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Comparative Analysis Of The Effectiveness Of Relaxation Techniques And Physical Exercise On Controlled Blood Pressure: A Meta-Analysis

Wahidin[1], Dina Raidanti[2], Cristin Djayanti[3], Didin Syaefudin[4], and Rina Widjayanti[5]
Fikes Muhammadiyah University of Tangerang[1],
STIKES RSAD Gatot Soebroto Jakarta[2345]
E-mail: didinwahidin1977@students.unnes.ac.id

Abstract

Background: Hypertension is a major global public health problem, with prevalence increasing particularly among adults and older adults. Non-pharmacological interventions such as relaxation techniques (e.g., breathing exercises, massage-based relaxation, progressive muscle relaxation, mindfulness, and guided imagery) and physical exercise (e.g., aerobic exercise, isometric handgrip exercise, yoga, tai chi, and multicomponent training) are widely recommended for blood pressure control. However, comparative evidence regarding their relative effectiveness remains limited**. Objective:** This study aimed to compare the efficacy of relaxation techniques and physical exercise in reducing blood pressure using a meta-analytic approach**. Methods:** This meta-analysis was conducted in accordance with PRISMA 2020 guidelines. Randomized controlled trials and quasi-experimental studies evaluating relaxation techniques or physical exercise interventions on blood pressure outcomes were included. Statistical analyses were performed using a random-effects model with standardized mean differences (SMDs) as effect sizes. Subgroup analyses by age group and intervention type were conducted, and heterogeneity was assessed using the I^2 statistic**. Results:** A total of 33 studies were included. Overall, non-pharmacological interventions significantly reduced blood pressure (SMD = −0.744; $p < 0.001$). Subgroup analysis showed that relaxation techniques produced a greater reduction in blood pressure (SMD = −0.954) than physical exercise (SMD = −0.570). The most significant effect was observed among older adults (SMD = −1.075). Substantial heterogeneity was identified across studies ($I^2 = 74.1\%$), likely reflecting variations in intervention type, intensity, duration, and population characteristics**. Conclusion:** Both relaxation techniques and physical exercise are effective non-pharmacological interventions for reducing blood pressure. Relaxation techniques demonstrate greater and more consistent effects, particularly among older adults, supporting their prioritization in age-appropriate hypertension management strategies**.**

Keywords: Hypertension; Older adults; Relaxation techniques; Physical exercise; Meta-analysis

INTRODUCTION

Hypertension is one of the most prevalent non-communicable diseases worldwide and a leading risk factor for cardiovascular disease, stroke, and renal failure [1]–[3]. The World Health Organization estimates that more than one billion people globally live with hypertension, and prevalence increases markedly with age [4]. In both developing and developed countries, hypertension among older adults poses a significant challenge because of its association with functional decline, multimorbidity, and increased healthcare costs [5].

Hypertension management has increasingly shifted toward comprehensive approaches that combine pharmacologic and nonpharmacologic strategies. Nonpharmacologic interventions are strongly recommended

as first-line or complementary therapy because they are generally safe, cost-effective, and sustainable [6]. Among these interventions, relaxation techniques—such as slow-stroke back massage, deep breathing, progressive muscle relaxation, mindfulness, and guided imagery—and physical exercise—including aerobic exercise, isometric handgrip exercise, yoga, tai chi, and multicomponent training—have been widely studied and implemented [7]–[10].

From a physiological perspective, relaxation techniques primarily influence blood pressure regulation by modulating the autonomic nervous system, reducing sympathetic activity, and enhancing parasympathetic dominance [11]. Physical exercise, by contrast, lowers blood pressure through structural and functional cardiovascular adaptations, including improved endothelial function, reduced peripheral resistance, and enhanced arterial compliance [12], [13]. Despite strong theoretical support, empirical findings across studies remain heterogeneous [14].

Despite strong theoretical and empirical support for both relaxation techniques and physical exercise as non-pharmacological strategies for blood pressure control, the existing evidence remains inconsistent and fragmented. Most previous studies and meta-analyses have evaluated these interventions separately, making it difficult to draw direct comparisons regarding their relative effectiveness. In addition, variations in intervention type, study design, population characteristics, and age group have contributed to heterogeneous findings across the literature. Notably, comparative evidence evaluating relaxation techniques and physical exercise simultaneously within a single meta-analytic framework, particularly with attention to age-related differences, remains limited.

