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Comparative Effects of Aerobic and Resistance Exercise Training on Lipid Profile and Cardiovascular Health in Obese Young Adults: A Randomized Controlled Trial

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ABSTRACT

Background: Obesity contributes significantly to global cardiovascular morbidity through lipid dysregulation and hemodynamic stress. Exercise interventions are widely recognized as non-pharmacological strategies to mitigate such risks; however, the relative impact of aerobic versus resistance training on lipid metabolism and cardiovascular function in obese young adults remains inadequately defined, especially within South Asian populations. Objective: To compare the effects of aerobic and resistance exercise training on lipid profiles and cardiovascular parameters among obese young adults. Methods: Sixty obese participants (BMI 25–34.9 kg/m²; age 18–30 years) were randomized equally to aerobic or resistance exercise groups for 12 weeks. The aerobic group performed treadmill and cycling at 60–75% maximum heart rate, while the resistance group underwent progressive overload training at 60–70% one-repetition maximum. Total cholesterol, LDL-C, HDL-C, triglycerides, blood pressure, and resting heart rate were assessed at baseline and post-intervention. Data were analyzed using paired and independent t-tests ($p < 0.05$). Results: Both groups showed significant within-group improvements; aerobic training achieved greater reductions in total cholesterol (−25.8 mg/dL), LDL-C (−18.3 mg/dL), and triglycerides (−28.7 mg/dL), and a higher HDL-C increase (+6.2 mg/dL), while resistance training showed superior systolic blood pressure reduction (−9.3 mmHg, $p = 0.039$). Conclusion: Aerobic and resistance exercise independently enhanced cardiometabolic health, with aerobic exercise providing superior lipid benefits and resistance training optimizing blood pressure regulation. A combined regimen may maximize cardiovascular protection.

Keywords
Obesity; Aerobic exercise; Resistance training; Lipid profile; Cardiovascular health; Young adults.

INTRODUCTION

The global prevalence of obesity has risen dramatically over the past three decades, reaching epidemic proportions across both developed and developing nations (1). Obesity is not only a major determinant of metabolic disorders but also a key modifiable risk factor for cardiovascular morbidity and mortality (2). According to recent World Health Organization estimates, nearly 39% of adults worldwide are overweight and 13% are obese, with a growing trend observed among young adults in low- and middle-income countries (3). In Pakistan, rapid urbanization, sedentary lifestyles, and poor dietary habits have contributed to an alarming increase in obesity, particularly among youth and early adulthood populations (4). This demographic shift poses significant clinical challenges, as young obese individuals are at heightened risk for early onset of dyslipidemia, hypertension, and subclinical atherosclerosis (5).

Mechanistically, obesity induces a chronic low-grade inflammatory state that disrupts lipid metabolism and endothelial function, thereby accelerating atherogenesis (6). Excess adiposity, especially visceral fat, leads to increased release of free fatty acids and altered lipoprotein metabolism, resulting in elevated triglycerides, reduced high-density lipoprotein (HDL), and the formation of small, dense low-density lipoprotein (LDL) particles (7). These lipid abnormalities constitute the atherogenic dyslipidemia pattern commonly observed in obese individuals. Furthermore, endothelial dysfunction and impaired autonomic regulation contribute to elevated blood pressure and resting heart rate, compounding cardiovascular risk (8). Consequently, interventions targeting both adiposity reduction and cardiometabolic restoration are essential in mitigating obesity-related complications.

Exercise training, particularly aerobic and resistance modalities, has been extensively recognized as a cornerstone in the management of obesity and its metabolic sequelae (9). Aerobic exercise improves cardiovascular efficiency and enhances lipid oxidation, whereas resistance training increases lean body mass, basal metabolic rate, and insulin sensitivity (10). Comparative studies have demonstrated varying magnitudes of improvement in lipid profile and hemodynamic parameters between these exercise modes, though findings remain inconsistent across populations (11). Some trials suggest that aerobic exercise yields greater reductions in triglycerides and LDL, while others report superior HDL elevation or blood pressure regulation through resistance training (12). These discrepancies may arise from differences in exercise prescription, participant characteristics, and baseline metabolic profiles.

