



Original Article

## Effect of carbohydrate type on small dense low-density lipoprotein levels in patients with coronary heart disease: a randomized controlled trial

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### ABSTRACT

**Background:** Coronary heart disease (CHD) is closely associated with dyslipidemia, particularly elevated small dense low-density lipoprotein (sdLDL), which contributes to increased atherogenic risk. Evidence from controlled dietary interventions examining the impact of carbohydrate type on sdLDL levels among patients with coronary heart disease in Indonesia remains limited.

**Objective:** This study aimed to evaluate the effect of simple versus complex carbohydrate intake on lipid profiles, with a primary focus on sdLDL levels, in patients with CHD.

**Methods:** A pretest–posttest single-blind randomized controlled trial was conducted among 40 clinically stable patients with coronary heart disease at a community health center in Padang City, Indonesia. Participants were randomly assigned to consume either refined white rice (simple carbohydrate) or unrefined brown rice (complex carbohydrate) for four weeks. Lipid profiles were assessed at baseline and post-intervention.

**Results:** The complex carbohydrate group demonstrated a significantly greater reduction in sdLDL levels compared with the simple carbohydrate group. Significant improvements in total cholesterol, LDL cholesterol, and HDL cholesterol were also observed in the complex carbohydrate group, while triglyceride levels did not change significantly in either group.

**Conclusion:** Complex carbohydrate intake resulted in more favorable modulation of atherogenic lipid profiles than simple carbohydrate intake in patients with coronary heart disease. These findings highlight the importance of carbohydrate quality, particularly unrefined rice-based staples, as a complementary dietary strategy in CHD management.

### INTRODUCTION

Coronary heart disease (CHD) remains a leading cause of global morbidity and mortality. It is estimated that CHD accounts for more than 9 million deaths annually worldwide, making it the foremost contributor to cardiovascular mortality.<sup>1</sup> In Indonesia, the burden of CHD continues to rise, with approximately 4.2 million cases reported in the 2018 Basic Health Research (Riskesdas).<sup>2</sup> At the regional level, West Sumatra—particularly Padang City—has demonstrated a relatively high prevalence of CHD, emphasizing the need for context-specific preventive and therapeutic strategies.<sup>3</sup>

Atherosclerosis, the primary pathological process underlying CHD, is closely associated with dyslipidemia, a

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condition that affects a substantial proportion of adults.<sup>4</sup> Low-density lipoprotein cholesterol (LDL-C) has traditionally been used as the principal biomarker for cardiovascular risk assessment. However, growing evidence indicates that LDL-C alone does not fully account for residual atherosclerotic risk, as many patients continue to experience disease progression despite achieving recommended LDL-C targets.<sup>5,6</sup> This phenomenon suggests the involvement of additional atherogenic lipoprotein fractions, particularly small dense low-density lipoprotein (sdLDL), which exhibits greater arterial wall penetration, increased susceptibility to oxidative modification, and enhanced plaque-forming capacity.<sup>7,8</sup>

Dietary factors, particularly carbohydrate intake, play a critical role in lipid metabolism and the formation of sdLDL. High consumption of refined carbohydrates promotes

hepatic de novo lipogenesis, leading to increased triglyceride synthesis and elevated secretion of triglyceride-rich very-low-density lipoprotein (VLDL).<sup>9,10</sup> These VLDL particles are subsequently remodeled into sdLDL through lipolytic processes, contributing to an atherogenic lipid profile.<sup>11,12</sup> Furthermore, diets characterized by a high glycemic index have been associated with adverse cardiovascular outcomes and unfavorable lipid remodeling.<sup>13,14</sup>

This mechanism is particularly relevant in Indonesia, where carbohydrates contribute approximately 60%–70% of total daily energy intake, with rice serving as the predominant staple food.<sup>15-17</sup> The high reliance on refined rice, coupled with relatively low consumption of fiber-rich whole grains, may increase susceptibility to sdLDL formation and exacerbate cardiovascular risk.<sup>18,19</sup>

Although numerous studies have investigated the relationship between carbohydrate intake and cardiovascular risk factors, most have treated carbohydrates as a homogeneous dietary component without differentiating between refined and unrefined sources.<sup>20,21</sup> Moreover, evidence specifically examining the effects of carbohydrate type on sdLDL remains limited.<sup>22,23</sup> Existing studies in Indonesia are largely observational and have not directly evaluated causal relationships between carbohydrate quality and sdLDL levels in patients with CHD.<sup>24</sup>

Therefore, this study aimed to evaluate the effects of different types of culturally dominant carbohydrate sources on lipid biomarkers, with a particular focus on sdLDL, in patients with CHD. By employing a randomized controlled trial design in a population highly dependent on rice-based diets, this study seeks to generate novel, context-specific evidence to inform dietary recommendations for CHD management in Indonesia.

