Eating Index (HEI-2015) is a validated measurement tool for diet quality used to assess adherence to the 2015 Dietary Guidelines for Americans (DGA).[2] While eating higher amounts of red meat is often associated with less-healthy diets and lifestyles, there is minimal research evaluating the role of red meat in the context of high HEI (high diet quality) diets. The role of red meat within high-HEI diets remains underexplored, particularly in relation to microbiome diversity and mental health.

Objective:

To evaluate whether red meat could be integrated into a high HEI diet to improve brain health-critical nutrient adequacy without compromising diet quality, mental health, or gut microbiota.

[1] Xiong RG, et al. The role of gut microbiota in anxiety, depression, and other mental disorders as well as the protective effects of dietary components. Nutrients 2023;15(14):3258.
[2] Krebs-Smith SM, et al. Update of the Healthy Eating Index: HEI-2015. J Acad Nutr Diet 2018;118(9):1591-1602.

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Study Design:
Data from the American Gut Project (AGP), a cross-sectional study with microbial and health data from over 10,000 adults, 18+ years, and across diverse demographics (around the world, but mostly western countries) was used for this analysis. Each AGP participant submitted a self-collected fecal sample and completed a validated Food Frequency Questionnaire (FFQ). The food frequency questionnaire was done through VioScreen. The AGP staff conducted 16S rRNA sequencing on the fecal sample and the fecal microbiota data along with the FFQ was added to the publicly available database.

Dr. Dhakal and colleagues conducted a secondary analysis of the AGP data, using data from 3,643 adults. The participants were stratified into four groups based on diet quality and red meat consumption. Diet quality was assessed using the HEI-2015. It should be noted that the number of participants that fell into each category has a large amount of variation.

- HH-R = high-HEI (≥80) with red meat [n=319]
- HH-NR = high-HEI without red meat [n=325]
- LH-R = low-HEI (<80) with red meat [n=2,121]
- LH-NR = low-HEI without red meat [n=878]

It was hypothesized that when diet quality is controlled, red meat within a higher-quality diet does not adversely impact mental health outcomes, nutrient intakes, or gut microbiota. Instead, it is anticipated that red meat consumed within higher-quality diets may improve nutrient adequacy for some brain health-critical nutrients.

Results:
Diet Quality

- A majority of participants, 82% of the study population, had a low-quality diet, reflected by a low HEI score.
- 58% of the study population had low-HEI diets that included red meat.
- A minority, less than 20%, of the study population had high-quality diets reflected by a high HEI diet score, and the distribution of high HEI-diets that did or did not include red meat was equal.

Body Composition

- Both high-HEI groups maintained a healthy BMI, regardless of red meat intake. High-HEI participants collectively had lower BMI than low-HEI groups, regardless of red meat intake.

Total Energy and Macronutrient Profiles

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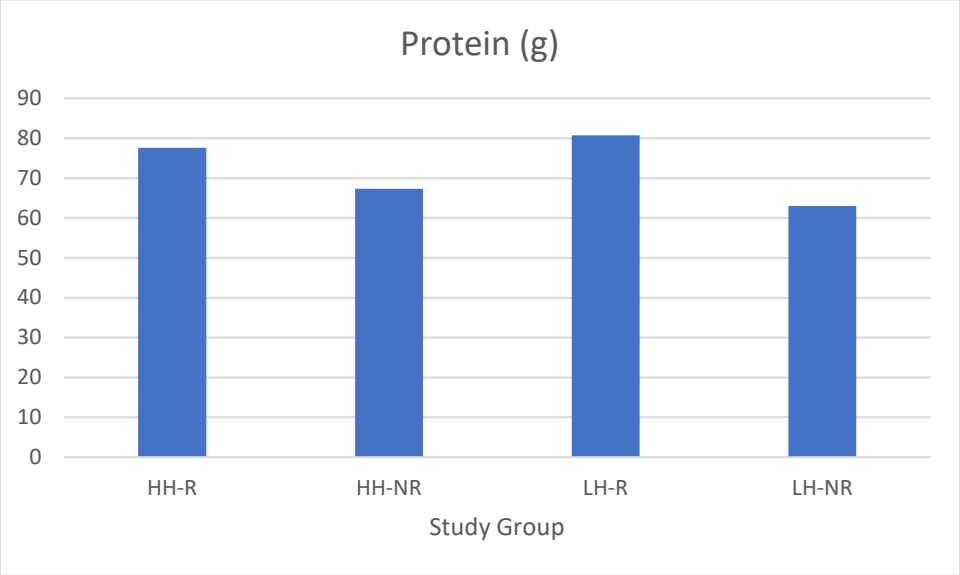
- Energy intake did not differ significantly between the high-HEI groups but was significantly lower than both low-HEI groups.
- Protein intake was significantly higher in both groups of red meat consumers (HH-R and LH-R) compared to both groups of non-red meat consumers, suggesting the contribution of red meat.
    - The red meat consumer diets contained, on average, 17% of calories from protein, while the non-red meat consumer diets contained, on average, 15% of calories from protein.