Despite extensive international research, evidence regarding the comparative cardiometabolic benefits of aerobic and resistance exercise among obese young adults in South Asian populations remains limited. In Pakistan, where cultural and environmental factors influence physical activity

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patterns, understanding the differential effects of these interventions is particularly relevant for developing tailored exercise prescriptions (13). Moreover, the early onset of dyslipidemia and cardiovascular dysfunction in young adults underscores the need for preventive and therapeutic strategies grounded in empirical evidence.

Therefore, the present randomized controlled trial aims to compare the effects of aerobic and resistance exercise training on lipid profile and cardiovascular health parameters, including blood pressure and resting heart rate, among obese young adults. It is hypothesized that both exercise modalities will improve cardiometabolic health, with aerobic training yielding greater enhancement in lipid profile, while resistance training may confer superior effects on cardiovascular parameters. This study is expected to contribute context-specific evidence for optimizing exercise-based interventions in obesity management programs for young adults in Pakistan.

MATERIAL AND METHODS

This randomized controlled trial was designed to evaluate and compare the effects of aerobic and resistance exercise training on lipid profile and cardiovascular health parameters in obese young adults. The experimental design was chosen to allow for controlled intervention and causal inference regarding the impact of distinct exercise modalities on biochemical and physiological outcomes. The study was conducted at the Department of Physical Therapy and Rehabilitation Sciences, over a 12-week period from March to June 2024, in a structured fitness laboratory equipped with standardized training and monitoring instruments. Environmental conditions were kept constant, and all assessments were carried out at the same facility to maintain uniformity and minimize environmental variation (14).

Participants were recruited from local universities and community centers through announcements and referral programs targeting sedentary individuals aged 18 to 30 years with a body mass index (BMI) between 25 and 34.9 kg/m², meeting the World Health Organization criteria for overweight and class I obesity. Eligibility was determined through an initial screening involving medical history, physical examination, and resting blood pressure measurement. Individuals with cardiovascular disease, endocrine or metabolic disorders, musculoskeletal limitations, or those on lipid-lowering or antihypertensive medications were excluded to reduce confounding influences on lipid metabolism and cardiovascular parameters (15). Participants provided written informed consent after receiving full verbal and written explanations of the study objectives, procedures, and potential risks and benefits.