## METHOD

### Study Design

This study was designed as a randomized controlled trial with a pretest–posttest approach, in which serum sdLDL levels were measured at baseline and after the intervention period. Randomization was performed using a computer-generated random sequence to ensure allocation concealment. Due to the nature of dietary interventions, participant blinding was not feasible. However, laboratory personnel responsible for biochemical analyses were blinded to group allocation to minimize measurement bias. Therefore, the study was conducted as a single-blind randomized controlled trial with blinded outcome assessment.<sup>10,11</sup>

### Study Setting and Population

The study was conducted at the Lubuk Buaya Community Health Center, Padang City, Indonesia, from January to June 2024. The study population consisted of patients aged 35–70 years with physician-diagnosed CHD registered in

the Padang City Health Service database. At study initiation, 112 patients were actively registered at the health center. After eligibility screening, 40 patients met the inclusion criteria and provided written informed consent.

Inclusion criteria included clinically stable CHD patients attending regular outpatient follow-up visits and able to consume an oral diet. Exclusion criteria included severe comorbidities (chronic kidney disease, stroke, or decompensated heart failure), incomplete medical records, acute illness during the study period, or refusal to participate.

### Sample Size Consideration

The sample size was determined based on feasibility considerations and the exploratory nature of this initial dietary intervention study conducted in a primary health care setting. Although a formal sample size calculation was not performed, a total of 40 participants (20 per group) was considered sufficient to provide preliminary evidence on the effect of carbohydrate type on sdLDL levels in patients with CHD.<sup>1-3</sup>

### Randomization and Group Allocation

Eligible participants were randomly assigned to one of two parallel intervention groups using a computer-generated random allocation sequence. Allocation was performed by an independent staff member not involved in recruitment or outcome assessment. Participants were assigned to either the refined carbohydrate group or the complex carbohydrate group.

### Outcome Measures and Variables

The primary outcome was serum sdLDL level. The independent variable was carbohydrate type, classified as refined carbohydrates (white rice) and complex carbohydrates (brown rice). Covariates included age, sex, occupation, history of acute coronary syndrome, and lipid-lowering medication use. Dietary intake was assessed using a validated Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ). Serum sdLDL concentrations were measured using a standardized direct enzymatic assay (Denka Seiken method). All laboratory analyses were performed by certified personnel using calibrated instruments.

### Intervention Procedure

All participants received standardized nutrition counseling at baseline from a trained nutritionist using uniform educational materials. The intervention lasted four weeks. Participants in the refined carbohydrate group consumed white rice, while those in the complex carbohydrate group consumed brown rice. Both groups were instructed to consume two to three servings of rice per day according to their habitual portion sizes.

Carbohydrate classification was based on glycemic index and dietary fiber content from standardized food composition tables. Participants were instructed to maintain their usual dietary patterns without intentionally altering

total energy intake. Dietary adherence was monitored weekly through brief dietary recalls and WhatsApp-based follow-up. Serum sdLDL levels were measured at baseline and at the end of the intervention. Laboratory analysts remained blinded to group allocation.

### Data Analysis

Data analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize participant characteristics. Normality was assessed using the Shapiro–Wilk test, and homogeneity of variance was evaluated using Levene’s test.<sup>20</sup> Within-group differences were analyzed using paired t-tests or Wilcoxon signed-rank tests, as appropriate. Between-group differences were analyzed using independent t-tests or Mann–Whitney U tests based on change scores. Multivariable linear regression was performed to assess the association between carbohydrate type and post-intervention sdLDL levels, adjusting for baseline sdLDL and selected covariates. A p-value < 0.05 was considered statistically significant.

### Ethical Consideration

This study was conducted in accordance with the Declaration of Helsinki and the Indonesian National Guidelines for Health Research Ethics. Ethical approval was obtained from the Health Research Ethics Commission of Universitas Syedza Saintika Padang, Indonesia (Certificate No. 07/UNSYKA/VI/2024). Written informed consent was obtained from all participants.

## RESULTS

### Baseline Characteristics

Baseline characteristics of the participants are presented in Table 1. A total of 40 patients with coronary heart disease were included, with 20 participants allocated to each group. The majority of participants were male and aged 46–60 years. Occupational distribution, history of acute coronary syndrome (ACS), and lipid-lowering medication use were comparable between the refined and complex carbohydrate groups. No statistically significant differences were observed in any baseline variables (all p-values > 0.05), indicating adequate baseline comparability.