Therefore, the present study aimed to conduct a comparative meta-analysis to evaluate the effectiveness of relaxation techniques and physical exercise in controlling blood pressure. This study also sought to examine whether the magnitude of intervention effects differs across age groups, thereby providing more targeted evidence to inform age-appropriate, non-pharmacological hypertension management strategies in nursing and community health practice.

RESEARCH METHODOLOGY

Literature Search Strategy

This study used a meta-analytic Design, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [15], [16]. A comprehensive literature search was conducted to identify relevant studies published up to December 2025. Electronic databases, including PubMed, Scopus, Web of Science, CINAHL, and Google Scholar, were systematically searched to ensure broad coverage of both international and regional publications. The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to hypertension and non-pharmacological interventions, including *"hypertension," "blood pressure," "relaxation techniques," "deep breathing," "massage," "mindfulness," "guided imagery," "physical exercise," "aerobic exercise," "yoga," "tai chi,"* and *"isometric exercise."* Boolean operators (AND/OR) were applied to refine the search. Reference lists of included articles were also manually screened to identify additional eligible studies.

Study Selection and Data Extraction

After removal of duplicates, titles and abstracts were independently screened by two reviewers to assess eligibility based on the predefined inclusion and exclusion criteria. Full-text articles were

subsequently reviewed to confirm eligibility. Discrepancies between reviewers were resolved through discussion and consensus. Data extracted included author, year of publication, country, study design, sample size, participant characteristics, intervention type, comparison group, outcome measures, and intervention duration.

Risk-of-Bias Assessment

The methodological quality and risk of bias of the included studies were assessed independently by two reviewers. Randomized controlled trials were evaluated using the Cochrane Risk of Bias tool, while quasi-experimental studies were assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist. The domains assessed included selection bias, performance bias, detection bias, attrition bias, and reporting bias. Studies were categorized as having low, moderate, or high risk of bias. Any disagreements in assessment were resolved through consensus. The overall risk-of-bias assessment was considered in the interpretation of the pooled results and subgroup analyses.

Eligible studies included randomized controlled trials (RCTs) and quasi-experimental studies that examined the effects of relaxation techniques or physical exercise on blood pressure outcomes. The inclusion criteria were: (1) participants with elevated blood pressure or diagnosed hypertension; (2) non-pharmacological interventions categorized as relaxation techniques or physical exercise; (3) reported systolic and/or diastolic blood pressure outcomes; and (4) sufficient quantitative data for effect size calculation. Studies that focused exclusively on pharmacological therapy or lacked a control group were excluded.

Data extracted from each study included author, year, country, study Design, sample size, population characteristics, intervention type, control group, and study weight. A random-effects model was used to account for between-study variability, and the analysis was conducted in Open MEE. Effect sizes were calculated as standardized mean differences (SMDs) with 95% confidence intervals. Heterogeneity was assessed using Cochran's Q test and the I^2 statistic. Subgroup analyses were conducted by age group and intervention type.

RESULTS AND DISCUSSION

RESULTS

3.1 Characteristics of the Analyzed Study

A total of 33 studies were included in this meta-analysis. The characteristics of the included studies are presented in Table 1A and Table 1 B.

Table 1A. Characteristics of the Relaxation Method Study

No	Author (Year)	Intervention	n	Populasi	Country	Control Type	Weight (%)
1	Tricahyo (2024) [17]	Slow Stroke Back Massage	51	Adult	Indonesia	No intervention	3,692
2	Wulan (2025)[12]	Slow Stroke Back Massage	5	Elderly	Indonesia	Usual care	1,065
3	Gusti Ayu (2023) [18]	Slow Stroke Back Massage	44	Adult	Indonesia	Usual care	3,204
4	Octalina (2024) [19]	Acupressure + Murottal Al-Qur'an	18	Elderly	Indonesia	Usual care	4,424
5	Hafid (2022)[20]	Progressive Muscle Relaxation	18	Elderly	Indonesia	Placebo	2,536
6	Hafid (2022) [20]	Guided Imagery	18	Elderly	Indonesia	Usual care	2,201