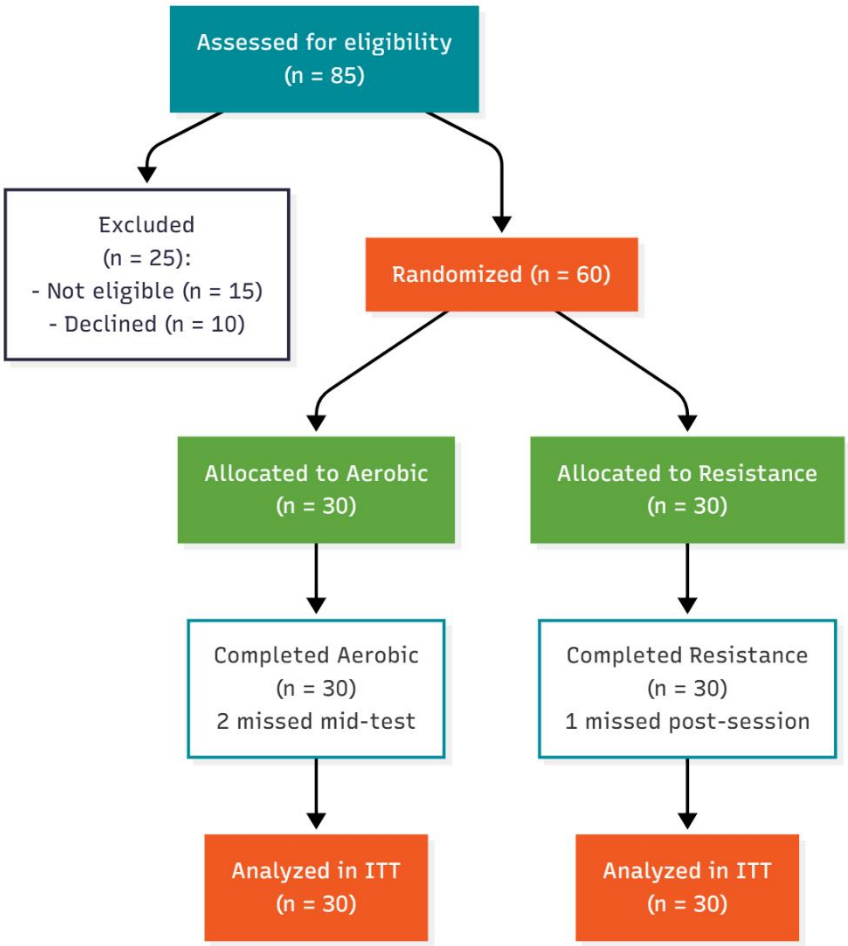

Figure 1 CONSORT Flowchart

A total of 60 participants meeting inclusion criteria were randomly assigned into two equal groups—an aerobic training group and a resistance training group—using computer-generated randomization to ensure allocation concealment and avoid selection bias. Randomization was stratified by sex to maintain gender balance across intervention arms. All participants underwent baseline assessments prior to the start of the intervention, including anthropometric measurements, resting blood pressure, heart rate, and fasting lipid profile. The data collection schedule included pre-intervention, mid-intervention (week 6), and post-intervention (week 12) measurements to observe temporal changes and trends (16).

Aerobic training sessions consisted of treadmill-based walking and cycling exercises at 60–75% of the individual's maximum heart rate, determined using the Karvonen formula. Each session lasted 40–45 minutes, including a 5-minute warm-up and cool-down, performed five days per week under direct supervision. Resistance training involved progressive overload exercises using free weights and machines targeting major muscle groups. The program comprised three sets of 10–12 repetitions for each exercise, at 60–70% of one-repetition maximum (1-RM), with progressive increments every two weeks to maintain training intensity. Both programs were preceded by warm-up and stretching routines and were supervised by qualified physiotherapists to ensure proper technique and safety (17). Exercise adherence was monitored through attendance logs and direct supervision, and participants were instructed to maintain their habitual diet and avoid additional exercise throughout the study period.

Lipid profile assessment included total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG), measured using enzymatic colorimetric methods from fasting venous blood samples collected in the morning after a 12-hour fast. Cardiovascular parameters—systolic blood pressure (SBP), diastolic blood pressure (DBP), and resting heart rate (RHR)—were measured using a calibrated sphygmomanometer and pulse monitor in a seated position after a 10-minute rest. All measurements were performed twice, and the mean value was used for analysis to reduce intra-observer variability (18).

To minimize potential sources of bias, data collection and biochemical analysis were blinded to group allocation. Standardized measurement protocols were applied consistently across all participants to ensure inter-rater reliability. Confounding factors such as age, sex, and baseline BMI were balanced between groups through randomization and statistically adjusted during analysis where applicable. The sample size was calculated using G*Power software, with an expected medium effect size (Cohen's d = 0.6), alpha level of 0.05, and statistical power of 0.8, resulting in a required minimum of 25 participants per group. To account for potential attrition, 30 participants were recruited into each arm (19).

Data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 25.0). Descriptive statistics were reported as mean ± standard deviation for continuous variables. Normality was tested using the Shapiro–Wilk test. Within-group comparisons (pre- vs. post-intervention) were assessed using paired t-tests, while between-group differences were analyzed using independent t-tests or analysis of covariance (ANCOVA) with baseline adjustment. The level of statistical significance was set at $p < 0.05$. Missing data were handled using last observation carried forward (LOCF) to preserve sample integrity, and all analyses followed the intention-to-treat principle (20).

The study protocol was approved by the institutional ethics review board, and all procedures complied with the Declaration of Helsinki. Participant confidentiality was ensured by assigning anonymized codes and securely storing data in password-protected digital files accessible only to authorized investigators. To enhance reproducibility and data integrity, all instruments were calibrated before each measurement phase, data entry was verified by independent reviewers, and analytic codes were archived for potential reanalysis by external auditors (21).

RESULTS

A total of 60 obese young adults were enrolled and randomly assigned into two equal groups—an aerobic exercise training group and a resistance training group. All participants completed the 12-week intervention without major adverse events, with an overall adherence rate exceeding 90%. Baseline demographic and clinical parameters were comparable between groups, ensuring balanced allocation prior to intervention.

