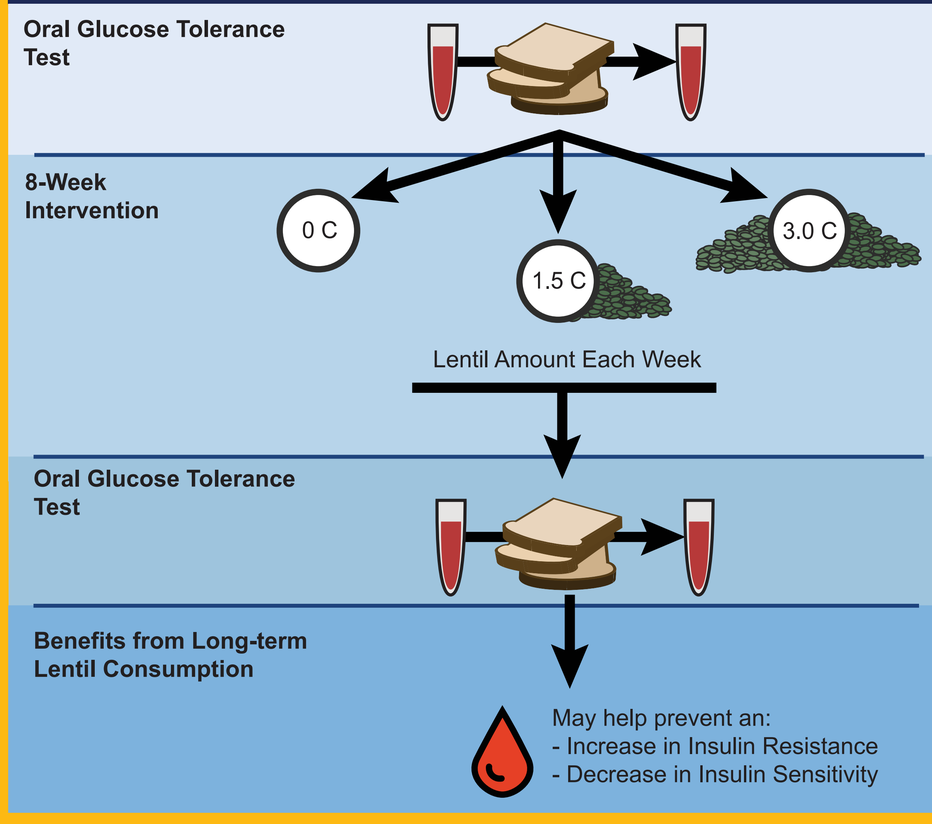
8 Weeks of Lentil Consumption Improves Insulin Sensitivity in Overweight and Obese Adults - A Randomized Controlled Trial

Stephanie Wilson, Emily Peterson, Marcy Gaston, Colleen McMilin, Wan-Yuan Kuo, Mary P Miles
Montana State University, Bozeman, MT

MONTANA STATE UNIVERSITY
College of EDUCATION, HEALTH & HUMAN DEVELOPMENT

Graphical Abstract



Introduction

- Lentils, a type of pulse crop, are low in fat but rich in protein, fiber, and polyphenolic compounds.
- The 2015-2020 Dietary Guidelines for Americans recommends 1.5 cups of legumes a week at the 2,000-Calorie level.[1]
- Acute lentil consumption can promote a lower blood glucose and insulin response than observed with ingestion of high glycemic index foods.[2]
- Individuals with high BMIs are at greater risk of cardiovascular disease than normal BMI individuals with fat accumulation around the abdomen in particular has been linked to insulin resistance.[3]
- Long-term lentil consumption has not been evaluated for its ability to improve glycemic control.[4]
- The purpose of this study was to determine the effects of different weekly doses (0, 1.5, or 3 cups) of lentils for 8-weeks on glycemic control and whole body insulin resistance and sensitivity.