- Total carbohydrate intake was lower among red meat consumers compared to the non-red meat consumers, likely reflecting increased inclusion of protein, fruits, vegetables, and whole grain.
- Dietary fiber intake was below adequate intake level of 25-38g/day for all groups. Even individuals adhering to dietary guidelines may struggle to meet fiber recommendations.
    - Both red meat groups had lower fiber intake compared to their counterpart of diet quality, but HH-R still exceeded both Low-HEI groups.

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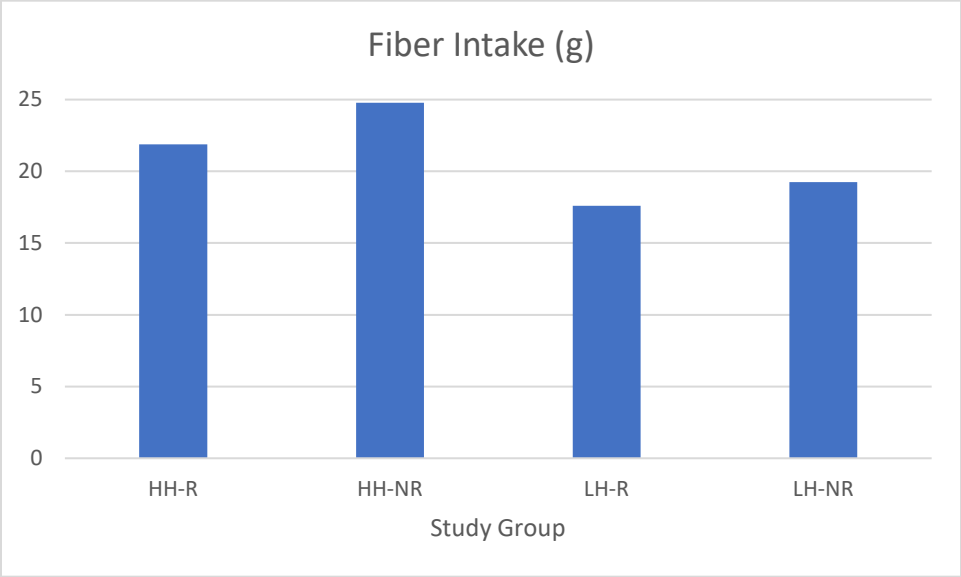

- Saturated fatty acid consumption was different between groups.
    - HH-R had significantly higher saturated fatty acid intake (19.88 ± 8.32 g) than HH-NR (16.89 ± 8.84 g), corresponding to 9.73% vs. 8.49% of total calories, respectively—both high-HEI diets were below the DGA threshold of less than 10%.
    - Both low-HEI groups exceeded the less than 10% recommendation: suggesting that red meat does not necessarily pose a high saturated fatty acid risk when incorporated into a healthy dietary pattern. (LH-R: 28.69 ± 14.76 g; 13.51% of calories and LH-NR: 20.67 ± 12.77 g; 11.02% of calories)

Micronutrient Adequacy

- Participants consuming red meat consistently demonstrated higher intakes of some brain-health critical micronutrients, including selenium, vitamin B12, zinc, calcium, vitamin D3, and choline, than their non-red-meat counterparts, in addition to other essential nutrients, including iron.
    - Calcium intake levels were still below recommended levels, but the HH-R group was the closest to meeting recommended intake.

Mental and Neurodevelopmental Disorders

- Higher HEI scores showed an inverse association with the prevalence of nearly all mental health and neurodevelopmental disorders examined including depression, PTSD, and bipolar disorder.
- Red meat consumption was not associated with statistically significant differences in the prevalence of bipolar disorders, PTSD, non-specified mental illnesses, and migraines, suggesting that adherence to a high-quality diet is important for mental health disorders, independent of red meat consumption.

- Higher HEI scores were significantly associated with lower odds of attention deficit disorder/attention-deficit/hyperactivity disorder and autism spectrum disorder diagnoses.

Gut Microbiota Health

- High-HEI diets were associated with greater microbial diversity—a marker of gut health—regardless of red meat consumption.
- Gut microbiota diversity and richness were highest in HH-R, with increased *Bacteroides caccae* (padj = 0.003) and *Clostridium hathewayi* (padj < 0.001), while HH-NR showed higher *Bifidobacterium adolescentis* and *Bacteroides eggerthii* (padj < 0.001).
- No significant differences in beta-diversity composition were detected.
- Red meat consumption within a high-HEI diet may not drive unfavorable shifts in microbiota, particularly in taxa linked to mental disorders.

Study Implications:

- When red meat is consumed within the context of a high-quality diet, evidenced by a high HEI score in this case, it is associated with improved nutrient adequacy for nutrients associated with brain health without negatively impacting BMI or gut microbiota.
- Following a healthy dietary pattern, with or without red meat, improves macronutrient intake -- yet including red meat is favorable for micronutrient adequacy, namely iron, B vitamins, zinc, and selenium.
- Focusing on adherence to a healthy dietary pattern, rather the specifically eliminating specific foods like red meat, may be effective in long term well-being, associated with reduced prevalence of mental and neurodevelopmental disorders and a favorable gut microbial profile.

Citation: Dhakal S, Hossain M, Parajuli S. Red meat consumption in higher healthy eating index diets is associated with brain health critical nutritional adequacy, and fecal microbial diversity. Sci Rep. 2025 Sep 29;15(1):33428.