7	Yeh (2024) [10]	Slow Deep Breathing	14	Elderly	Taiwan	Usual care	2,043
8	Yeh (2024) [10]	Natural Deep Breathing	12	Elderly	Taiwan	Usual care	2,058
9	Zulkarnain (2025) [21]	Structured Deep Breathing	16	Elderly	Indonesia	No intervention	2,522
10	Amaliah (2024) [22]	Aromatherapy	18	Adult	Indonesia	Usual care	3,720
11	Eguchi (2016) [8]	Aroma Foot Massage	51	Adult	Japan	Usual care	3,720
12	Babak (2022) [23]	Mindfulness-Based Stress Reduction	37	Adult	Iran	Usual care	3,337
13	Yoon (2024) [24]	Mindfulness & Qigong	32	Adult	Korea	Usual care	3,171
14	Ellya (2021) [25]	Music Therapy	62	Elderly	Indonesia	Usual care	3,670
15	Iko (2019) [26]	Guided Imagery	20	Elderly	Indonesia	No intervention	2,453
16	Untari (2023) [9]	Autogenic Training	14	Elderly	Indonesia	Usual care	1,852
17	Mir (2024) [27]	Mindfulness Meditation	543	Adult	Malaysia	Usual care	4,820

Source: Scunder Data 2026

Table 1 B. Characteristics of Physical Exercise Studies

No	Author (Year)	Intervention	n	Populasi	Country	Control Type	Weight (%)
1	Rodrigues (2023) [28]	Sodium Restriction Education	60	Adult	Brazil	Usual care	3,862
2	Saptarisi (2009) [29]	Community-based Intervention	28	Young adults	India	Usual care	3,041
3	Saptarisi (2009) [29]	Physical Exercise	27	Young adults	India	Usual care	2,940
4	Saptarisi (2009) [29]	Salt Reduction	25	Young adults	India	Usual care	2,747
5	Saptarisi (2009) [29]	Yoga	21	Young adults	India	Usual care	3,152
6	Riyanto (2024) [29]	Isometric Handgrip Exercise	30	Adult	Indonesia	Usual care	2,167
7	Sarinukul (2023) [30]	Stepping Exercise	17	Elderly	Thailand	No intervention	2,788
8	Lovez (2023) [31]	Multicomponent Training	150	Elderly	Multi-country	Usual care	3,252
9	Cohen (2015) [32]	Yoga (Cardiac Autonomic Function)	33	Young adults	India	No intervention	2,155
10	Li (2023) [13]	Tai Chi	173	Adult	China	No intervention	4,532
11	Li (2023) [13]	Aerobic Exercise	169	Adult	China	No intervention	4,514
12	Cohen (2016) [32]	Yoga Therapy	90	Adult	America	Usual care	4,189
13	Zhang (2024) [33]	Tai Chi Training	50	Adult	China	No intervention	3,655
14	Loh (2022) [24]	Progressive Muscle Relaxation*	35	Adult	Taiwan	Usual care	3,267

Source: Scunder Data 2026

The characteristics of the study in Table 1A indicate that relaxation methods are more widely used among older adults than among other age groups. This pattern suggests that relaxation methods are considered more clinically appropriate for older adults, who generally have limited physical activity and a higher risk of side effects from pharmacological interventions. The diversity of relaxation

interventions—from touch and breathing to mindfulness-based approaches—demonstrates the flexibility of applying these methods across a variety of nursing and community health service contexts. The consistency in the use of a control group in the form of usual care or no intervention also strengthens the relevance of relaxation methods as an additional intervention that is realistic and easily integrated into clinical practice.

In contrast, the study characteristics in Table 1B indicate that physical exercise is used across a broader age range, from young adults to older adults. The variety of physical exercises used reflects a range of approaches to improving cardiovascular function, but it can also lead to variation in responses between individuals. The dependence of physical exercise on participants' intensity, duration, and functional capacity may explain the heterogeneity of effects observed in the analysis. Nonetheless, these findings confirm that physical exercise remains an essential part of blood pressure management, especially as a supportive intervention tailored to the individual's physical abilities and clinical condition.