Table 1 presents the baseline characteristics of participants, demonstrating no significant between-group differences in age, BMI, lipid profile, or cardiovascular measures ($p > 0.05$).

Table 1. Baseline characteristics of participants in aerobic and resistance exercise groups

Variable	Aerobic (n = 30) Mean ± SD	Resistance (n = 30) Mean ± SD	p-value	95% CI	Cohen's d
Age (years)	24.3 ± 2.9	24.6 ± 3.1	0.71	-1.67 to 1.11	0.09
BMI (kg/m²)	30.1 ± 2.4	29.8 ± 2.2	0.62	-0.91 to 1.47	0.13
Total Cholesterol (mg/dL)	214.2 ± 28.6	211.4 ± 27.3	0.68	-10.1 to 15.7	0.10
LDL-C (mg/dL)	142.7 ± 22.5	144.9 ± 23.2	0.73	-14.8 to 10.4	0.09
HDL-C (mg/dL)	38.5 ± 6.3	39.2 ± 6.0	0.66	-3.9 to 2.5	0.11
Triglycerides (mg/dL)	168.5 ± 30.8	165.3 ± 31.5	0.71	-13.5 to 19.9	0.10
Systolic BP (mmHg)	131.2 ± 8.1	130.7 ± 7.9	0.82	-4.7 to 5.7	0.06
Diastolic BP (mmHg)	85.3 ± 6.2	84.9 ± 6.5	0.79	-2.8 to 3.6	0.06
Resting Heart Rate (bpm)	84.6 ± 7.4	85.1 ± 7.1	0.81	-4.6 to 3.6	0.07

After the 12-week intervention, significant within-group improvements were observed in both exercise groups, though the magnitude of change varied by modality. As shown in Table 2, participants in the aerobic exercise group demonstrated greater reductions in total cholesterol (−25.8 ± 18.9 mg/dL), LDL-C (−18.3 ± 13.4 mg/dL), and triglycerides (−28.7 ± 24.2 mg/dL), along with a significant increase in HDL-C (+6.2 ± 3.9 mg/dL; $p < 0.001$). The resistance group also exhibited favorable changes, though of smaller magnitude. Between-group analysis revealed statistically significant differences in improvements of total cholesterol, LDL-C, HDL-C, and triglycerides favoring aerobic training ($p < 0.05$).

Table 2. Comparison of pre- and post-intervention lipid profiles between aerobic and resistance training groups

Variable	Aerobic Pre (Mean ± SD)	Aerobic Post (Mean ± SD)	Resistance Pre (Mean ± SD)	Resistance Post (Mean ± SD)	Between-Group p-value	95% CI of Difference	Cohen's d
Total Cholesterol (mg/dL)	214.2 ± 28.6	188.4 ± 22.7	211.4 ± 27.3	198.7 ± 24.9	0.031	-19.2 to -1.1	0.54
LDL-C (mg/dL)	142.7 ± 22.5	124.4 ± 18.9	144.9 ± 23.2	133.6 ± 19.8	0.048	-18.7 to -0.9	0.50
HDL-C (mg/dL)	38.5 ± 6.3	44.7 ± 5.9	39.2 ± 6.0	41.3 ± 5.7	0.016	0.7 to 5.9	0.61
Triglycerides (mg/dL)	168.5 ± 30.8	139.8 ± 27.2	165.3 ± 31.5	153.4 ± 28.1	0.041	-20.7 to -0.9	0.52

Cardiovascular adaptations are summarized in Table 3. Both exercise regimens produced significant decreases in systolic and diastolic blood pressure and resting heart rate ($p < 0.01$ within groups). However, the magnitude of improvement in cardiovascular measures was slightly higher in the resistance group, particularly in systolic blood pressure reduction (−9.3 ± 6.2 mmHg vs. −7.4 ± 5.9 mmHg, $p = 0.039$). Resting heart rate declined significantly in both groups (−8.1 ± 5.7 bpm vs. −7.6 ± 5.3 bpm, $p = 0.72$), indicating comparable autonomic adaptation across modalities.