Methods

Participants
- 30 Adults between 21-62 years old with waist circumferences ≥35" for women (n=25) and ≥ 40" for men (n=5)
- No diabetes, cardiovascular, inflammatory conditions, or other chronic diseases.

Study Design
- Single-blind randomized controlled trial

Intervention
- 5 midday meals (tacos, curry, loaf, soup, pasta) were provided each week for 8 weeks. The following groups were isocaloric by week: 0, 1.5, or 3 cups of whole green lentils each week.
- Participants were instructed to maintain their regular diet and physical activity.

Body Composition
- Bioelectrical impedance analysis (SECA mBCA515) was performed before and after the intervention for fat mass percentage and visceral adipose.

Oral Glucose Tolerance Test (OGTT) and Blood Collection
- 175 g White Bread (Franz) for 75 g total carbohydrate and ad libitum water intake
- Blood sample taken after an overnight fast through venipuncture and then every 30 minutes after meal for 2 hours through fingersticks.

Blood Measures
- Fasting samples were analyzed for triglycerides and high-density lipoprotein through a Picollo Xpress lipid panel as well glycated hemoglobin (HbA1c) through the DCA Vantage.
- Glucose (GLU) and insulin (INS) were determined at each blood collection through HemoCue Hb 201+ and ALPCO Insulin ELISA, respectively.
- Calculations were performed for integrated area under the curve (iAUC) for GLU and INS, INS resistance (HOMA-IR), and INS sensitivity (Matsuda Index).

Statistical Analysis
- Linear mixed models were used to assess the impact of the 8-week diet on each of the responses: glucose iAUC, insulin iAUC, INS resistance, and INS sensitivity. All models controlled for age, BMI, and subject to subject variation (random effect)
. Power was calculated for the HOMA-IR and Matsuda Index mixed models using the *simr* package in R, running 100 simulations each. Our power to detect a meal effect was 89% for the HOMA-IR model and 87% for the Matsuda Index model.
- Analysis and data visualizations performed in RStudio running base R 4.0.2.

Results

Table 1 | Participant characteristics at baseline grouped by 8-week intervention group. Participants were randomized into 0, 1.5, or 3 cups of lentils per week. Groups were similar at baseline except for the proportion of men.

	0 C (n=10)	**1.5 C** (n=11)	**3 C** (n=9)	ρ **-value**
Men/Women	1/9	3/8	1/8	<0.01
Age (years)	38.8 ± 10.9	43.1 ± 12.5	43.0 ± 12.3	0.66
BMI (kg/m^2)	35.5 ± 5.2	34.2 ± 6.8	35.9 ± 7.3	0.82
FM (%)	45.3 ± 5.4	41.7 ± 8.4	47.0 ± 7.1	0.25
VAT (l)	3.5 ± 1.8	3.5 ± 1.6	3.3 ± 1.3	0.94
HbA1c (%)	5.2 ± 0.3	5.2 ± 0.3	5.4 ± 0.3	0.10
Fasting GLU (mmol/L)	4.9 ± 0.7	5.2 ± 0.6	5.2 ± 0.4	0.21
Fasting TG (mmol/L)	1.4 ± 0.7	1.3 ± 0.5	1.5 ± 0.5	0.70
Fasting CHOL (mmol/L)	4.9 ± 1.0	4.6 ± 0.9	4.8 ± 0.7	0.76
Fasting HDL (mmol/L)	1.4 ± 0.4	1.3 ± 0.3	1.5 ± 0.6	0.39

Data represent mean and standard deviation. Sex ρ-value determined through 3-sample test for given proportions; all other variable ρ-values were determined by ANOVA. Abbreviations: cups, C; body mass index, BMI; fat mass, FM; visceral adipose tissue, VAT; hemoglobin A1C, HbA1c; glucose, GLU; triglycerides, TG; cholesterol, CHOL; high density lipoprotein, HDL.