3.2 Overall Effectiveness of Non-Pharmacological Interventions

The overall pooled analysis showed that non-pharmacological interventions significantly reduced blood pressure. A total of 33 studies met the inclusion criteria and were included in the meta-analysis. The overall pooled analysis demonstrated that non-pharmacological interventions significantly reduced blood pressure compared with control conditions (SMD = −0.744; 95% CI: −0.894 to −0.595; $p < 0.001$), with substantial heterogeneity across studies ($I^2 = 74.12\%$). The overall forest plot is presented in **Figure 1**.

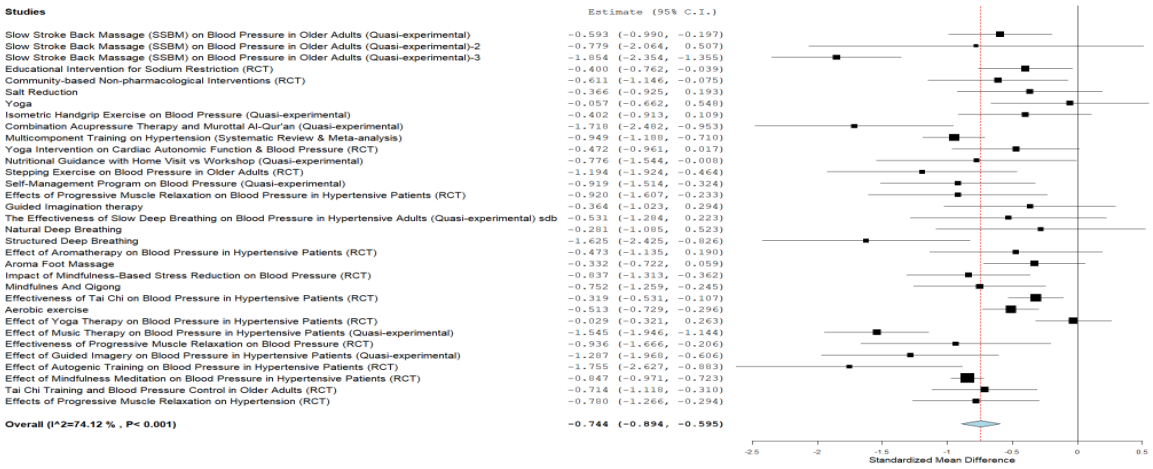

Figure 1. *Forest Plot Effectiveness of Non-Pharmacological Interventions on Blood Pressure Lowering*

Figure 1 shows that the overall non-pharmacological intervention resulted in a statistically significant reduction in blood pressure compared with the control group. Most studies reported effect measures that lowered blood pressure, indicating a consistent and beneficial direction of the effect.

Combined effect measures from randomized-effects models showed that the intervention's benefits remained significant despite variation in study

characteristics, intervention types, and populations. The width of the confidence interval varied between studies, reflecting differences in sample size and study Design, but the direction of the main effect did not change. These findings indicate that non-pharmacological interventions are clinically effective and can be incorporated into comprehensive blood pressure management.

3.3 Subgroup Analysis by Age

Subgroup analysis by age showed that older adults experienced the most significant reduction. Subgroup analysis by age revealed that the greatest reduction in blood pressure was observed among older adults (SMD = −1.075), followed by adults (SMD = −0.629) and young adults (SMD = −0.399). These findings indicate that the effectiveness of non-pharmacological interventions increases with age. The age-based subgroup analysis is illustrated in Figure 2.

