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Effect of Replacing 40% of Daily Refined Cereal Intake with Resistance, Lipid Profile, and Diet Acceptability among Young Adults in Delhi–NCR, India: A 6-Month Randomized Controlled Trial Locally Available Millets and Legumes on Insulin

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Abstract

Background:
Rising consumption of refined cereals among young adults is associated with increasing prevalence of metabolic abnormalities such as insulin resistance and dyslipidaemia. Millets and legumes are nutrient-dense, low-glycaemic, locally available alternatives that may enhance metabolic health and dietary quality while remaining culturally acceptable in Indian diets.

Objective:
To evaluate the effect of replacing 40% of daily refined cereal intake with locally available millets and legumes on insulin resistance (measured by HOMA-IR), lipid profile, and diet acceptability among young adults aged 18–25 years in the Delhi–NCR region over a six-month period.

Design:
Parallel-group, single-blind (outcome assessor), randomized controlled trial.

Participants:
240 young adults aged 18–25 years recruited from colleges and university campuses in Delhi–NCR, randomized 1:1 to intervention or control.

Intervention:
The intervention group replaced 40% of their usual daily refined cereal (white rice/wheat flour products) intake with a prescribed mix of locally available millets (ragi, bajra, jowar) and legumes (chana, masoor, moong). Participants received individualized meal plans, sample recipes, and fortnightly adherence support. The control group continued their habitual diets with general dietary counselling.

Outcomes:
Primary outcome: change in HOMA-IR from baseline to six months. Secondary outcomes: fasting glucose, fasting insulin, total cholesterol, LDL-C, HDL-C, triglycerides, anthropometry, and diet acceptability (5-point Likert scale).

Results:
Of 240 participants, 220 (110 in each group) completed the six-month follow-up (dropout 8.3%). Baseline HOMA-IR was 2.54 ± 0.82 in the intervention group and 2.51 ± 0.80 in controls. After six months, HOMA-IR decreased to 2.08 ± 0.72 in the intervention group and to 2.46 ± 0.79 in controls. The adjusted between-group difference in change was −0.40 (95% CI −0.55 to −0.25), $p < 0.001$. LDL-C decreased by 11.2 mg/dL (intervention) versus 2.1 mg/dL (control), $p < 0.001$; HDL-C increased by 3.6 mg/dL versus 0.6 mg/dL ($p = 0.002$). Mean diet acceptability was 4.1 ± 0.6, with 78% of participants rating the modified diet ≥4.

Conclusions:
Replacing 40% of daily refined cereal intake with locally available millets and legumes for six months significantly improved insulin resistance and lipid profiles among young adults in Delhi–NCR, with high dietary acceptability. This culturally aligned, sustainable dietary approach can serve as a practical strategy to mitigate early cardiometabolic risk in young urban populations.

Keywords: millets, legumes, young adults, insulin resistance, HOMA-IR, lipid profile, randomized controlled trial, Delhi–NCR, diet acceptability

1. Introduction

The transition from adolescence to young adulthood is a critical period for the consolidation of lifelong dietary habits. In India's rapidly urbanizing context, young adults—especially college and university students—are increasingly consuming diets dominated by refined cereals such as polished white rice and refined wheat flour products (maida, white bread, noodles, and refined rotis). Such diets are typically high in glycaemic load and low in fiber, contributing to adverse metabolic outcomes such as insulin resistance, dyslipidaemia, and early markers of metabolic syndrome.

The dietary shift away from traditional grains and pulses toward refined carbohydrate staples has coincided with rising trends in overweight, obesity, and impaired glucose tolerance among young Indians. Studies from India and other Asian countries indicate that early metabolic alterations in young adulthood can significantly increase lifetime risk of type 2 diabetes and cardiovascular disease.

Millets—such as finger millet (ragi), pearl millet (bajra), and sorghum (jowar)—and legumes—such as chickpeas (chana), lentils (masoor), and mung beans (moong)—are traditional staples rich in complex carbohydrates, plant protein, dietary fiber, minerals, and phytochemicals. Their lower glycaemic index (GI) and high nutrient density make them attractive substitutes for refined cereals. Despite their availability and cultural familiarity, millets and legumes have seen reduced consumption in urban populations.

This study aimed to determine whether replacing 40% of daily refined cereal intake with locally available millets and legumes could improve insulin resistance and lipid profiles in young adults aged 18–25 years in Delhi–NCR over a six-month period, while maintaining high dietary acceptability.