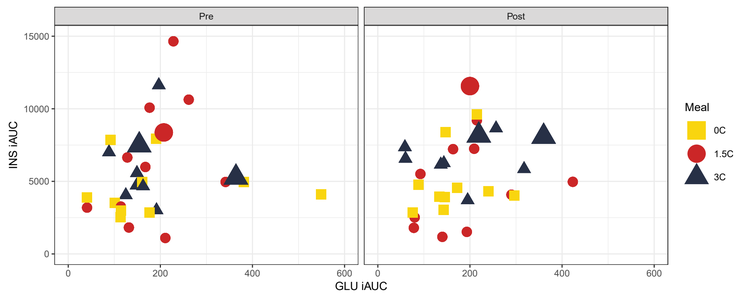


Figure 1 | Scatterplot depicting range of GLU and INS iAUC values by meal group before and after the 8-week dietary intervention. Each point in a panel depicts one individual. Three points are enlarged to indicate the individuals who had a HbA1c which categorized them as prediabetic HbA1c values were 5.7, 5.8, and 5.8.

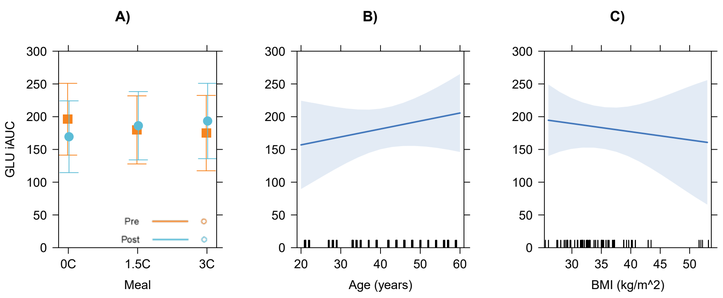


Figure 2 | Effect plots for the GLU iAUC linear mixed model. A) The GLU response to the OGTT increased with the addition of 1.5 cups (p = 0.035) and 3.0 cups (p = 0.006) of lentils over 8 weeks, controlling for age, BMI, and subject to subject variation. Main effects for B) Age (p =0.396) and C) BMI (p = 0.623) were not detected. Points indicate group mean estimates while bands and bars indicate 95% CI. Ticks on the axis in B) and C) indicate where participant values were observed.

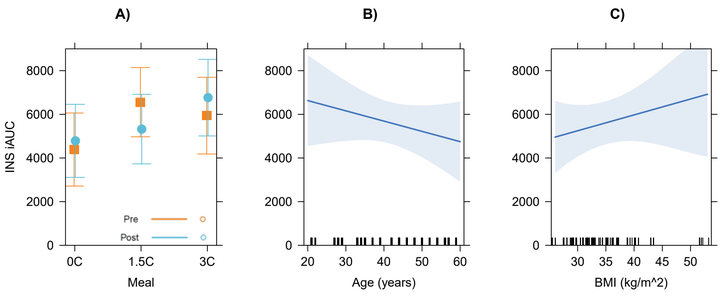


Figure 3 | Effect plots for the INS iAUC linear mixed model. A) The average estimated INS response to the OGTT decreased 1632 mmol/L with 1.5 C compared to 0 C lentils per week (p < 0.001), accounting for age, BMI, and subject to subject variation. The 8-week change seen with 3 cups did not differ from the change with 0 cups of lentils per week (p = 0.241). Main effects for B) Age (p = 0.289) and C) BMI (p = 0.343) were not detected. Points indicate group mean estimates while bands and bars indicate 95% CI. Ticks on the axis in B) and C) indicate where participant values were observed.