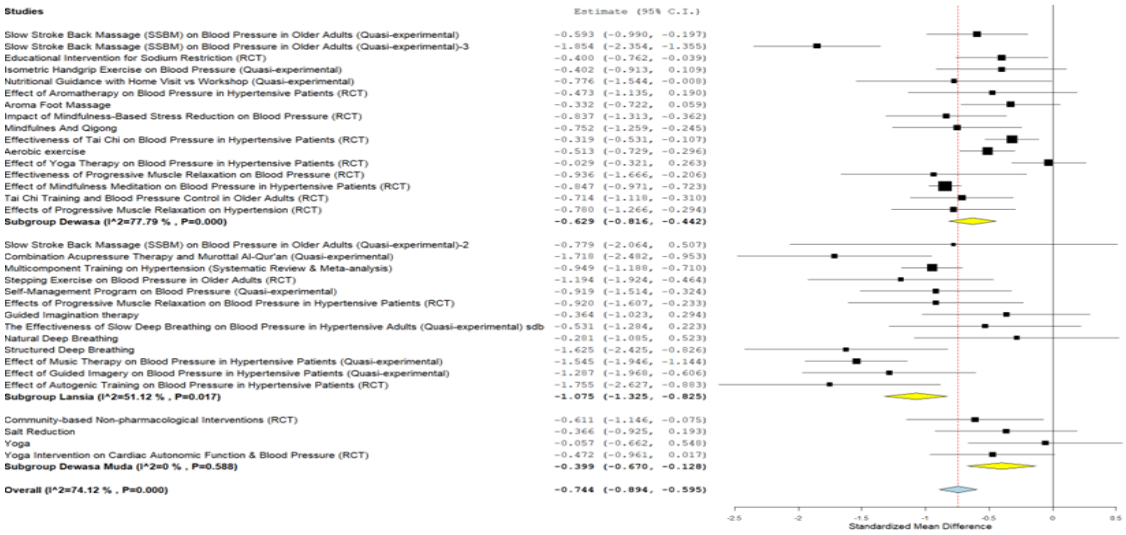

Figure 2. Forest Plot Subgroup Analysis by Age Group

Figure 2 shows differences in the effects of non-pharmacological interventions on blood pressure reduction across age groups. The elderly group showed the most significant decrease in blood pressure, followed by the adult group, while the younger adult group showed a negligible effect. These differences suggest that responses to non-pharmacological interventions tend to be more favorable among older people.

3.4 Subgroup Analysis by Intervention Type

When analyzed by intervention type, relaxation techniques were more effective. Relaxation techniques produced a greater reduction in blood pressure (SMD = −0.954) than physical exercise (SMD = −0.570), and both effects were statistically significant ($p < 0.001$). The comparative effectiveness of intervention types is shown in **Figure 3**.

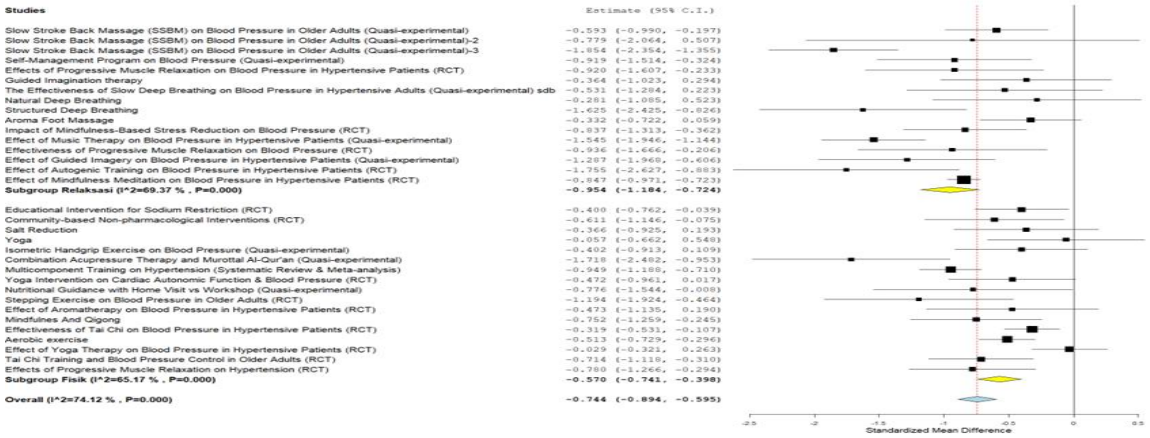

Figure 3. Forest Plot Subgroup Analysis by Intervention Type

Figure 3 shows that both relaxation methods and physical exercise are effective in lowering blood pressure. Pressure, but with different magnitudes of effect. The relaxation method showed a larger and more consistent effect size than physical exercise. Clinically, the relaxation method offers an advantage because it engages the autonomic nervous system's regulatory mechanisms, allowing it to lower blood pressure more reliably and more quickly. Physical exercise still provides significant benefits, primarily through cardiovascular adaptation, but its effectiveness is more influenced by exercise intensity, duration, and the individual's physical ability. Therefore, relaxation methods can be the primary intervention for patients with limited physical activity. In contrast, physical exercise can be used as a supportive approach, depending on the patient's clinical condition.