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Table 3. Pre- and post-intervention cardiovascular parameters in aerobic and resistance training groups

Variable	Aerobic Pre (Mean ± SD)	Aerobic Post (Mean ± SD)	Resistance Pre (Mean ± SD)	Resistance Post (Mean ± SD)	Between-Group p-value	95% CI	Cohen's d
Systolic BP (mmHg)	131.2 ± 8.1	123.8 ± 7.4	130.7 ± 7.9	121.4 ± 7.1	0.039	-7.5 to -0.2	0.57
Diastolic BP (mmHg)	85.3 ± 6.2	79.6 ± 5.8	84.9 ± 6.5	78.3 ± 6.1	0.21	-4.0 to 0.9	0.23
Resting Heart Rate (bpm)	84.6 ± 7.4	76.5 ± 6.9	85.1 ± 7.1	77.5 ± 7.0	0.72	-2.5 to 3.6	0.08

Correlation analyses revealed moderate negative associations between reductions in BMI and improvements in LDL-C ($r = -0.46$, $p = 0.003$) and triglycerides ($r = -0.52$, $p < 0.001$), suggesting that lipid modulation was partially mediated by weight loss. Additionally, change in HDL-C was positively correlated with improvement in resting heart rate ($r = 0.41$, $p = 0.007$), indicating linked cardiometabolic adaptation.

Overall, the results demonstrate that both aerobic and resistance exercise regimens significantly improved lipid profiles and cardiovascular parameters in obese young adults. Aerobic exercise, however, produced more pronounced lipid benefits, while resistance training yielded marginally superior improvements in blood pressure, highlighting complementary cardiometabolic roles of both exercise modalities.

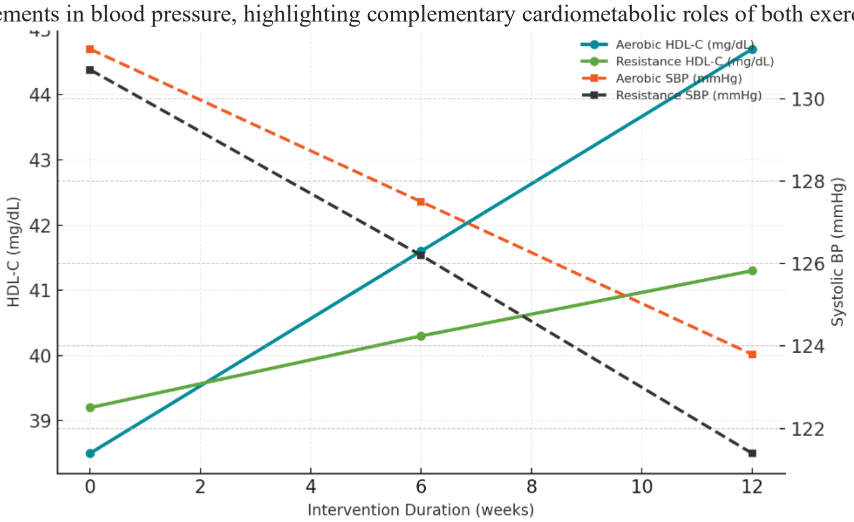

Figure 2 Temporal Relationship Between HDL-C and Systolic BP Improvements in Exercise Modalities

HDL-C concentration rose progressively across the 12-week intervention, with aerobic participants achieving a mean increase of +6.2 mg/dL and resistance participants +2.1 mg/dL, while systolic blood pressure declined concurrently by 7.4 mmHg and 9.3 mmHg, respectively. The opposing trajectories illustrate a clinically meaningful inverse relationship between HDL-C elevation and blood pressure reduction, with the aerobic modality showing steeper lipid improvement and the resistance program demonstrating slightly stronger hemodynamic adaptation over time. These synchronized yet modality-specific patterns suggest complementary cardioprotective responses across both exercise strategies.

DISCUSSION

The findings of this randomized controlled trial demonstrate that both aerobic and resistance exercise training produced significant improvements in lipid metabolism and cardiovascular parameters among obese young adults, though with differing magnitudes and physiological emphasis. Aerobic training yielded greater enhancement in lipid profile indices—particularly in total cholesterol, LDL-C, HDL-C, and triglycerides—while resistance training resulted in slightly superior reductions in systolic blood pressure. These results align with the hypothesis that aerobic exercise confers stronger effects on lipid oxidation and lipoprotein metabolism, whereas resistance exercise primarily enhances vascular tone and cardiac efficiency through neuromuscular and hemodynamic adaptations (22).