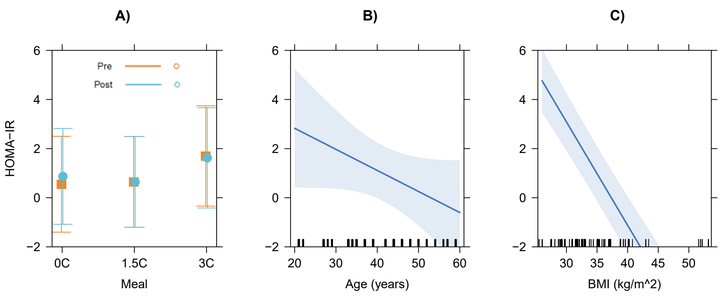


Figure 4 | Effect plots for the HOMA-IR linear mixed model. A) Insulin resistance increased in the 0 cup group but the increase was not observed with the addition of 1.5 (p < 0.001) and 3 cups (p < 0.001) of lentils for 8 weeks, accounting for age and BMI. A main effect was observed with C) BMI (p < 0.001) but not with B) age (p = 0.100). Values from the model were exponentiated to create plots, and thus, interpretations reflect a percentage change. Points indicate group median estimates while bands and bars indicate 95% CI. The y-axis was in A) was rescaled to better visualize estimated group medians. Ticks on the axis in B) and C) indicate where participant values were observed.

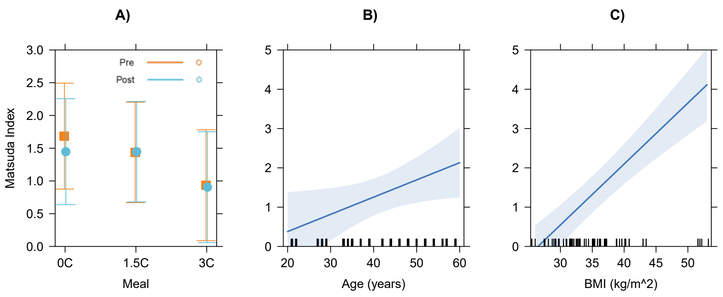


Figure 5 | Effect plots for the Matsuda Index linear mixed model. A) A decrease in insulin sensitivity was seen in the 0 cup group, but the addition of 1.5 (p < 0.001) and 3 cups (p < 0.001) of lentils was observed to maintain insulin sensitivity over 8 weeks, accounting for age, BMI, and subject to subject variation. A main effect was observed for both B) age (p = 0.046) and C) BMI (p < 0.001). Values from the model were exponentiated to create plots, and thus, interpretations reflect a percentage change. Points indicate group median estimates while bands and bars indicate 95% CI. The y-axis was in A) was rescaled to better visualize estimated group medians. Ticks on the axis in B) and C) indicate where participant values were observed.

Summary

- In our cohort of individuals with an increased waist circumference, the group which consumed the current dietary recommendation of weekly pulses (1.5 cups/week) for 8 weeks had a lower average insulin response during the OGTT even with a modest increase in the average glucose response compared to 0 cups/week group. This finding was not observed with pulse consumption above the current recommendation.
- The addition of lentils for 8 weeks prevented an increase in insulin resistance and decrease in insulin sensitivity.
- While this study was well-powered, future studies would be improved by a more even proportion of men to women. Gender-specific differences in insulin sensitivity have been previously noted, with women having greater sensitivity, and may improve statistical models.[5]
- These data suggest that long-term consumption of lentils can help heavier individuals at greater risk of impaired glucose tolerance prevent progression to a more insulin resistant state.

References

1. US HHS and USDA 2015-2020 Dietary Guidelines for Americans. (2015).
2. Ramdath DD, et al. *Foods*. 2018; 7(5): 76. doi: 10.3390/foods7050076.
3. Liu L, et al. *Curr Med Res Opin*. 2018; 34(1). doi: 10.1080/03007995.2017.1364226.
4. Bielefeld D, et al. *Nutrients*. 2020;12(7). doi: 10.3390/nu12072123.
5. Geer E & Shen W. *Gender medicine*. 2009. doi.org/10.1016/j.genm.2009.02.002

Acknowledgments

USA Dry Pea & Lentil Council

Many thanks to the undergraduate students who assisted with data collection and meal preparation on this project. My thanks also go to Tan Tran for his help in writing an R function for iAUC.