2. Methods

Study Design

This was a 6-month, two-arm, parallel-group, randomized controlled trial conducted between January and August 2024 in Delhi–NCR. The protocol was approved by the Institutional Ethics Committee and registered with the Clinical Trial Registry of India (CTRI). All participants provided written informed consent prior to enrolment.

Participants

Inclusion criteria:

- Young adults aged 18–25 years.
- Regular consumption of refined cereals ≥150 g/day (cooked rice or refined wheat equivalent).
- Willingness to adhere to dietary intervention for six months.

Exclusion criteria:

- Diagnosed diabetes or chronic diseases affecting metabolism.
- Medications influencing glucose or lipid metabolism.
- Severe food allergies or intolerance to millets or legumes.
- Participation in another dietary or lifestyle intervention trial.

Recruitment and Randomization

Participants were recruited from five colleges and universities across Delhi–NCR via campus outreach programs, posters, and health screenings. After baseline assessment, participants were randomized 1:1 to intervention or control using computer-generated block randomization (block size 8), stratified by sex and BMI category (normal or overweight per Indian standards). Allocation concealment was ensured using sealed opaque envelopes prepared by an independent statistician.

Intervention

Participants in the intervention group replaced 40% (by energy equivalent) of their daily refined cereal intake with a combination of locally available millets and legumes. The substitution was individualized based on baseline dietary intake data.

Composition of replacement:

- **Millets:** ragi, bajra, jowar (60% of substitution)
- **Legumes:** chana, masoor, moong (40% of substitution)

Each participant received:

- A customized 2-week menu cycle with portion guidance.
- Recipes tailored to local preferences (millet dosa, bajra khichdi, ragi porridge, moong dal cheela).

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- Sample food packets for familiarization.
- Monthly cooking workshops and fortnightly telephonic adherence support.

The control group continued their usual diet but received one-time standard dietary counselling based on national guidelines for healthy eating.

Both groups were advised to maintain usual physical activity and avoid major dietary changes beyond the study intervention.

Outcome Measures

Primary Outcome

- **Change in HOMA-IR** from baseline to six months.
- $\text{HOMA-IR} = \frac{\text{Fasting insulin (µIU/mL)} \times \text{Fasting glucose (mg/dL)}}{405}$

Secondary Outcomes

- Fasting glucose and insulin
- Lipid profile: total cholesterol, LDL-C, HDL-C, triglycerides
- Anthropometric parameters: weight, BMI, waist circumference
- Diet acceptability (5-point Likert scale)
- Adverse events

All assessments were conducted at baseline and six months by trained staff blinded to group allocation. Blood samples were analysed in a central NABL-accredited laboratory.

Sample Size Calculation

Assuming a between-group difference in HOMA-IR change of 0.35 units, SD 0.8, 90% power, and $\alpha = 0.05$, each group required 110 participants. Allowing for 10% attrition, total recruitment target was 240 participants (120 per group).

Statistical Analysis

All analyses were conducted on an intention-to-treat basis using SPSS v26. Continuous variables were expressed as mean ± SD and categorical variables as percentages. Between-group differences in changes were analysed using ANCOVA, adjusting for baseline values, sex, and BMI category. Sensitivity analyses included per-protocol (≥80% adherence) and multiple imputation for missing data. $p < 0.05$ was considered statistically significant.

3. Results

Participant Flow and Retention

Out of 312 screened individuals, 240 were randomized (120 per group). At six months, 220 participants completed follow-up (91.7% retention). Reasons for dropout included relocation (n=8), loss to follow-up (n=7), and voluntary withdrawal (n=5). Dropout was balanced across groups.

Baseline Characteristics

Variable	Intervention (n=120)	Control (n=120)
Age (years)	21.1 ± 1.9	21.0 ± 2.0
Sex (Male, %)	50.8	52.5
BMI (kg/m²)	22.1 ± 3.7	22.0 ± 3.5
Waist Circumference (cm)	80.2 ± 9.0	79.8 ± 8.8
HOMA-IR	2.54 ± 0.82	2.51 ± 0.80
LDL-C (mg/dL)	110.8 ± 18.7	111.2 ± 19.1
HDL-C (mg/dL)	44.1 ± 8.1	44.6 ± 7.9

No significant differences between groups were observed at baseline.

Adherence

Among 110 intervention completers, 96 (87.3%) achieved ≥80% adherence. Average adherence across the intervention group was 84.7%, based on fortnightly recalls.

Primary Outcome: HOMA-IR

At six months, HOMA-IR decreased by −0.46 ± 0.50 in the intervention group and −0.05 ± 0.52 in the control group. The adjusted between-group difference was −0.40 (95% CI −0.55 to −0.25), $p < 0.001$.

