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The Impact of Nurse-Led Cardiac Rehabilitation on Physiological Risk Parameters: A Systematic Review and Meta-Analysis

ABSTRACT

Background: Nurse-led cardiac rehabilitation (NLCR) is a patient-centered approach for managing cardiovascular disease (CVD) risk factors, but its physiological effects are unclear. This study evaluates NLCR's impact on key physiological parameters, including systolic and diastolic blood pressure (SBP, DBP), body mass index (BMI), body weight, and waist circumference (WC).

Methods: PubMed, Scopus, Embase, Cochrane Library, Web of Science, Google Scholar, ClinicalTrials.gov, and International Clinical Trials Registry Platform were searched from inception to May 30, 2025, to identify randomized controlled trials (RCTs) comparing NLCR to usual care in adult patients with CVDs (e.g., coronary heart disease, acute coronary syndrome, myocardial infarction, chronic heart failure, and atrial fibrillation). Standardized mean differences (SMDs) were pooled using random-effects models, and heterogeneity, subgroup, and sensitivity analyses were performed.

Results: Eleven RCTs (15 records, N = 1146 participants) were included, with mean ages of ~59 years in both intervention (133 male, 415 female) and control groups (126 male, 407 female). Nurse-led cardiac rehabilitation significantly reduced SBP (SMD = −0.20; 95% CI: −0.34 to −0.05) and DBP (SMD = −0.20; 95% CI: −0.37 to −0.03) compared to usual care, with low heterogeneity across studies. A significant reduction in body weight was also observed (SMD = −0.27; 95% CI: −0.46 to −0.07), while changes in BMI and WC did not reach statistical significance. A 12-week follow-up optimized blood pressure improvements, while longer durations better influenced anthropometric outcomes.

Conclusion: Nurse-led cardiac rehabilitation improves hemodynamics and modestly reduces weight in cardiac patients, supporting its inclusion in standard rehab protocols. Optimizing program duration may enhance outcomes. Future research should assess NLCR's components and long-term benefits.

Keywords: Blood pressure, body mass index, cardiac rehabilitation, meta-analysis, nurse led

META-ANALYSIS

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INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality worldwide, accounting for over 17 million deaths annually and imposing a substantial burden on global healthcare systems.[1] Despite significant advances in medical interventions, much of the global CVD burden is driven by modifiable metabolic risk factors, including elevated blood pressure, high body mass index (BMI), and excess weight.[2] High systolic blood pressure (SBP) and increased BMI are among the top contributors to disability-adjusted life years globally, with their impact especially pronounced in low- and middle-income regions.[3] Trends from the Global Burden of Disease studies highlight that while age-standardized death rates from high SBP have shown some decline, the burden due to high BMI continues to rise significantly, particularly in South and Southeast Asia.[4] Alarmingly, metabolic factors such as these contribute to more than 80% of CVD mortality in many regions.[5] Against this backdrop, exploring the potential of innovative, frontline healthcare strategies, such as cardiac rehabilitation (CR), becomes increasingly vital for sustainable, long-term CVD risk management.

Cardiac rehabilitation has emerged as a cornerstone intervention in secondary prevention strategies for CVD disease, offering a multifaceted approach to mitigating physiological risk factors and enhancing long-term patient outcomes.[6] Extensive evidence supports the efficacy of CR programs in improving key CVD health indicators, such as blood pressure, lipid profiles, glycemic control, and anthropometric measures, particularly in patients with coronary artery disease and chronic heart failure.[7] For instance, significant reductions in SBP and diastolic blood pressure (DBP), waist circumference (WC), and low-density lipoprotein (LDL) cholesterol have been observed following structured CR interventions.[8] These improvements not only enhance clinical parameters but also reduce the risk of recurrent cardiac events and overall mortality.[9] Importantly, the benefits of CR are not confined to center-based programs; home-based and hybrid models have also demonstrated promising outcomes, especially in increasing accessibility and adherence during public health disruptions like the COVID-19 pandemic.[10] While the clinical gains of CR are well established, less is known about how program delivery format, particularly nurse-led models, might influence the magnitude of physiological risk reduction.

Nurses play a pivotal role in the delivery of CR, contributing to patient education, risk factor monitoring, and behavioral change facilitation.[11,12] Recent trials comparing nurse-led cardiac rehabilitation (NLCR) to standard care have consistently shown favorable outcomes. Arjunan et al[13] and Su et al[12] reported significant reductions in SBP, DBP, and BMI following structured nurse-led programs involving education and follow-up. Premkumar et al[14] similarly found that NLCR enhanced adherence and led to better BMI and BP control after percutaneous coronary intervention (PCI). Collectively, these findings support NLCR as a feasible and effective model for addressing physiological risk factors in cardiac populations.

Despite increasing evidence on NLCR, no prior synthesis has systematically assessed its effect on physiological risk parameters such as SBP, DBP, BMI, weight, and WC. Given the heterogeneity of individual studies and the growing demand for cost-effective, scalable interventions, a focused meta-analysis is needed. This study aims to bridge that gap by quantitatively evaluating the impact of NLCR compared to usual care. Its findings may guide clinical practice and policy in optimizing secondary prevention strategies.

HIGHLIGHTS

- The meta-analysis demonstrated that nurse-led cardiac rehabilitation significantly reduced both systolic blood pressure (SBP) and diastolic blood pressure, with a standardized mean difference (SMD) of −0.20 for each, indicating its effectiveness in improving hemodynamic stability in cardiac patients.
- Nurse-led cardiac rehabilitation was associated with a statistically significant reduction in body weight (SMD = −0.27), highlighting its potential to support weight management as part of cardiovascular risk factor modification.
- Subgroup analyses revealed that a 12-week follow-up period was most effective for achieving blood pressure improvements, while longer durations showed greater (though non-significant) trends for anthropometric outcomes like body mass index, suggesting tailored program lengths for different goals.
- The study reported low to negligible heterogeneity across most outcomes (e.g., I^2 = 8.62% for SBP), indicating consistent results across diverse settings and reinforcing the reliability of the conclusions.

METHODS

Study Design

This review was conducted and reported in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[15]

Search Strategy

A comprehensive literature search was conducted across major electronic databases, including PubMed/MEDLINE, Scopus, Embase, Cochrane Library, Web of Science, and Google Scholar, as well as clinical trial registries such as ClinicalTrials.gov and the International Clinical Trials Registry Platform, from database inception to May 30, 2025. The search strategy incorporated the MeSH keywords: "Rehabilitation," "Nurses," "Blood Pressure," "Body Weight," "Waist Circumference," "Clinical Trials," and "Body Mass Index." No language or date restrictions were applied. To enhance completeness, relevant gray literature was also reviewed. The entire search strategy was developed and executed by a single researcher, who systematically searched all databases (Supplementary Table 1).

Eligibility Criteria

Following the development of tailored search strategies for each database, 2 independent reviewers imported all retrieved records into EndNote software (version 2019). Duplicate entries were identified and removed using the software's automated function. The remaining articles were then independently screened by the same 2 reviewers to identify studies that met the inclusion criteria. Any discrepancies were resolved through discussion with a third reviewer who supervised the study and made the final decision.

Eligible studies included randomized controlled trials (RCTs) published as full-text articles that compared NLCR with a usual care or non-intervention control group. Studies were required to include at least 1 relevant physiological or anthropometric outcome, such as BMI, WC, blood pressure (SBP or DBP), or body weight. Exclusion criteria were non-randomized studies, reviews, case reports, case series, observational studies (including cohort and case-control designs), laboratory-based experiments, and trials lacking a control group. Additionally, studies were excluded if the intervention was delivered to non-cardiac patients, if nurses were not the primary providers of the rehabilitation program, or if the reported outcomes did not include any anthropometric or physiological parameters of interest.

In this review, NLCR refers to a multifaceted intervention delivered by trained nurses, which may include physical assessments, education on cardiovascular health, lifestyle counseling, risk factor management, and in some cases, supervised exercise.[16]

Quality Assessment

The methodological quality of the included studies was assessed using the revised Cochrane Risk of Bias tool for randomized trials (RoB 2.0). This instrument evaluates 5 key domains of bias, each rated as having a low risk, high risk, or some concerns based on predefined criteria. An overall risk of bias judgment is then derived by synthesizing the assessments across all domains.[17] Quality appraisal was independently conducted by 2 reviewers, with any disagreements resolved through discussion with a third reviewer.

Screening of Studies and Data Extraction Form

Following the selection of eligible studies, data extraction was independently performed by 2 reviewers. Any discrepancies were resolved through discussion with a third investigator who oversaw the study. Data were recorded using Microsoft Excel 2019. Anthropometric and physiological outcomes were extracted based on standardized classifications described in prior literature, including Kim et al,[18] and comprised BMI (kg/m^2), WC (cm), SBP (mm Hg), DBP (mm Hg), and body weight (kg). The final data sheet included study author and year of publication, country, age of intervention, control groups, year of data collection, number of participants in each group before and after the intervention, type of cardiac condition, and relevant physiological parameters.