3.5 Publication Bias Assessment

Publication bias was assessed using a funnel plot. The funnel plot showed a relatively symmetrical distribution of studies around the pooled effect size, suggesting that publication bias was unlikely to influence the results substantially **(Figure 4).**

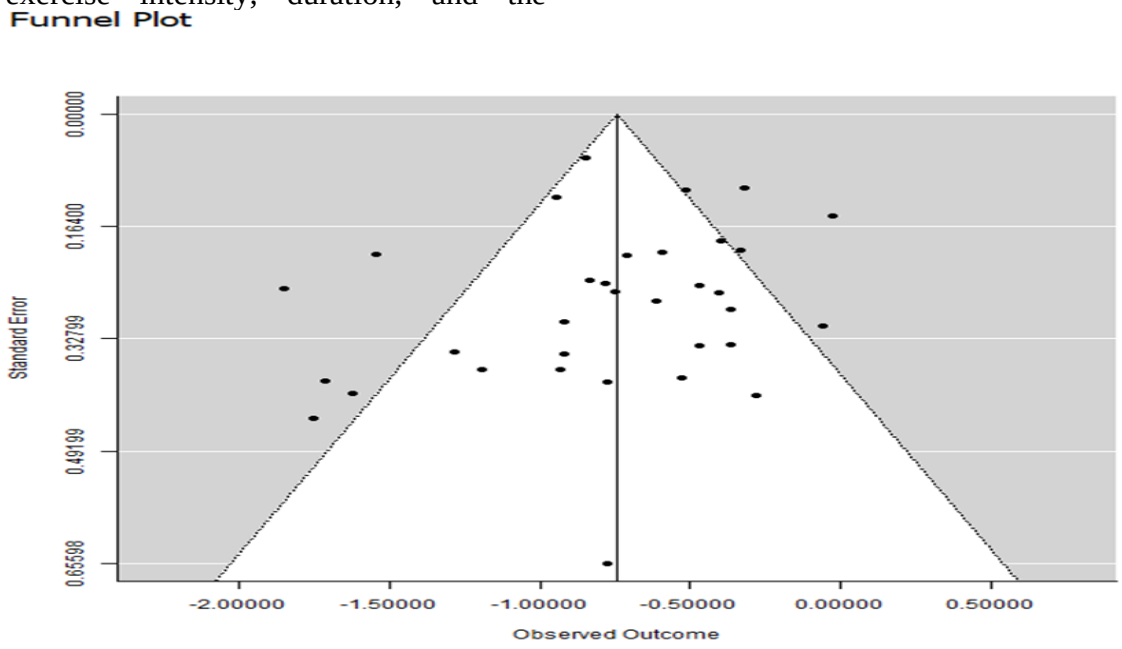

Figure 4. Publication Bias Assessment Funnel plot On Included Studies

Figure 4 shows the funnel plot used to assess potential publication bias among the studies included in this meta-analysis. In general, the distribution of study points on the funnel plot appears relatively symmetrical around the combined effect size, especially at the top of the graph, where studies with large sample sizes and high precision are represented.

At the bottom of the funnel plot, points are more widely dispersed, a common feature of studies with small sample sizes and lower precision. This pattern reflects reasonable variation in effect and does not automatically indicate publication bias. No patterns of extreme asymmetry or systematic emptiness were found on either side of the funnel plot, indicating the dominance of significant outcomes or the omission of studies with little or no significant effect. Based on visual inspection of the funnel plot, the risk of publication bias in this meta-analysis was rated as low to moderate. It was not expected to materially affect the study's main conclusions. These findings support the stability and reliability of the meta-analysis results.