### Changes in sdLDL and Lipid Profile Parameters

Pre- and post-intervention changes in sdLDL and lipid profile parameters are presented in Table 2. In the complex carbohydrate group, sdLDL levels decreased significantly after the 4-week intervention (mean change  $-11.45 \pm 4.01$  mg/dL;  $p < 0.001$ ). Significant reductions were also observed in total cholesterol and LDL cholesterol, along with a significant increase in HDL cholesterol (all  $p < 0.05$ ). Triglyceride levels showed a small, non-significant increase. In contrast, the refined carbohydrate group did not show statistically significant changes in sdLDL or other lipid parameters (all  $p > 0.05$ ).

**Table 1.** Baseline Characteristics of Participants by Carbohydrate Group

Characteristics	Complex Carbohydrate	Simple Carbohydrate	p-value
<b>Sex</b>			
Male	12 (60%)	13 (65%)	0.74
Female	8 (40%)	7 (35%)	
<b>Occupation</b>			
Civil servant	4 (20%)	5 (25%)	0.89
Private sector	8 (40%)	7 (35%)	
Other	8 (40%)	8 (40%)	
<b>Age (years)</b>			
30–45	6 (30%)	8 (40%)	0.47
46–60	9 (45%)	10 (50%)	
>60	5 (25%)	2 (10%)	
<b>History of ACS</b>			
UAP	6 (30%)	7 (35%)	0.63
STEMI	8 (40%)	9 (45%)	
NSTEMI	6 (30%)	4 (20%)	
<b>Lipid-lowering medication use</b>			
Yes	15 (75%)	14 (70%)	0.72
No	5 (25%)	6 (30%)	

### Between-Group Comparison of sdLDL Changes

Between-group comparison demonstrated a significantly greater reduction in sdLDL levels in the complex carbohydrate group compared with the refined carbohydrate group ( $p < 0.001$ ) (Table 3).

**Table 3.** Between-group Comparison of Changes in sdLDL Levels

Parameter	Complex	Simple	p-value
$\Delta$ sdLDL (mg/dL)	$-11.45 \pm 4.01$	$-1.30 \pm 3.87$	<0.001

### Correlation Analysis

An exploratory correlation analysis was conducted within the complex carbohydrate group ( $n = 20$ ) to examine associations among lipid parameters (Table 4). Significant negative correlations were observed between sdLDL-related changes and total cholesterol ( $r = -0.62$ ,  $p = 0.003$ ) and LDL cholesterol ( $r = -0.71$ ,  $p < 0.001$ ). A significant positive correlation was found with HDL cholesterol ( $r = 0.68$ ,  $p = 0.001$ ). No significant association was observed with triglyceride levels.

**Table 4.** Correlation Between Lipid Parameters in the Complex Carbohydrate Group

Lipid parameter	r	p-value
Total cholesterol	-0.62	0.003
HDL cholesterol	+0.68	0.001
LDL cholesterol	-0.71	<0.001
Triglycerides	-0.19	0.445

**Table 2.** Pre- and Post-intervention Changes in sdLDL and Lipid Profile Parameters

Variable	Group	Pre	Post	Δ Change	p-value (within-group)
sdLDL (mg/dL)	Complex	46.30 ± 5.12	34.85 ± 4.76	-11.45 ± 4.01	<0.001
	Simple	45.90 ± 5.08	44.60 ± 5.01	-1.30 ± 3.87	0.214
Total cholesterol (mg/dL)	Complex	246.75 ± 12.88	222.90 ± 13.01	-23.85 ± 10.12	<0.001
	Simple	250.60 ± 13.21	246.75 ± 14.12	-3.85 ± 9.44	0.081
HDL cholesterol (mg/dL)	Complex	61.50 ± 2.03	71.40 ± 2.17	+9.90 ± 2.86	<0.001
	Simple	60.80 ± 2.15	62.90 ± 2.32	+2.10 ± 2.74	0.092
LDL cholesterol (mg/dL)	Complex	147.20 ± 12.26	144.25 ± 11.91	-2.95 ± 5.84	0.041
	Simple	146.10 ± 11.89	145.80 ± 12.40	-0.30 ± 5.67	0.733
Triglycerides (mg/dL)	Complex	100.55 ± 7.27	105.55 ± 8.68	+5.00 ± 9.10	0.063
	Simple	101.10 ± 7.45	102.20 ± 8.12	+1.10 ± 8.54	0.412

### Dietary Adherence

Adherence to the dietary intervention is presented in Table 5. Weekly adherence ranged from 84–90% in the complex carbohydrate group and 82–88% in the refined carbohydrate group. Compliance with WhatsApp-based follow-up was 100% in both groups, and recall completion rates exceeded 90%. No participants withdrew from the study, indicating good adherence and supporting the intervention's internal validity.