Statistical Analysis

Data analysis was conducted using STATA software, version 17.0 (StataCorp, College Station, TX, USA). A random-effects model was applied to account for between-study variability and to manage potential heterogeneity. Standard mean difference (SMD) was used as the effect size metric to compare the intervention and control groups, accompanied by corresponding 95% CIs. The mean differences and SDs were derived from pre- and post-intervention values reported in the original studies and calculated using Microsoft Excel.[19] Forest plots were generated to visually present study-specific and pooled effect estimates. Statistical significance was set at a P-value < .05. Heterogeneity was assessed using Cochran's Q test and Higgins' I^2 statistic, with I^2 values interpreted as low (<25%), moderate (25%-50%), or high (>50%) heterogeneity.[20,21] Sensitivity analysis was performed using a leave-one-out approach to examine the robustness of the pooled estimates by sequentially excluding each study. Subgroup analyses were also conducted based on the length of follow-up. Potential publication bias was evaluated through visual inspection of funnel plots and Egger's weighted regression test.[22] A P-value greater than .05 in Egger's test was considered indicative of no significant publication bias.

RESULTS

Study Selection

A total of 1596 records were identified through comprehensive searches of international databases. After removing 210 duplicates, 1386 records remained for title and abstract screening. Following the screening process, 18 full-text articles were assessed for eligibility. Ultimately, 11 RCTs[12-14,16,23-29]

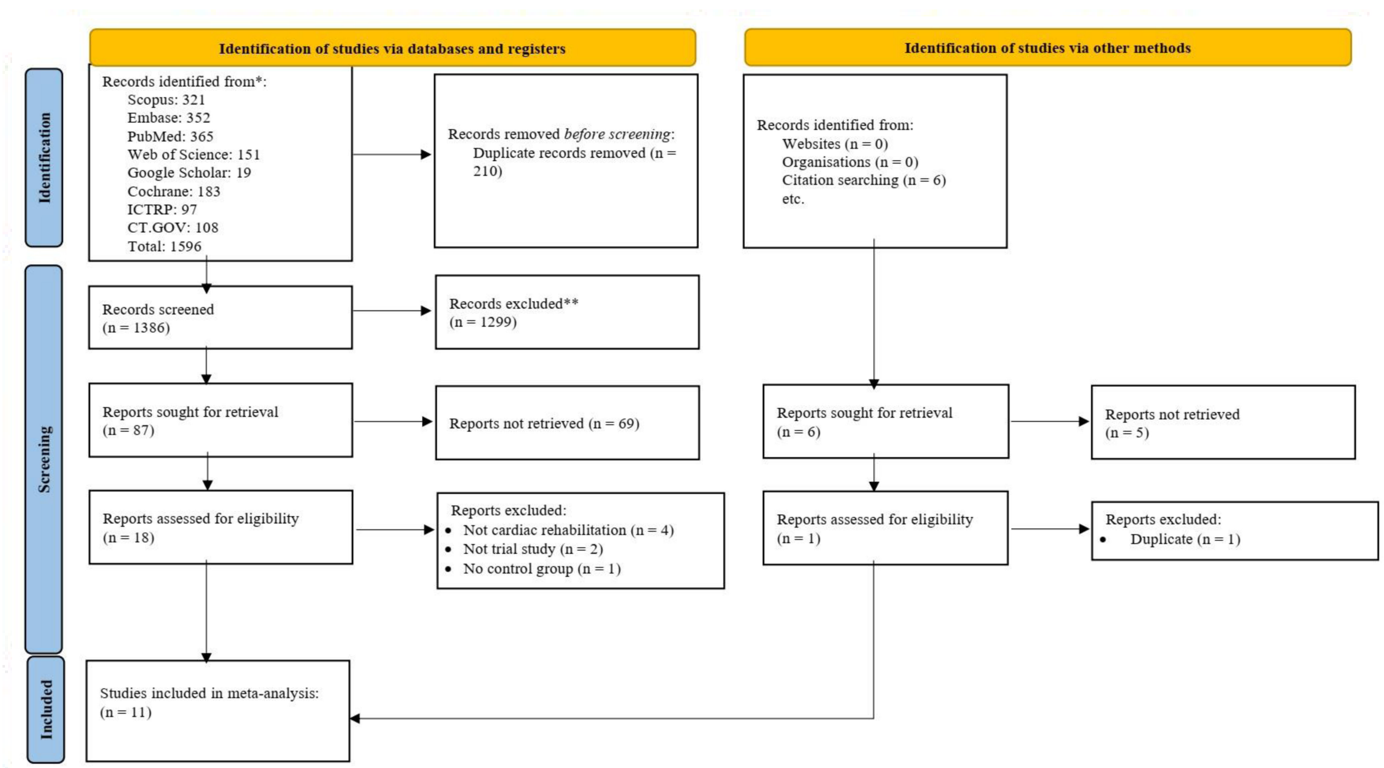

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart.

Table 1. Main Characteristics of Included Studies

Authors	Start Year of Data Collection	End Year of Data Collection	Country	Age of Intervention / Control Group (Mean ± SD)	Female / Male of Intervention Group	Female / Male of Control Group	Rehabilitations Components	Follow-Up Duration	Intensity of Rehabilitation	Patients' Diagnosis	Intervention Group	Control Group	Outcomes
Arjunan et al (2021)[13]	2011	2014	India	NA	22 / 78	21 / 79	Education, exercise training, psychological support, telephonic follow-up	12 weeks	Weekly follow-up, home-based + clinic sessions	Chronic heart failure	100	100	BMI, SBP, and DBP
Fernandez et al (2009)[23]	2006	2006	Australia	57.14 ± 8.96 / 56.41 ± 8.73	8 / 21	3 / 19	Group education sessions, home-based walking program, dietary counseling	8 weeks	Weekly group sessions	Acute coronary syndrome	29	22	BMI, SBP, and DBP
Jiang et al (2006)[24]	2002	2003	China	62.11 ± 7.44 / 61.37 ± 7.61	26 / 57	22 / 62	Individualized education, telephone follow-up, lifestyle counseling	12 weeks / 24 weeks	Weekly calls, in-person education	Coronary heart disease	83	84	Weight, SBP, and DBP
Köhler et al (2020)[25]	2011	2015	Sweden	68.5 ± 9.2 / 68.9 ± 7.7	19 / 60	16 / 62	Nurse-led home visits, medication management, lifestyle counseling, motivational interviewing, monitoring adherence	48 weeks	Fortnightly home visits + medication check-ins	Coronary heart disease	79	78	BMI, Weight, WC, SBP, and DBP
Ponpinij et al (2017)[16]	2017	2017	Thailand	NA	6 / 33	4 / 29	Risk assessment, personalized education, goal setting, action planning, self-monitoring, ongoing follow-up	16 weeks	Weekly structured sessions with follow-up support	Acute coronary syndrome	36	40	BMI, SBP, and DBP
Premkumar et al (2022)[14]	2017	2017	India	NA	1 / 30	9 / 22	Discharge education, dietary and medication adherence counseling, telephone follow-up	12 weeks	Post-discharge education + biweekly phone calls	Cardiovascular disease	31	31	BMI, Weight, SBP, and DBP

(*Continued*)

Table 1. Main Characteristics of Included Studies (*Continued*)

Authors	Start Year of Data Collection	End Year of Data Collection	Country	Age of Intervention / Control Group (Mean ± SD)	Female / Male of Intervention Group	Female / Male of Control Group	Rehabilitations Components	Follow-Up Duration	Intensity of Rehabilitation	Patients' Diagnosis	Intervention Group	Control Group	Outcomes
Su et al (2021)[12]	2019	2019	China	55.53 ± 7.3 / 56.03 ± 7.02	11 / 62	13 / 60	Exercise training, diet, medication education, psychological support, motivational interviewing, follow-up phone calls	6 weeks / 12 weeks	Supervised sessions + follow-up calls	Coronary heart disease	73	73	BMI, WC, SBP, and DBP
Vanharen et al (2023)[26]	2021	2021	Belgium	65.9 ± 10.9 / 64.7 ± 10.2	14 / 18	15 / 18	Group education, physical activity guidance, nutritional advice, smoking cessation counseling, psychological support, telephonic support	4 weeks / 24 weeks	Weekly group education + telephonic follow-up	Arterial fibrillation	36	33	BMI
Wohlfahrt et al (2024)[27]	2019	2023	Czech Republic	51.6 ± 10.2 / 51.2 ± 10.5	3 / 28	3 / 27	Exercise training, cardiovascular risk education, dietary advice, psychological counseling, regular nurse follow-up	12 weeks	Supervised exercise + regular nurse monitoring	Myocardial infarction	31	30	Weight
Jiegang et al (2019)[28]	2017	2017	China	53.3 ± 4.2 / 54.6 ± 4.7	22 / 21	18 / 24	Online intake, individualized education by nurse/dietitian/ exercise specialist, BP and HR monitoring, web-based tracking	12 weeks	Self-directed online modules + nurse contact as needed	Coronary heart disease	43	42	BMI, SBP, and DBP
Zutz et al (2006)[29]	2006	2006	Canada	58.0 ± 4.0 / 59.0 ± 12.0	1 / 7	2 / 5	Education based on Theory of Reasoned Action, lifestyle goal setting, smoking/ alcohol cessation, nutrition, exercise promotion	12 weeks	Weekly nurse-led sessions with lifestyle counseling	Cardiovascular disease	8	7	BMI, WC, SBP, and DBP

BMI, body mass imdex; DBP, diastolic blood pressure; NA, not available; SBP, systolic blood pressure; WC, waist circumference.