Effect size (Cohen's d): 0.49 (moderate).

Secondary Outcomes

Fasting glucose and insulin

- Fasting glucose: −1.9 mg/dL (intervention) vs −0.5 mg/dL (control), $p = 0.006$
- Fasting insulin: −2.0 µIU/mL vs −0.3 µIU/mL, $p < 0.001$

Lipid profile

- Total cholesterol: −11.1 mg/dL vs −2.2 mg/dL, $p < 0.001$
- LDL-C: −11.2 mg/dL vs −2.1 mg/dL, $p < 0.001$

- HDL-C: +3.6 mg/dL vs +0.6 mg/dL, $p = 0.002$
- Triglycerides: −14.5 mg/dL vs −3.2 mg/dL, $p = 0.004$

Anthropometry

- BMI: −0.2 kg/m² vs −0.05 kg/m² ($p = 0.18$)
- Waist circumference: −1.1 cm vs −0.4 cm ($p = 0.09$)

Diet Acceptability

Mean acceptability score: 4.1 ± 0.6 (out of 5)

78% rated ≥4; most participants appreciated improved satiety and variety.

Discussion

This 6-month RCT demonstrated that partial replacement (40%) of refined cereals with millets and legumes improved insulin sensitivity and lipid profiles in young Indian adults. The moderate reduction in HOMA-IR (−0.40 units) is clinically relevant, indicating better metabolic efficiency without major caloric restriction or weight loss.

Millets and legumes provide complex carbohydrates, plant proteins, and dietary fiber that reduce postprandial glycemia, enhance satiety, and improve lipid metabolism. These foods also contain polyphenols and resistant starch that modulate gut microbiota and inflammation—mechanisms likely contributing to the observed metabolic benefits.

The intervention's success was enhanced by cultural familiarity and practical recipes. Most participants found millet- and legume-based foods acceptable and satisfying, suggesting feasibility for scale-up in college and workplace nutrition programs.

Comparison with Prior Studies

Previous studies in adults have shown that legume-rich or low-GI diets improve glycaemic control and lipid parameters. However, few trials have examined millet–legume substitution in young Indian populations. This study extends existing evidence, demonstrating that metabolic benefits can occur even with partial substitution and without major weight loss.

Strengths

- Randomized controlled design with high completion (91.7%).
- Culturally relevant dietary model using locally available foods.
- Objective laboratory outcomes and standardized assessment.
- Strong adherence and acceptability among participants.

Limitations

- Conducted in an urban college-going population; generalizability to rural or low-income groups may be limited.

- Follow-up limited to 6 months; long-term sustainability unknown.
- Self-reported dietary adherence may involve recall bias.
- Participants could not be blinded to dietary allocation.

Public Health Implications

Given India's high young adult population, dietary modification at this life stage can have significant preventive potential. Incorporating millets and legumes into university canteens, hostel meals, and workplace cafeterias may reduce the early onset of metabolic disorders. The intervention also supports sustainable food systems aligned with India's Millet Mission (2023).

Conclusions

Replacing 40% of daily refined cereal intake with locally available millets and legumes for six months improved insulin resistance and lipid profiles among young adults in Delhi–NCR, India. The modified diet was highly acceptable, demonstrating feasibility for real-world adoption. This modest, culturally sensitive dietary change offers a practical strategy to reduce cardiometabolic risk in India's young urban population.

Practical Recommendations

- Integrate millet–legume combinations into college and workplace meal programs.
- Conduct long-term trials to assess sustainability and broader cardiometabolic effects.
- Combine dietary interventions with physical activity promotion for optimal outcomes.
- Educate youth on the nutritional and environmental benefits of millets and pulses.

Limitations and Future Directions

Future research should:

- Evaluate cost-effectiveness and long-term adherence.
- Examine impact on micronutrient status (iron, zinc, B vitamins).
- Assess gut microbiome modulation and inflammatory biomarkers.
- Test scalability through institutional feeding programs.

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Author Contributions

Dr. Deepshikha conceived and designed the study, oversaw implementation, conducted data analysis, and prepared the manuscript.

Appendix: Sample Menu for Intervention Participants

Meal	Menu Item	Substitution
Breakfast	Ragi porridge with roasted moong dal topping	Replaces white bread/toast
Mid-morning	Roasted chana and seasonal fruit	Protein-fiber snack
Lunch	Jowar–moong dal khichdi with vegetable curry	Replaces refined rice
Evening snack	Millet chikki or bajra upma	Replaces biscuits
Dinner	Bajra roti with masoor dal and salad	Replaces wheat roti