4. DISCUSSION

The findings in Figure 1 showed that the non-pharmacological intervention significantly lowered blood pressure compared with the control group (SMD = −0.744; 95% CI: −0.894 to −0.595; $p < 0.001$). Most studies reported effects that lowered blood pressure, indicating the consistency of the beneficial effect.

The substantial heterogeneity observed in this meta-analysis reflects the inherent diversity of non-pharmacological interventions and study populations. Variations in intervention modalities (e.g., breathing-based relaxation, massage, mindfulness, aerobic exercise, and mind–body exercise), intervention intensity and duration, as well as differences in study design and baseline blood pressure levels, are likely major contributors to this heterogeneity. Furthermore, age-related physiological differences, particularly autonomic nervous system function and vascular elasticity, may influence individual responsiveness to specific interventions, especially among older adults.

To address this variability, a random-effects model was applied, and subgroup analyses by age group and intervention type were conducted. These analyses partially explained the observed heterogeneity by demonstrating more consistent and larger effect sizes for relaxation techniques and among older adults. Rather than undermining the validity of the findings, the heterogeneity highlights the importance of tailoring non-pharmacological interventions to individual and population characteristics in clinical practice.

Although effect sizes and confidence interval widths varied across studies, the uniform direction of effect reinforced the overall effectiveness of non-pharmacological interventions. The predominance of non-pharmacological interventions provides a meaningful clinical benefit in lowering blood pressure. The consistency of the direction of effects in most studies suggests that this approach is reliable as part of hypertension management strategies, despite variations in study Design and population characteristics.

The age subgroup analysis in Figure 2 showed a clear difference in effect size. The elderly group had the most significant reduction in blood pressure (SMD = −1.075), followed by adults (SMD = −0.629) and young adults (SMD = −0.399). This pattern indicates that the elderly benefit most from non-pharmacological interventions. Clinically, this can be explained by age-related physiological changes, such as increased sympathetic activity and decreased vascular elasticity. These changes make older adults more responsive to interventions that focus on stress

regulation and cardiovascular balance. These findings are relevant to gerontological nursing practice, where safe, low-risk interventions are urgently needed.

A comparison of the intervention types in **Figure 3** shows that the relaxation method produced a larger and more consistent effect size (SMD = −0.954) than physical exercise (SMD = −0.570). However, both interventions were equally statistically significant ($p < 0.001$). The difference in magnitude indicates that the relaxation method is more effective at reducing blood pressure than physical exercise. The advantage of the relaxation method likely lies in its mechanism of action, which directly modulates the autonomic nervous system, leading to a more sustained decrease in blood pressure [34]. Physical exercise still provides significant benefits through cardiovascular adaptation, but its effectiveness depends more on exercise intensity, duration, and the individual's physical ability. Therefore, relaxation methods can be prioritized for patients with limited physical activity, while physical exercise can be used as a supportive intervention depending on clinical conditions [35].

The results of this meta-analysis indicate that non-pharmacological interventions are overall effective in lowering blood pressure, with a statistically significant effect. These findings confirm the critical role of non-pharmacological approaches as an integral part of hypertension management, particularly in adult and elderly populations. However, further analysis revealed a clear difference in effectiveness between relaxation methods and physical exercise, as shown in the subgroup analysis and study characteristics (Tables 1A and 1B).

Based on subgroup results, the relaxation method produced a greater reduction in blood pressure than physical exercise. These findings can be explained by the physiological mechanisms underlying the relaxation method, namely decreased sympathetic nervous system activity and increased parasympathetic dominance [34]. This autonomic nervous system regulation directly lowers peripheral vascular resistance and heart rate, thereby significantly reducing blood pressure. The predominance of relaxation method studies in the elderly population (Table 1A) also reinforces the finding that these interventions are more responsive in older adults who are prone to psychological stress and autonomic dysfunction [36]–[38].

In contrast, physical exercise remained effective, though less pronounced than the relaxation method. Physical exercise works through medium- to long-term cardiovascular adaptations, such as increased vascular elasticity, improved endothelial function, and reduced vascular resistance [15], [39], [40]. However, the variety of exercise types, intensities, and participants' fitness levels—as reflected in the variation in study characteristics in Table 1B—may contribute to the observed variation in effect size.