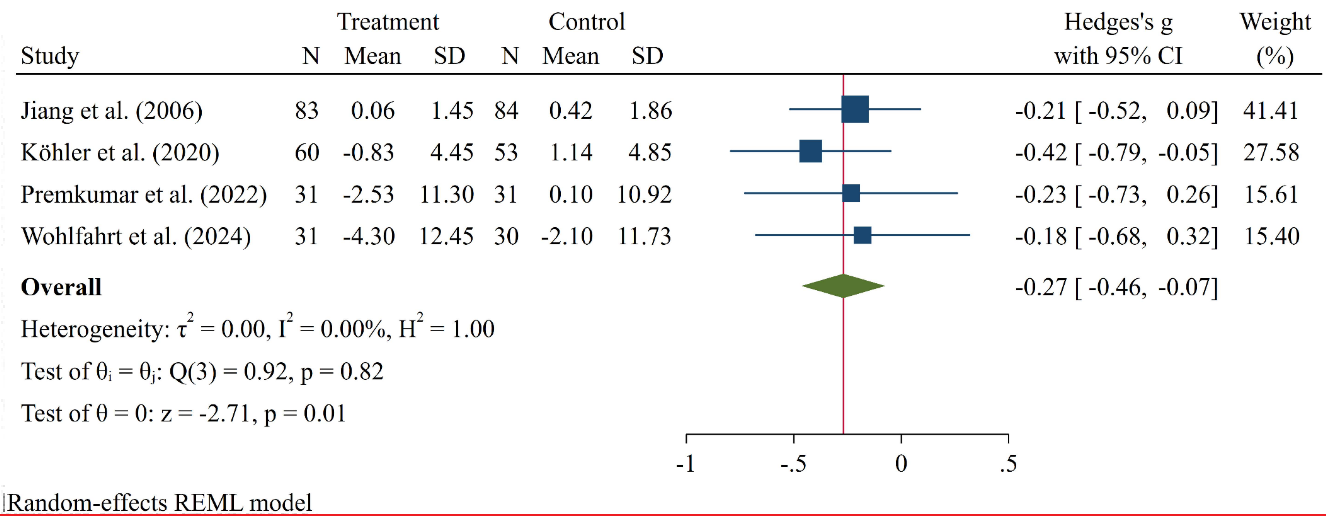

Figure 2. Forest plot of the impact of nurse-led cardiac rehabilitation vs. control on body weight.

comprising 15 records met the inclusion criteria and were included in the final quantitative synthesis (Figure 1).

Study Characteristics

All eleven included studies were RCTs conducted in patients with CVD. The publication years ranged from 2006 to 2023, with data collection periods spanning from 2002 to 2021. The mean ages of participants in the intervention and control groups were generally comparable across studies. The majority of the trials originated from China (n = 3) and India (n = 2). Most interventions lasted approximately 12 weeks, with follow-up commonly delivered weekly or biweekly through telephone or in-person nurse contact. The NLCR programs typically included patient education, supervised or guided exercise, dietary and medication counseling, psychological support, and structured follow-up. Additional study characteristics are summarized in Table 1. Regarding methodological quality, 3 studies were rated as having "some concerns" in risk of bias, while the remaining 8 studies were judged to have a low risk of bias (Supplementary Table 2).

RESULTS OF THE META-ANALYSIS FOR IMPACT OF NURSE-LED CARDIAC REHABILITATION ON PHYSIOLOGICAL PARAMETERS

Results of the Meta-Analysis for Impact of Nurse-Led Cardiac Rehabilitation on Body Weight

The meta-analysis of 4 RCTs revealed a significant reduction in body weight among participants receiving NLCR compared to controls (SMD = −0.27; 95% CI: −0.46 to −0.07). Importantly, the studies showed no heterogeneity (I^2 = 0.0%, P = .82), indicating high consistency across trials (Figure 2).

Results of the Meta-Analysis for Impact of Nurse-Led Cardiac Rehabilitation on Body Mass Index

In terms of BMI, pooled data from 9 RCTs demonstrated a non-significant decline in the intervention group relative to controls (SMD = −0.09; 95% CI: −0.24 to 0.07). Again, heterogeneity was negligible (I^2 = 13.41%, P = .52), supporting the robustness of this finding (Figure 3).

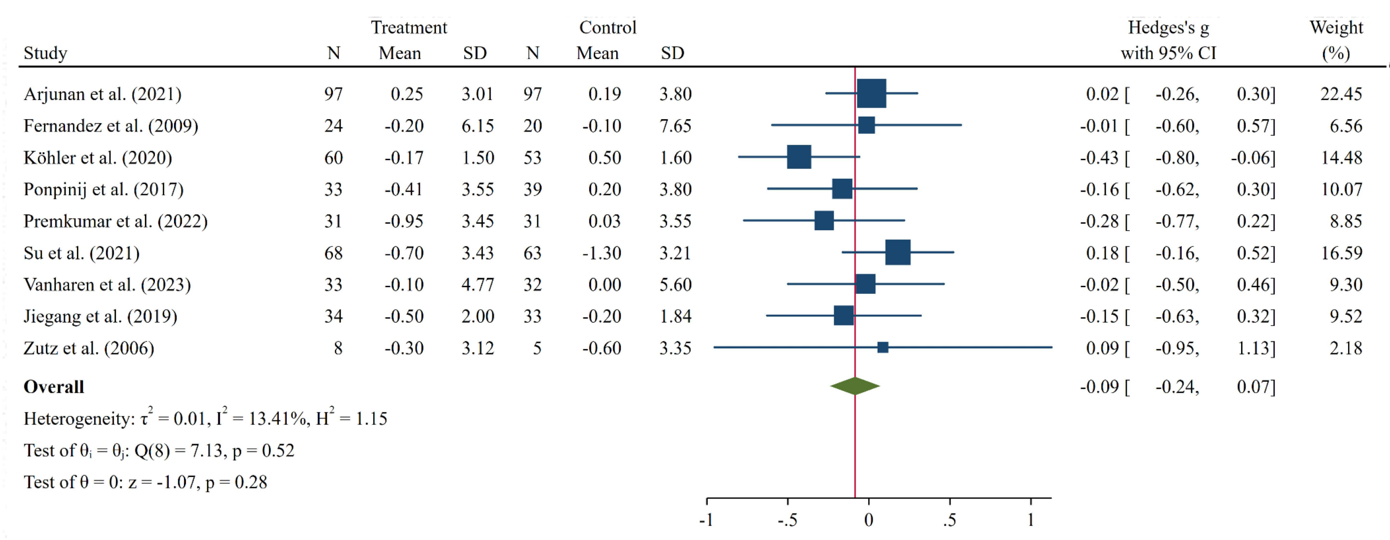

Figure 3. Forest plot of the impact of nurse-led cardiac rehabilitation vs. control on body mass index.

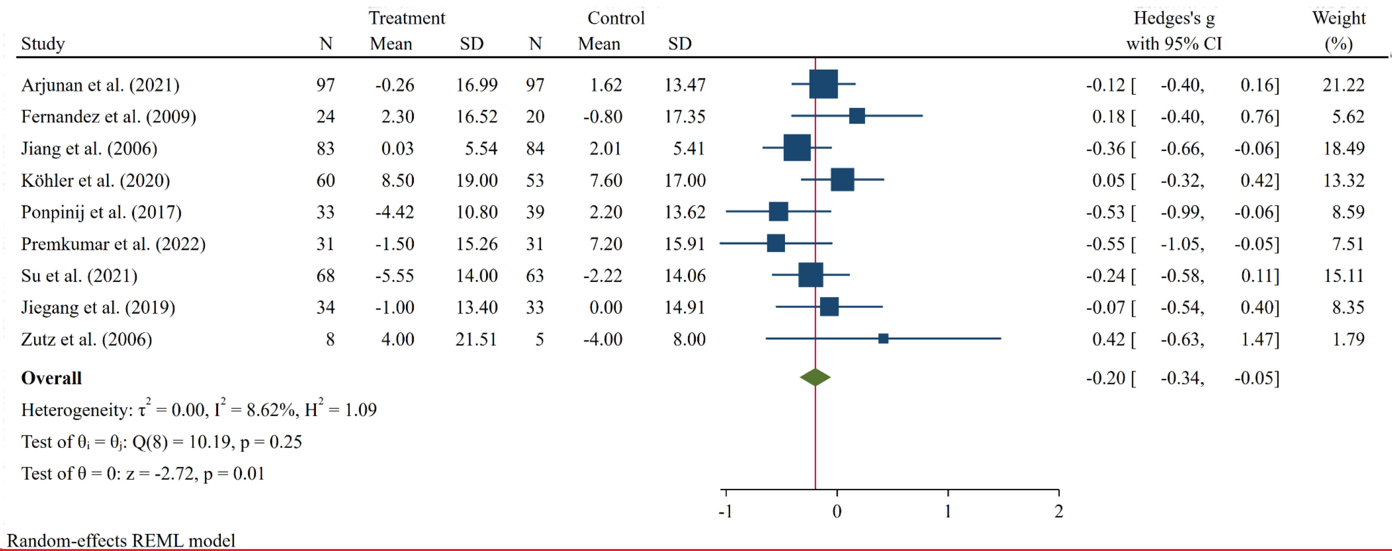

Figure 4. Forest plot of the impact of nurse-led cardiac rehabilitation vs. control on systolic blood pressure.

Results of the Meta-Analysis for Impact of Nurse-Led Cardiac Rehabilitation on Systolic Blood Pressure

For SBP, the integration of 9 trials highlighted a statistically meaningful reduction in the NLCR group (SMD = −0.20; 95% CI: −0.34 to −0.05), with low between-study heterogeneity (I^2 = 8.62%, P = .25). This suggests that the intervention consistently contributed to SBP control across different settings (Figure 4).