**Table 5.** Dietary Adherence During the Intervention

Parameter	Complex Carbohydrate	Simple Carbohydrate
Weekly adherence range	84–90%	82–88%
WhatsApp check-in compliance	100%	100%
Recall completion	95%	92%
Drop-out	0	0

## DISCUSSION

This randomized controlled trial demonstrates that improving carbohydrate quality by substituting refined carbohydrates with complex, unrefined sources is associated with favorable changes in atherogenic lipid profiles among patients with CHD. A significant reduction in sdLDL levels was observed in the complex carbohydrate group following the intervention, whereas changes in the refined carbohydrate group were minimal. Given the established role of sdLDL as a key determinant of residual cardiovascular risk, these findings highlight carbohydrate quality as a clinically relevant and modifiable factor in CHD management.<sup>7,8</sup>

The observed reduction in sdLDL is consistent with prior evidence indicating that diets high in refined carbohydrates and glycemic load contribute to adverse lipoprotein remodeling and increased cardiovascular risk.<sup>13,14,25</sup> Several studies have demonstrated that high-glycemic index diets promote the formation of small dense LDL particles through mechanisms involving insulin resistance and hepatic lipid overproduction.<sup>9,10</sup> However, most of these studies were conducted in non-Asian populations or

employed observational designs, limiting their applicability to rice-dependent populations.

In the present study, direct comparison between refined white rice and unrefined brown rice within a randomized controlled design provides stronger causal evidence linking carbohydrate quality to sdLDL modulation. This approach addresses an important gap in the literature, particularly in Indonesia, where rice constitutes the primary dietary carbohydrate source and contributes substantially to daily energy intake.<sup>15-17</sup>

In addition to sdLDL reduction, improvements in conventional lipid parameters—including decreased total cholesterol and LDL cholesterol and increased HDL cholesterol—were observed in the complex carbohydrate group. These findings are in line with previous studies demonstrating the lipid-lowering effects of whole grains and dietary fiber.<sup>18</sup> Triglyceride levels remained relatively unchanged, which may reflect the short duration of the intervention and the high intra-individual variability of triglycerides, as reported in previous metabolic studies.<sup>10</sup>

The biological plausibility of these findings is supported by established metabolic pathways. Complex carbohydrates, characterized by higher fiber content and lower glycemic indices, result in slower glucose absorption, improved insulin sensitivity, and reduced hepatic VLDL production.<sup>9,10</sup> This process limits the conversion of LDL into its small dense subfraction. In contrast, refined carbohydrates induce rapid postprandial glycemic responses and stimulate hepatic de novo lipogenesis, thereby promoting sdLDL formation.<sup>11</sup>

From a clinical perspective, these findings are particularly relevant in Indonesia, where dietary patterns are heavily dominated by refined rice consumption. Promoting substitution with unrefined rice represents a culturally acceptable and cost-effective strategy to improve lipid profiles and reduce atherogenic risk among patients with CHD. Integration of carbohydrate quality into routine dietary counseling may strengthen secondary prevention strategies in primary health care settings.

Several limitations should be acknowledged. The relatively short duration limits interpretation to short-term metabolic effects. In addition, inflammatory biomarkers were not

assessed, restricting a more comprehensive understanding of cardiometabolic pathways. Potential recall bias from dietary assessment and the modest sample size may also limit generalizability. Nevertheless, the randomized design and blinded outcome assessment strengthen the internal validity of the study.

In conclusion, improving carbohydrate quality through the consumption of complex, unrefined carbohydrates significantly reduces sdLDL levels and improves lipid profiles in patients with CHD. This study provides context-specific evidence from a rice-dependent population and supports the role of dietary carbohydrate quality as a key target in cardiovascular risk management. Further large-scale and long-term studies are warranted to confirm these findings.

## CONCLUSIONS AND RECOMMENDATION

This randomized controlled trial demonstrates that consumption of complex, unrefined carbohydrates results in a greater reduction in sdLDL levels than consumption of refined carbohydrates in patients with coronary heart disease. Improvements in total cholesterol, LDL cholesterol, and HDL cholesterol were also observed, while triglyceride levels remained unchanged.

These findings highlight the importance of carbohydrate quality as a modifiable dietary factor in the management of coronary heart disease, particularly in rice-dependent populations. Incorporating complex carbohydrate sources into dietary counseling may complement standard lipid management. However, larger studies with longer follow-up are needed to confirm these findings and support evidence-based dietary recommendations.

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