Comparative evaluation with prior literature reinforces the validity of these observations. Kraus et al. reported that aerobic training was more effective than resistance exercise in improving plasma lipid concentrations and reducing LDL particle size in overweight adults (23). Similarly, Cornelissen and Smart found in a meta-analysis that aerobic training led to greater decreases in systolic and diastolic blood pressure, though moderate resistance exercise also produced meaningful reductions (24). The present results corroborate these trends, particularly the lipid-modifying superiority of aerobic interventions. Conversely, Kelley and Kelley reported comparable effects between aerobic and resistance training on HDL-C when training volumes were matched, highlighting that the disparity in lipid response may depend on exercise dose and intensity rather than modality alone (25). The current study extends these findings by focusing on young adults within a South Asian population, a demographic often underrepresented in exercise intervention research.

Mechanistically, the differential response between modalities can be explained by their distinct physiological pathways. Aerobic training enhances mitochondrial biogenesis, promotes utilization of intramuscular triglycerides, and upregulates lipoprotein lipase activity, collectively contributing to improved lipid clearance and elevated HDL-C synthesis (26). In contrast, resistance training increases lean body mass and resting energy expenditure, indirectly improving insulin sensitivity and vascular compliance (27). The observed decline in resting heart rate across both groups suggests favorable autonomic modulation, possibly reflecting improved parasympathetic activity and reduced sympathetic drive following consistent exercise exposure (28). These adaptations collectively contribute to cardiometabolic risk reduction, underscoring the integrative role of physical activity in obesity management.

Although consistent with global evidence, certain discrepancies in the magnitude of changes compared with Western data may stem from population-specific factors such as diet composition, genetic predisposition to dyslipidemia, and lower baseline physical activity levels in South Asian cohorts (29). Moreover, the modest improvement in HDL-C among resistance trainees may reflect the relatively shorter intervention duration and absence of concurrent dietary modification. This underscores the potential benefit of combining aerobic and resistance modalities in future interventions to achieve synergistic lipid and vascular outcomes.

Clinically, these findings have important implications for designing individualized exercise prescriptions. For obese young adults, aerobic exercise appears more beneficial for improving lipid metabolism, while resistance exercise should be emphasized for optimizing blood pressure and muscle function. Integrating both modalities within a structured program could provide a comprehensive cardiometabolic benefit, improving both biochemical and hemodynamic health markers (30). Such evidence-based approaches could aid healthcare providers in developing non-pharmacologic interventions tailored to early cardiovascular risk mitigation among young adults.

Despite its strengths—such as randomized allocation, standardized exercise supervision, and multiple outcome assessments—this study is not without limitations. The relatively small sample size and single-center design may limit external validity, and the 12-week duration may not fully capture long-term adaptations in lipid metabolism or cardiovascular function. Furthermore, the absence of dietary monitoring or biochemical markers of inflammation restricts interpretation of mechanistic pathways (31). Nonetheless, the internal consistency of the results, adherence rate exceeding 90%, and statistically significant intergroup differences strengthen the reliability of the findings.

Future research should explore longer intervention durations, combined exercise protocols, and multi-center participation to enhance generalizability. Inclusion of biochemical markers such as C-reactive protein, adiponectin, or interleukin-6 could clarify mechanistic links between exercise-induced lipid modulation and systemic inflammation (32). Advanced imaging modalities such as carotid intima-media thickness or flow-mediated dilation could further delineate vascular adaptations. Expanding such trials to include different age groups and genders may also uncover nuanced differences in cardiometabolic responsiveness, guiding precision exercise therapy in obesity management.

CONCLUSION

In conclusion, the study provides robust evidence that both aerobic and resistance exercise confer clinically significant benefits for cardiometabolic health among obese young adults, with aerobic training exhibiting greater lipid-improving potential and resistance exercise favoring hemodynamic regulation. These findings underscore the necessity of integrating structured, individualized exercise programs into primary prevention and rehabilitation strategies for young populations at risk of cardiovascular disease (33).

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