Results of the Meta-Analysis for Impact of Nurse-Led Cardiac Rehabilitation on Diastolic Blood Pressure

Similarly, analysis of DBP indicated a significant decrease following NLCR (SMD = −0.20; 95% CI: −0.37 to −0.03). Although moderate heterogeneity was observed (I^2 = 33.10%, P = .12), the direction and magnitude of effect were relatively stable among included studies (Figure 5).

Results of the Meta-Analysis for Impact of Nurse-Led Cardiac Rehabilitation on Waist Circumference

Regarding WC, results from 3 studies showed a non-significant trend toward reduction in the intervention group compared to controls (SMD = −0.26; 95% CI: −0.68 to 0.16) (Supplementary Figure 1).

Subgroup Analysis Based on Follow-Up Duration

Subgroup analyses based on follow-up duration revealed temporal trends in the effectiveness of NLCR on key physiological outcomes. For BMI, no statistically significant effect

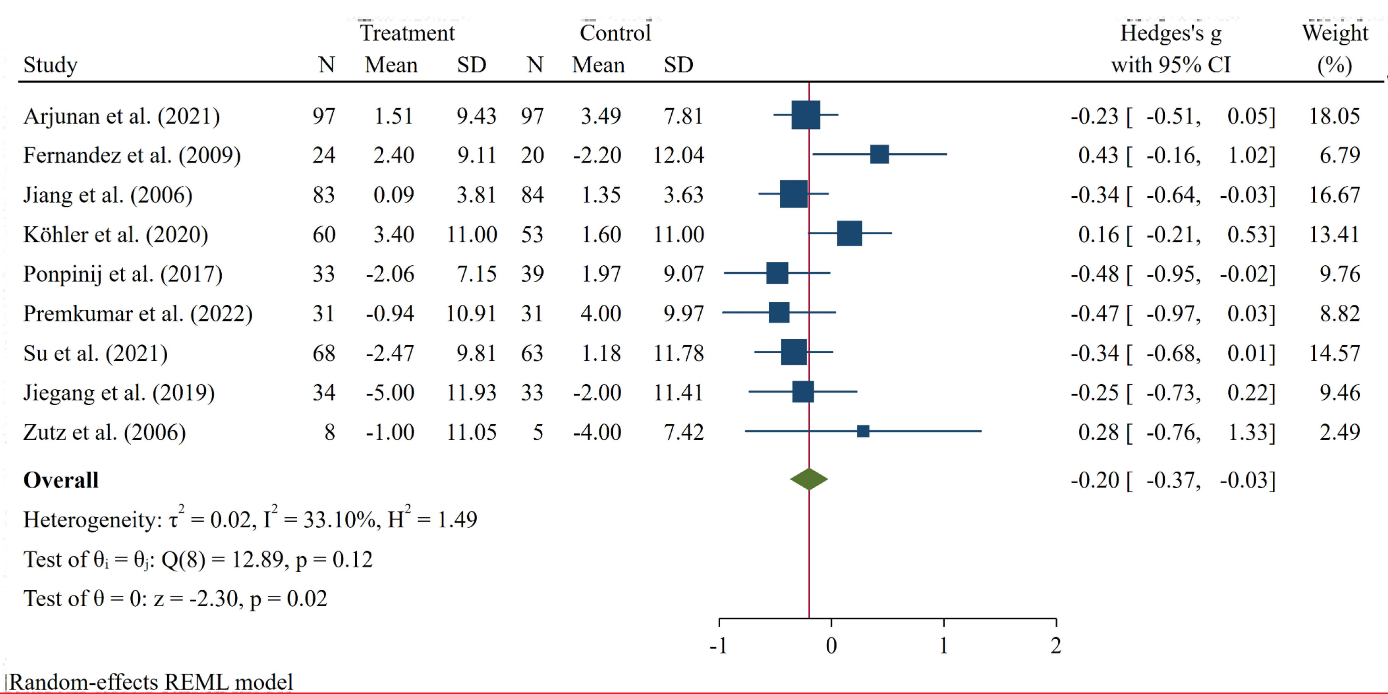

Figure 5. Forest plot of the impact of nurse-led cardiac rehabilitation vs. control on diastolic blood pressure.

was observed across any time interval, although the greatest reduction was noted in studies with more than 12 weeks of follow-up (SMD = −0.24, 95% CI: −0.50 to 0.02) (Supplementary Figure 2). In contrast, SBP showed a significant decrease in the 12-week follow-up (SMD = −0.29, 95% CI: −0.46 to −0.11), while no meaningful effect was detected in studies with shorter or longer durations (Supplementary Figure 3). Similarly, a significant reduction in DBP was observed only in the 12-week follow-up group (SMD = −0.27, 95% CI: −0.43 to −0.12) (Supplementary Figure 4). Heterogeneity was low to negligible in most subgroups, except for DBP in studies with follow-up durations under 12 weeks, which exhibited substantial heterogeneity (I^2 = 79.28%).

Publication Bias and Sensitivity Analysis

Leave-one-out sensitivity analyses revealed that although the omission of certain individual studies slightly influenced the statistical significance of the pooled estimates for BMI, SBP, and DBP, the overall direction of effect consistently favored a reduction in these outcomes, indicating the robustness of the observed negative effect sizes (Supplementary Figure 5).

Finally, funnel plots were generated to assess potential publication bias for the 3 parameters: BMI, SBP, and DBP. Egger's test results indicated no evidence of publication bias in any of the parameters; BMI (bias = −0.28, SE = 1.209, *P* = .817), SBP (bias = 0.98, SE = 1.166, *P* = .400), and DBP (bias = 1.40, SE = 1.246, *P* = .262) (Supplementary Figure 6).

DISCUSSION

The findings of this study demonstrated that NLCR resulted in a modest but statistically significant reduction in both SBP and DBP, indicating its potential value in managing hemodynamic stability. While the reduction in body weight was also significant, the effects on BMI and WC were not statistically meaningful, though the direction of change consistently favored the intervention. Notably, heterogeneity across included studies was generally low, suggesting a high level of consistency in the observed effects despite variations in settings and populations. Subgroup analyses revealed that the benefits of NLCR on blood pressure were most prominent at 12-week follow-up, highlighting the importance of sustained engagement with rehabilitation programs. These results provide a coherent picture of the physiological benefits of NLCR and lay a solid foundation for further interpretation and application in clinical practice.

The observed reductions in SBP and DBP among participants receiving NLCR are aligned with a growing body of literature emphasizing the role of structured, nurse-managed programs in CVD risk factor control. Such interventions are typically characterized by patient-centered education, individualized follow-up, lifestyle counseling, and medication adherence monitoring, components that collectively enhance hemodynamic stability and health outcomes.[30-33]

Specific studies within this review support these pooled findings. For SBP, Arjunan et al[13] demonstrated a modest decline within the NLCR group (MD = −0.26), contrasted with a slight increase in the control group (MD = +1.62). Ponpinij et al[16] reported a more pronounced reduction in the intervention group (MD = −4.42), while the control group again showed an increase (MD = +2.20). These patterns strongly reflect the results of this meta-analysis, where NLCR was associated with a statistically significant and consistent reduction in SBP (SMD = −0.20; 95% CI: −0.34 to −0.05). These blood pressure improvements may be explained by the regular monitoring and counseling provided by nurses, which enhances medication adherence and lifestyle compliance. Nurse-led programs often emphasize salt reduction, smoking cessation, and stress management, each of which independently contributes to lowering both systolic and diastolic pressure. Furthermore, patient education enhances self-efficacy, enabling better home-based monitoring and early response to hypertensive symptoms.[24] Conversely, Zutz et al[29] observed a greater reduction in the control group, a discrepancy likely due to their small sample size (fewer than 10 participants per group) and different follow-up duration, reducing the reliability of their effect estimates. The analysis of DBP revealed similar findings. Premkumar et al[14] found a decrease in DBP within the NLCR group (MD = −0.94), while controls experienced an increase (MD = +4.00). Su et al[12] also observed a meaningful reduction in the intervention group (MD = −2.47) compared to a rise in the control arm (MD = +1.18). Although Fernandez et al[23] failed to detect a benefit for NLCR in DBP reduction, the study's brief follow-up and limited power may have obscured potential effects. Overall, the pooled estimate for DBP mirrored these trends, with a significant reduction associated with NLCR (SMD = −0.20; 95% CI: −0.37 to −0.03). In terms of anthropometric indices, the findings were more nuanced. Several trials, namely those conducted by Ponpinij et al,[16] Premkumar et al,[14] and Vanharen et al,[26] reported favorable changes in BMI for NLCR participants, with reductions approaching or exceeding 1 unit, while the control groups either remained static or showed increases. These results align with prior evidence suggesting that nurse-led programs support weight management through behavioral strategies and motivational interviewing.[24,25] These anthropometric improvements may arise from behaviorally-oriented interventions such as motivational interviewing, goal setting, and dietary coaching, which are core components of many NLCR models. Nurses provide frequent and personalized contact, which helps sustain engagement in physical activity and healthy eating over time. Moreover, involving patients in self-monitoring of weight and WC encourages accountability and facilitates earlier behavior modification.[34] Nonetheless, this meta-analysis indicated a non-significant effect of NLCR on BMI (SMD = −0.09; 95% CI: −0.24 to 0.07). This could be attributed to variability in program duration, frequency of patient contact, or heterogeneity in baseline BMI levels across trials. Additionally, while the direction of change in WC favored the intervention, the limited number of studies (n = 3) and their inconsistent findings likely contributed to the non-significant pooled estimate. Despite these plausible mechanisms, inconsistencies in program intensity, patient adherence, and baseline obesity levels across studies may have attenuated the statistical signal. Additionally, behavioral interventions often require longer durations to produce measurable changes in anthropometric indicators, suggesting that follow-up duration may be a limiting factor in detecting significant changes. Taken together, these findings reinforce the clinical relevance of NLCR in reducing key physiological risk parameters, particularly blood pressure and weight, even though effects on BMI and WC were less robust. The consistency in effect direction across all outcomes underscores the potential of nurse-led models to deliver meaningful CVD risk reduction through tailored, accessible, and scalable interventions. Future studies should explore the dose–response relationship between intervention intensity and clinical outcomes, as well as identify which specific behavioral strategies within NLCR are most effective. A better understanding of how nurse-patient interactions influence physiological parameters may also guide the development of optimized, personalized rehabilitation models.