Another important finding was the magnitude of the intervention's effect on the elderly group relative to adults and young adults. This indicates that older adults have a greater potential response to non-pharmacological interventions, particularly relaxation methods. From a clinical and nursing perspective, this is particularly relevant because older adults often experience limited mobility, comorbidities, and the risk of side effects from pharmacotherapy [8], [41], [42]. Relatively safe, easy-to-apply, and low-cost relaxation methods are becoming a very strategic alternative in gerontological nursing practice and community health services.

The high heterogeneity in the meta-analysis results reflects variation in study Design, intervention type, duration, and population characteristics. Nonetheless, the consistency of effect direction across

nearly all studies reinforces the validity of the study's main findings. Publication bias assessment using funnel plots also indicates that the meta-analysis results were relatively stable and not dominated by small-sample studies.

The main novelty of this study lies in the comparative meta-analysis approach that directly compares relaxation and physical exercise methods within a single integrated analysis framework. In contrast to previous meta-analyses that generally assessed the two interventions separately, this study provides more definitive quantitative evidence about which interventions offer greater benefit to specific population groups. Thus, the results of this study not only contribute to scientific development but also provide practical implications for clinical decision-making and the planning of nursing and public health interventions.

Based on the discussion, it can be concluded that the effectiveness of relaxation methods and physical exercise is influenced not only by the type of intervention but also by participants' physiological and functional characteristics, especially in the elderly group. The relaxation method offers relative advantages for lowering blood pressure because it directly modulates the autonomic nervous system and is easier to apply in older adults with limited physical activity. In contrast, physical exercise still provides significant benefits through cardiovascular adaptation, but its effectiveness depends more on the individual's intensity, duration, and physical ability. These findings underscore the importance of selecting non-pharmacological interventions tailored to population characteristics and health care contexts.

Study Limitations and Potential Confounding Factors

Several limitations should be considered when interpreting the findings of this meta-analysis. First, substantial heterogeneity was observed across studies, which may be attributed to variations in intervention modalities, intensity, duration, and study design, as well as differences in participant characteristics. Although a random-effects model and subgroup analyses were applied to address this variability, residual heterogeneity may remain.

Second, including both randomized controlled trials and quasi-experimental studies may introduce methodological variability, potentially affecting effect size estimates. However, this approach was adopted to capture a broader range of evidence relevant to clinical and community-based nursing practice.

Potential confounding factors, including differences in baseline blood pressure, adherence to interventions, lifestyle behaviors (such as diet and physical activity outside the intervention), and concurrent non-pharmacological or pharmacological treatments, could not be fully controlled due to limitations in the primary studies. In addition, publication bias cannot be entirely excluded despite the relatively symmetrical funnel plot. These limitations highlight the need for future high-quality randomized trials with standardized intervention protocols and more comprehensive reporting to clarify further the comparative effectiveness of non-pharmacological interventions for blood pressure control.

CONCLUSIONS

This meta-analysis demonstrated that both relaxation techniques and physical exercise are effective in lowering blood pressure; however, relaxation techniques provide greater and more consistent benefits, particularly among older adults. This advantage relates to the autonomic nervous system's regulatory mechanisms and to the ease and safety of its application in individuals with physical limitations**.**

Physical exercise remains an essential component of hypertension management because of the long-term cardiovascular adaptation benefits it offers. However,

variations in exercise type, intensity, and participant characteristics contribute to differences in the magnitude of the observed effects. Therefore, physical exercise needs to be tailored to each individual to provide optimal benefits.

The findings of this study confirm that selecting non-pharmacological interventions for blood pressure control should be context- and age-based. In nursing practice and community health services, relaxation methods can be prioritized as a safe, effective, and sustainable strategy for older adults. At the same time, physical exercise can be used as a complementary approach, depending on individual ability.

Overall, the novelty of this study lies in its comparative meta-analysis approach, which directly compares the effectiveness of relaxation and physical exercise methods within a single analytical framework. The results of this study are expected to serve as the basis for the development of evidence-based nursing practice guidelines and to encourage further research into more optimal combinations of non-pharmacological interventions for hypertension control.

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