Subgroup analyses based on follow-up duration highlighted time-sensitive trends in the physiological benefits of NLCR. Notably, both SBP and DBP showed statistically significant improvements in studies with 12-week follow-ups. In contrast, studies with follow-ups shorter or longer than 12 weeks demonstrated no significant change in either outcome. These findings suggest that a structured 12-week intervention period may represent an optimal threshold for achieving hemodynamic benefits through NLCR. This is consistent with studies such as Su et al[12] and Kim et al,[18] where marked reductions in SBP and DBP were observed after approximately 3 months of intervention. In Jiang et al,[24] a greater reduction in DBP was also seen by week 24 compared to week 12, though SBP showed more variability, indicating that different parameters may respond to intervention timing in distinct ways. This timing effect has been supported in broader research as well. For instance, Morrin et al[35] demonstrated that physical health outcomes such as blood pressure improved significantly within the first 3 months of CR and plateaued thereafter, indicating a diminishing return from extending CR duration for certain outcomes. Similarly, El Missiri et al[36] found that a 12-week CR program yielded substantial reductions in both SBP and DBP, particularly among obese patients. Regarding BMI, no subgroup achieved statistical significance, although greater reductions were observed in studies with follow-up durations beyond 12 weeks (SMD = −0.24, 95% CI: −0.50 to 0.02). This pattern aligns with physiological expectations, as anthropometric changes typically require longer durations of behavioral consistency to manifest. For example, Vanharen et al[26] and Kim et al[18] both reported progressive improvements in BMI and WC as follow-up periods extended from 4 to 24 weeks. Another study by Bubnova and Aronov demonstrated that BMI significantly decreased only after extended rehabilitation durations beyond 6 months.[37] Similarly, Shubair et al[38] found that despite stable weight, longer CR durations consistently improved BMI-related metabolic profiles. Altogether, these subgroup findings underscore the importance of tailoring the duration of NLCR to the outcome of interest. While blood pressure may respond optimally within a 12-week period, more sustained interventions are likely needed to impact anthropometric indicators such as BMI in a clinically meaningful way.

This systematic review and meta-analysis offers several notable strengths that enhance the validity and reliability of its findings. First, the comprehensive and multi-database search strategy minimized the risk of publication bias and ensured a wide coverage of relevant studies. Second, the exclusive inclusion of RCTs strengthens the internal validity of the pooled estimates by reducing confounding and selection bias. Third, the observed heterogeneity was low or negligible across most analyses, indicating consistent effects across studies and populations. This consistency adds robustness to the interpretation of findings and supports the generalizability of NLCR effects on physiological parameters.

Despite these strengths, several limitations should be acknowledged. A relatively small number of studies contributed data to some specific outcomes, such as WC and body weight, potentially limiting statistical power and the precision of effect estimates in these domains. Additionally, variability in intervention protocols, duration, and the intensity of NLCR across studies may have introduced clinical heterogeneity that could not be fully captured in subgroup analyses. The lack of standardized reporting on components such as nurse training, patient adherence, and behavioral components also limits the ability to identify which aspects of NLCR are most effective. Finally, while publication bias was not detected statistically, the small number of included studies still warrants cautious interpretation.

CONCLUSION

In summary, this systematic review and meta-analysis provides compelling evidence that NLCR yields significant improvements in CVD risk parameters, particularly in reducing SBP and DBP. Although the intervention was associated with modest reductions in body weight and BMI, these effects were not consistently statistically significant, indicating that longer intervention durations or more targeted lifestyle components may be necessary to achieve substantial anthropometric change. The 12-weeks follow-up period emerged as a particularly effective window for capturing hemodynamic improvements. These findings reinforce the growing recognition of nurses' central role in the multidisciplinary management of cardiac patients and support the integration of NLCR into standard rehabilitation protocols. By tailoring program duration and structure to specific outcomes, NLCR may serve as a scalable and patient-centered approach to long-term CVD risk reduction.

Availability of data and materials: We included all data in the main manuscript and supplementary files. Further data that supports the findings of this study is available from the corresponding authors upon reasonable request.

Ethics Committee Approval: Not applicable. This study is a systematic review and meta-analysis of previous ublished data and no needs to ethical approval.

Peer-review: Externally peer-reviewed.

Author Contributions: W.Z., O.W., X.N., and X.W. conceived and designed this study. W.Z. and O.W. searched databases and collected data from included studies. W.Z. and X.N. performed the statistical

analyses. W.Z., O.W., X.N., and X.W. wrote, revised, and confirmed the original draft of the manuscript. All authors reviewed and approved the final version before submission.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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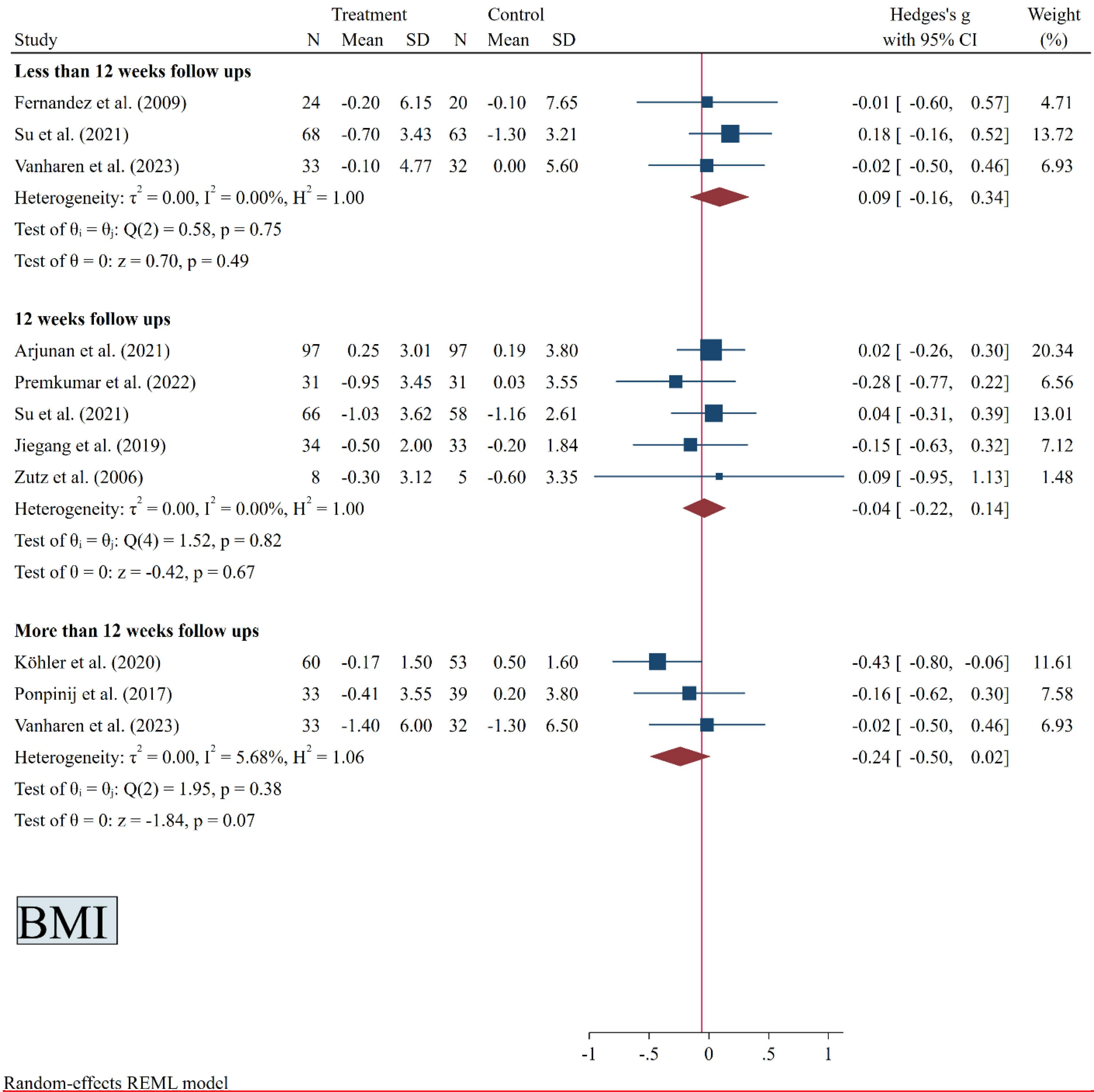
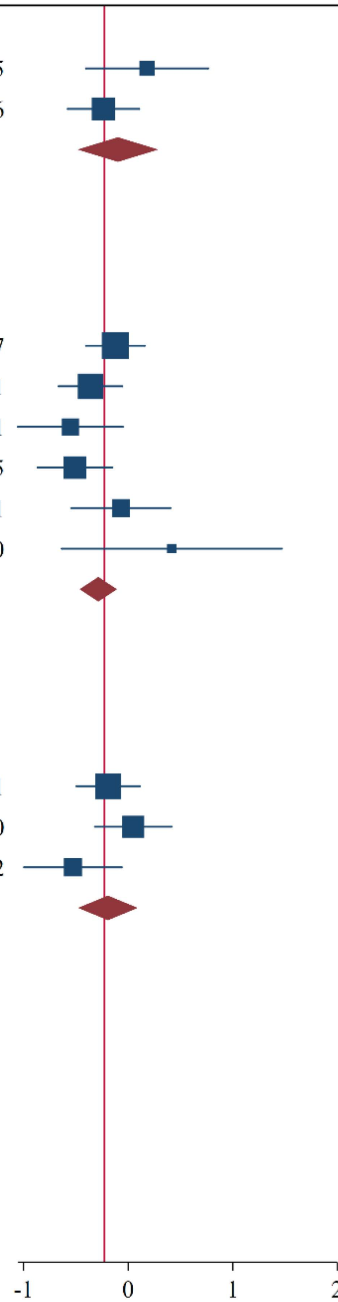


Supplementary Figure 1. Forest plot of the impact of NLCR vs. control on BMI based on follow up.

Study	Treatment N	Treatment Mean	Treatment SD	Control N	Control Mean	Control SD	Hedges's g with 95% CI	Weight (%)
Less than 12 weeks follow ups								
Fernandez et al. (2009)	24	2.30	16.52	20	-0.80	17.35	0.18 [-0.40, 0.76]	4.24
Su et al. (2021)	68	-5.55	14.00	63	-2.22	14.06	-0.24 [-0.58, 0.11]	11.38
Heterogeneity: $\tau^2 = 0.03$, $I^2 = 31.15\%$, $H^2 = 1.45$							-0.10 [-0.48, 0.29]	
Test of $\theta_i = \theta_j$: Q(1) = 1.45, p = 0.23								
Test of $\theta = 0$: z = -0.50, p = 0.62								
12 weeks follow ups								
Arjunan et al. (2021)	97	-0.26	16.99	97	1.62	13.47	-0.12 [-0.40, 0.16]	15.97
Jiang et al. (2006)	83	0.03	5.54	84	2.01	5.41	-0.36 [-0.66, -0.06]	13.92
Premkumar et al. (2022)	31	-1.50	15.26	31	7.20	15.91	-0.55 [-1.05, -0.05]	5.67
Su et al. (2021)	66	-6.52	13.92	58	0.81	14.75	-0.51 [-0.87, -0.15]	10.59
Jiegang et al. (2019)	34	-1.00	13.40	33	0.00	14.91	-0.07 [-0.54, 0.40]	6.30
Zutz et al. (2006)	8	4.00	21.51	5	-4.00	8.00	0.42 [-0.63, 1.47]	1.35
Heterogeneity: $\tau^2 = 0.01$, $I^2 = 16.76\%$, $H^2 = 1.20$							-0.29 [-0.46, -0.11]	
Test of $\theta_i = \theta_j$: Q(5) = 6.64, p = 0.25								
Test of $\theta = 0$: z = -3.15, p = 0.00								
More than 12 weeks follow ups								
Jiang et al. (2006)	83	1.18	7.78	84	2.67	7.81	-0.19 [-0.49, 0.11]	14.06
Köhler et al. (2020)	60	8.50	19.00	53	7.60	17.00	0.05 [-0.32, 0.42]	10.04
Ponpinij et al. (2017)	33	-4.42	10.80	39	2.20	13.62	-0.53 [-0.99, -0.06]	6.48
Heterogeneity: $\tau^2 = 0.03$, $I^2 = 42.99\%$, $H^2 = 1.75$							-0.19 [-0.48, 0.09]	
Test of $\theta_i = \theta_j$: Q(2) = 3.64, p = 0.16								
Test of $\theta = 0$: z = -1.34, p = 0.18								



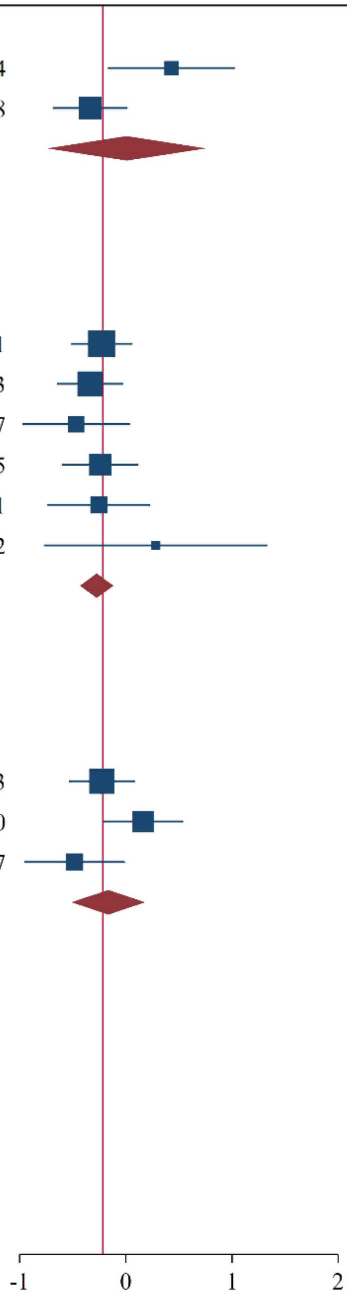
SBP

Random-effects REML model

Supplementary Figure 2. Forest plot of the impact of NLCR vs. control on SBP based on follow up.

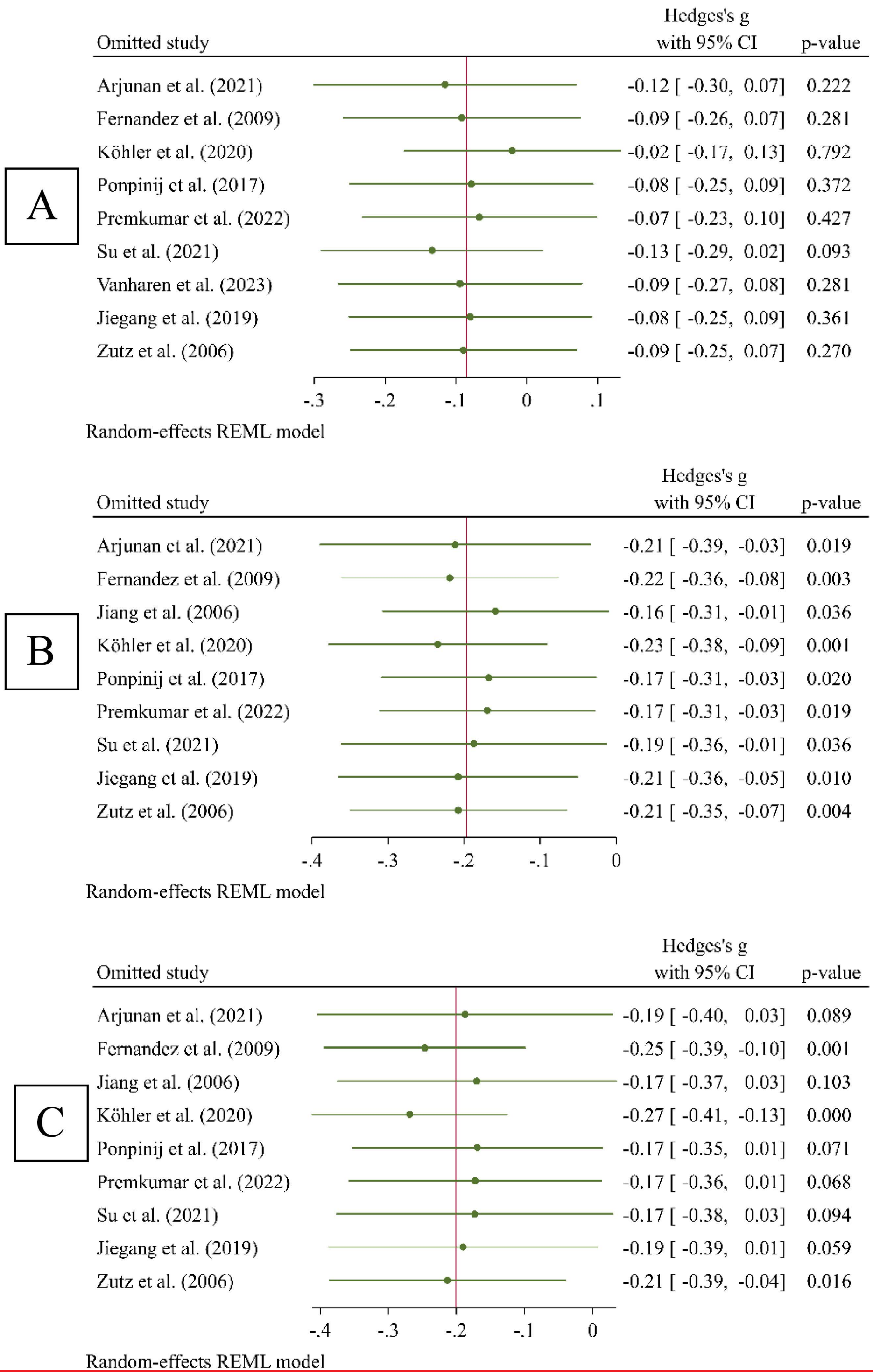
Study	Treatment N	Treatment Mean	Treatment SD	Control N	Control Mean	Control SD	Hedges's g with 95% CI	Weight (%)
Less than 12 weeks follow ups								
Fernandez et al. (2009)	24	2.40	9.11	20	-2.20	12.04	0.43 [-0.16, 1.02]	3.83
Su et al. (2021)	68	-2.47	9.81	63	1.18	11.78	-0.34 [-0.68, 0.01]	11.29
Heterogeneity: $\tau^2 = 0.23$, $I^2 = 79.28\%$, $H^2 = 4.83$							0.01 [-0.74, 0.75]	
Test of $\theta_i = \theta_j$: Q(1) = 4.83, p = 0.03								
Test of $\theta = 0$: z = 0.02, p = 0.98								
12 weeks follow ups								
Arjunan et al. (2021)	97	1.51	9.43	97	3.49	7.81	-0.23 [-0.51, 0.05]	16.81
Jiang et al. (2006)	83	0.09	3.81	84	1.35	3.63	-0.34 [-0.64, -0.03]	14.38
Premkumar et al. (2022)	31	-0.94	10.91	31	4.00	9.97	-0.47 [-0.97, 0.03]	5.35
Su et al. (2021)	66	-3.05	10.15	58	-0.49	10.95	-0.24 [-0.59, 0.11]	10.74
Jiegang et al. (2019)	34	-5.00	11.93	33	-2.00	11.41	-0.25 [-0.73, 0.22]	5.89
Zutz et al. (2006)	8	-1.00	11.05	5	-4.00	7.42	0.28 [-0.76, 1.33]	1.22
Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$							-0.27 [-0.43, -0.12]	
Test of $\theta_i = \theta_j$: Q(5) = 1.97, p = 0.85								
Test of $\theta = 0$: z = -3.44, p = 0.00								
More than 12 weeks follow ups								
Jiang et al. (2006)	83	1.04	5.89	84	2.26	4.83	-0.23 [-0.53, 0.08]	14.49
Köhler et al. (2020)	60	3.40	11.00	53	1.60	11.00	0.16 [-0.21, 0.53]	9.84
Ponpinij et al. (2017)	33	-2.06	7.15	39	1.97	9.07	-0.48 [-0.95, -0.02]	6.14
Heterogeneity: $\tau^2 = 0.06$, $I^2 = 61.04\%$, $H^2 = 2.57$							-0.17 [-0.51, 0.18]	
Test of $\theta_i = \theta_j$: Q(2) = 4.99, p = 0.08								
Test of $\theta = 0$: z = -0.94, p = 0.35								

SDP

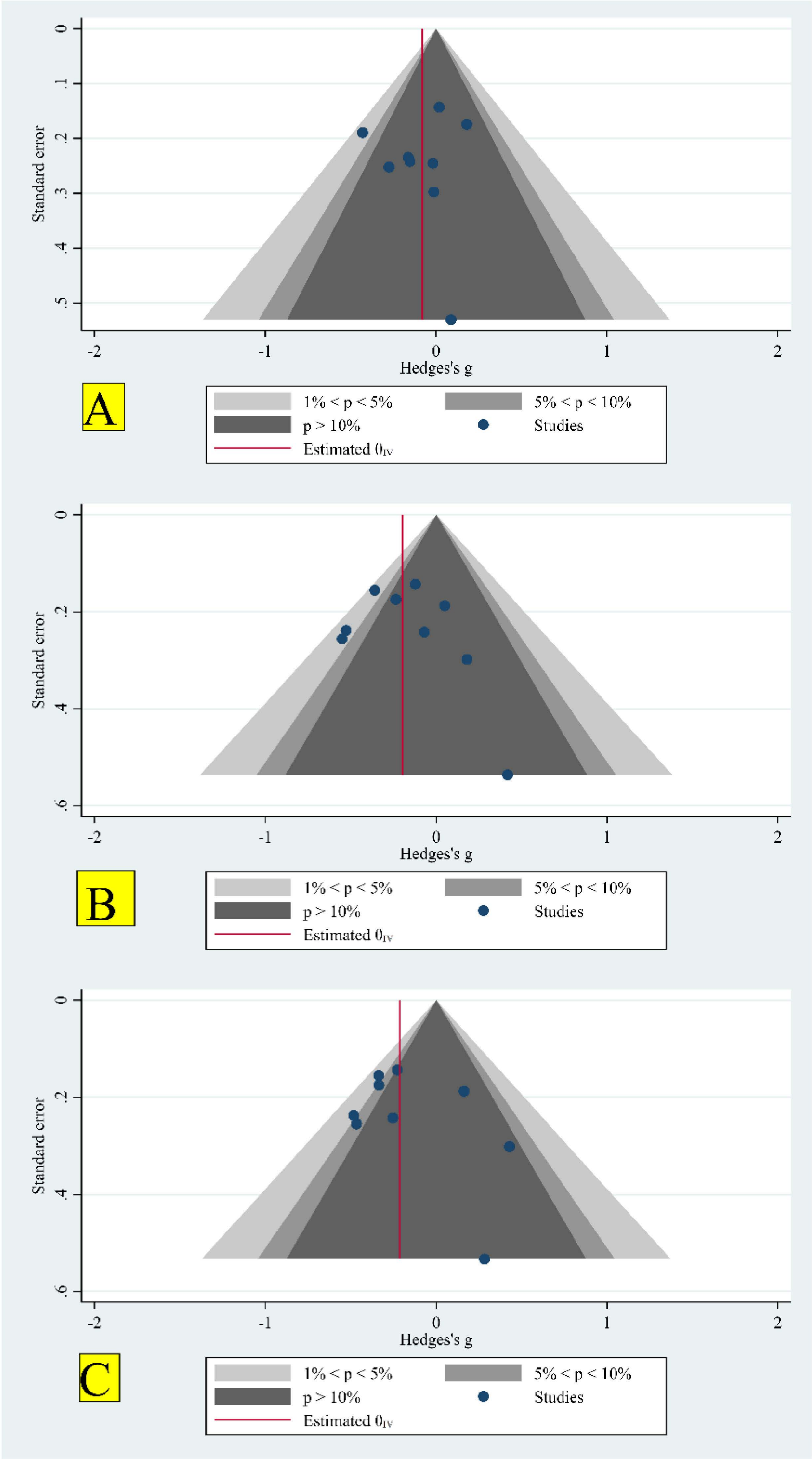


Random-effects REML model

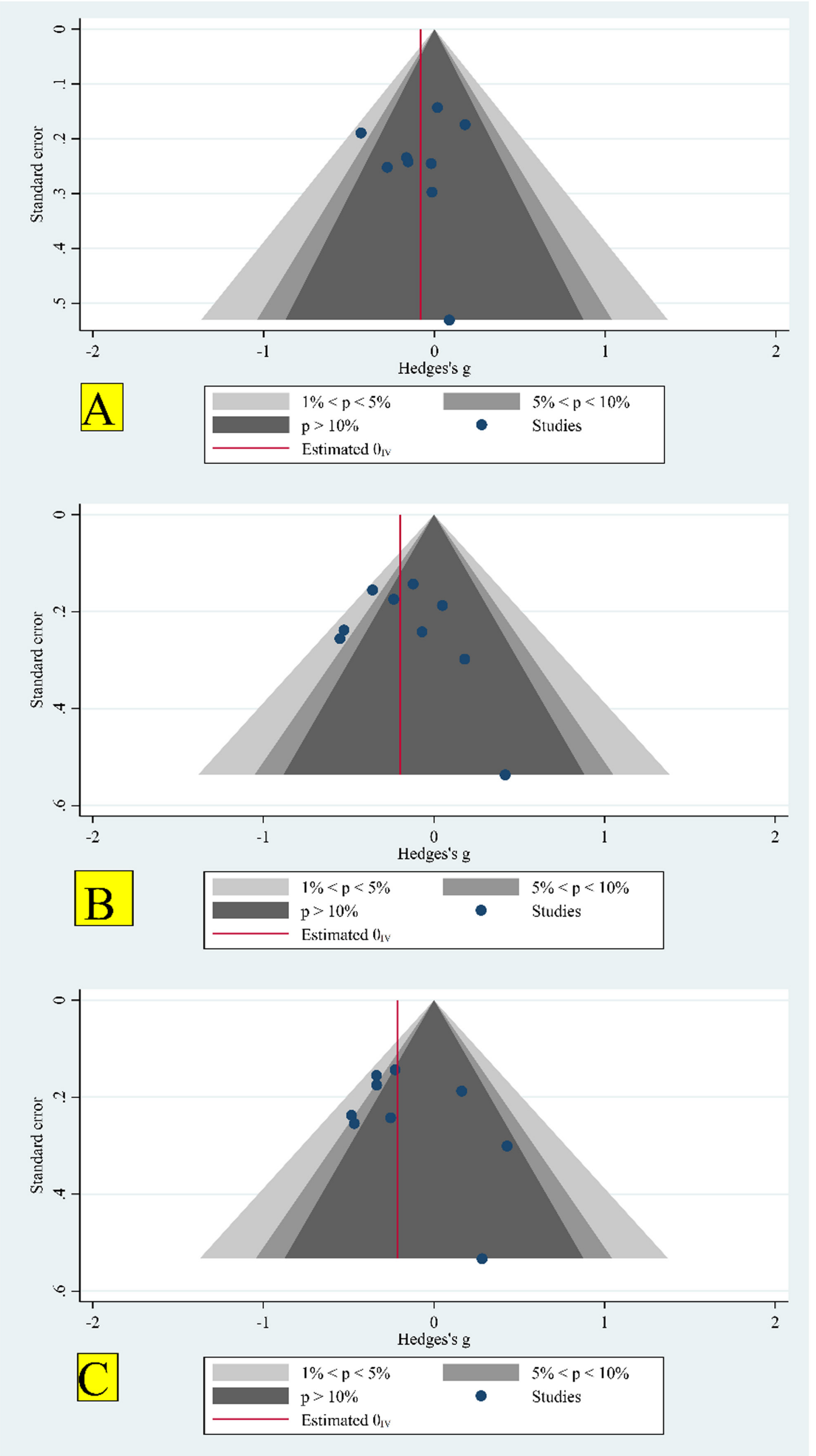
Supplementary Figure 3. Forest plot of the impact of NLCR vs. control on SDP based on follow up.



Supplementary Figure 4. Sensitivity Analysis of the Studies Included in the Meta-Analysis, Excluding One Study, for the Efficacy of NLCR on BMI (A), SBP (B), and DBP (C).



Supplementary Figure 5. Funnel plot for the publication bias assessing of the studies in meta-analysis; A = BMI, B = SBP, and C = DBP.



Supplementary Figure 6. Funnel plot for the publication bias assessing of the studies in meta-analysis; A = BMI, B = SBP, and C = DBP.

Supplementary Table 1. Search strategy

PubMed (ALL Fields)	(((((((((((((“Randomized Controlled Trials as Topic”[Mesh] OR “Randomized Controlled Trial” [Publication Type]) OR (“Controlled Clinical Trials as Topic”[Mesh] OR “Clinical Trials as Topic”[Mesh] OR “Clinical Trials, Phase III as Topic”[Mesh] OR “Clinical Trials, Phase IV as Topic”[Mesh] OR “Clinical Trials, Phase II as Topic”[Mesh] OR “Clinical Trials, Phase I as Topic”[Mesh] OR “Adaptive Clinical Trials as Topic”[Mesh] OR “Cross-Over Studies”[Mesh])) OR “Random Allocation”[Mesh]) OR (“Pragmatic Clinical Trial” [Publication Type] OR “Pragmatic Clinical Trials as Topic”[Mesh])) OR (Intervention)) OR (Experimental)) OR (RCT)) OR (trial)) OR (Randomized)) OR (double-blind method)) OR (single-blind method)) OR (RCTs)) AND ((“Nurses”[Mesh]) OR “Practice Patterns, Nurses’”[Mesh]) AND (“Rehabilitation”[Mesh] OR “Cardiac Rehabilitation”[Mesh])) AND (((((((“Waist Circumference”[Mesh]) OR “Body Weight”[Mesh]) OR “Blood Pressure”[Mesh]) OR “Body Mass Index”[Mesh]) OR (Physiological parameter)) OR (Physiological parameters)) OR (BP)) OR (BMI))
Scopus (TITLE-ABS-KEY)	TITLE-ABS-KEY ((“Rehabilitation” OR “Habilitation” OR “Cardiac Rehabilitation”) AND (“Practice Patterns” OR “Practice Pattern” OR “Nurse-Led” OR “Nurse Led” OR “Nurse” OR “Nurses”) AND (“Blood Pressure” OR “Pressure” OR “Waist” OR “Body Mass Index” OR “Weight” OR “Weights” OR “Index, Body Mass” OR “Quetelet’s Index” OR “Quetelets Index” OR “Quetelet” OR “Physiological parameter” OR “Physiological parameters” OR “BP” OR “BMI”) AND (“Randomized Controlled” OR “Trials” OR “Cross-Over studies” OR “Cross-Over study” OR “Crossover Studies” OR “Crossover Study” OR “Cross Over Design” OR “Cross Over Designs” OR “Crossover Designs” OR “Crossover Design” OR “Intervention” OR “Experimental” OR “RCT” OR “Randomization” OR “trial” OR “Randomized” OR “double blind method” OR “single blind method”))
Web of science (Topics)	TS= ((“Rehabilitation” OR “Habilitation” OR “Cardiac Rehabilitation”) AND (“Practice Patterns” OR “Practice Pattern” OR “Nurse-Led” OR “Nurse Led” OR “Nurse” OR “Nurses”) AND (“Blood Pressure” OR “Pressure” OR “Waist” OR “Body Mass Index” OR “Weight” OR “Weights” OR “Index, Body Mass” OR “Quetelet’s Index” OR “Quetelets Index” OR “Quetelet” OR “Physiological parameter” OR “Physiological parameters” OR “BP” OR “BMI”) AND (“Randomized Controlled” OR “Trials” OR “Cross-Over studies” OR “Cross-Over study” OR “Crossover Studies” OR “Crossover Study” OR “Cross Over Design” OR “Cross Over Designs” OR “Crossover Designs” OR “Crossover Design” OR “Intervention” OR “Experimental” OR “RCT” OR “Randomization” OR “trial” OR “Randomized” OR “double blind method” OR “single blind method”))
Embase (ti,ab,kw)	(‘rehabilitation’:ab,kw,ti OR ‘habilitation’:ab,kw,ti OR ‘cardiac rehabilitation’:ab,kw,ti) AND (‘practice patterns’:ab,kw,ti OR ‘practice pattern’:ab,kw,ti OR ‘nurse-led’:ab,kw,ti OR ‘nurse led’:ab,kw,ti OR ‘nurse’:ab,kw,ti OR ‘nurses’:ab,kw,ti) AND (‘blood pressure’:ab,kw,ti OR ‘pressure’:ab,kw,ti OR ‘waist’:ab,kw,ti OR ‘body mass index’:ab,kw,ti OR ‘weight’:ab,kw,ti OR ‘weights’:ab,kw,ti OR ‘index, body mass’:ab,kw,ti OR ‘quetelets index’:ab,kw,ti OR ‘quetelet’:ab,kw,ti OR ‘physiological parameter’:ab,kw,ti OR ‘physiological parameters’:ab,kw,ti OR ‘bp’:ab,kw,ti OR ‘bmi’:ab,kw,ti) AND (‘randomized controlled’:ab,kw,ti OR ‘trials’:ab,kw,ti OR ‘cross-over studies’:ab,kw,ti OR ‘cross-over study’:ab,kw,ti OR ‘crossover studies’:ab,kw,ti OR ‘crossover study’:ab,kw,ti OR ‘cross over design’:ab,kw,ti OR ‘cross over designs’:ab,kw,ti OR ‘crossover designs’:ab,kw,ti OR ‘crossover design’:ab,kw,ti OR ‘intervention’:ab,kw,ti OR ‘experimental’:ab,kw,ti OR ‘rct’:ab,kw,ti OR ‘randomization’:ab,kw,ti OR ‘trial’:ab,kw,ti OR ‘randomized’:ab,kw,ti OR ‘double blind method’:ab,kw,ti OR ‘single blind method’:ab,kw,ti)
Cochrane (TITLE-ABS-KEY)	((“Rehabilitation” OR “Habilitation” OR “Cardiac Rehabilitation”) AND (“Practice Patterns” OR “Practice Pattern” OR “Nurse-Led” OR “Nurse Led” OR “Nurse” OR “Nurses”) AND (“Blood Pressure” OR “Pressure” OR “Waist” OR “Body Mass Index” OR “Weight” OR “Weights” OR “Index, Body Mass” OR “Quetelet’s Index” OR “Quetelets Index” OR “Quetelet” OR “Physiological parameter” OR “Physiological parameters” OR “BP” OR “BMI”) AND (“Randomized Controlled” OR “Trials” OR “Cross-Over studies” OR “Cross-Over study” OR “Crossover Studies” OR “Crossover Study” OR “Cross Over Design” OR “Cross Over Designs” OR “Crossover Designs” OR “Crossover Design” OR “Intervention” OR “Experimental” OR “RCT” OR “Randomization” OR “trial” OR “Randomized” OR “double blind method” OR “single blind method”))
Google scholar / CT.GOV / ICTRP	Each Query searched separately: Rehabilitation AND Nurse AND trial Rehabilitation AND Nurse AND Blood Pressure Rehabilitation AND Nurse AND Waist Rehabilitation AND Nurse AND Physiological parameters Rehabilitation AND Nurse AND Weight Rehabilitation AND Nurse AND Body Mass Index

Supplementary Table 2. Risk of bias assessment of included RCTs

Authors/Years	Randomization	Deviation from intended interventions	Missing outcome	Measurement of outcome	Selection of reported results	Overall Risk of bias
Arjunan et al (2021)	Low	Low	Low	Low	Low	Low
Fernandez et al (2009)	Low	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
Jiang et al (2006)	Low	Low	Low	Low	Low	Low
Köhler et al (2020)	Low	Low	Low	Low	Low	Low
Ponpinij et al (2017)	Low	Low	Low	Low	Low	Low
Premkumar et al (2022)	Low	Some concerns	Low	Low	Low	Some concerns
Su et al (2021)	Low	Low	Low	Low	Low	Low
Vanharen et al (2023)	Low	Low	Low	Low	Low	Low
Wohlfahrt et al (2024)	Low	Low	Low	Low	Low	Low
Jiegang et al (2019)	Low	Some concerns	Low	Low	Low	Some concerns
Zutz et al (2006)	Low	Low	Low	Low	Low	Low