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Effectiveness of Nurse-Led Counseling in the Prevention of Type 2 Diabetes among Hypertensive Adults: A Systematic Review and Meta-Analysis

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Abstract **Review Article**

Background: Type 2 diabetes mellitus represents a major global health challenge, with hypertensive adults facing significantly elevated diabetes risk. While nurse-led interventions show promise in chronic disease management, limited evidence exists regarding their effectiveness in diabetes prevention among hypertensive populations. This systematic review and meta-analysis evaluated nurse-led counseling interventions for preventing type 2 diabetes in hypertensive adults.

Methods: A systematic search across five databases (CINAHL, Cochrane, Embase, MEDLINE, Scopus) from January 2000 to August 2025 identified eligible randomized controlled trials, cluster randomized trials, and quasi-experimental studies. Two reviewers independently screened studies, extracted data, and assessed quality using Cochrane Risk of Bias 2.0 and ROBINS-I tools. Meta-analysis employed random-effects models with risk ratios for dichotomous outcomes and mean differences for continuous outcomes.

Results: Twelve studies involving 3,456 participants met inclusion criteria. Nurse-led counseling interventions significantly reduced type 2 diabetes incidence by 46% compared to usual care (pooled risk ratio = 0.54; 95% CI: 0.42–0.71; $p < 0.0001$; $I^2 = 23\%$). Secondary outcomes showed significant improvements: HbA1c reduction of 0.34% (95% CI: -0.52 to -0.16), BMI reduction of 1.2 kg/m² (95% CI: -1.8 to -0.6), and enhanced physical activity (standardized mean difference: 0.67; 95% CI: 0.34–1.00). Longer-duration interventions (≥12 months) with face-to-face delivery demonstrated more sustained effects.

Conclusions: Nurse-led counseling interventions effectively prevent type 2 diabetes among hypertensive adults, demonstrating clinically significant reductions in diabetes incidence alongside improvements in glycemic control and lifestyle behaviors. Healthcare systems should integrate these accessible, scalable interventions into routine hypertension care with appropriate nurse training and support.

Keywords: Nurse-led interventions, diabetes prevention, hypertension, lifestyle counseling, systematic review, meta-analysis

I Introduction

With an estimated 537 million adults living with diabetes in 2021 and a projected 783 million by 2045, type 2 diabetes mellitus (T2DM) poses a significant worldwide health concern (International Diabetes Federation [IDF], 2021). More than 1.28 billion adults across the globe are affected by hypertension at the same time (Mills et al., 2020). Lastra et al. (2014) and Petrie et al. (2018) found that these disorders often co-occur and share pathophysiological mechanisms, such as insulin resistance and chronic inflammation.

Emdin et al. (2015) and Gress et al. (2000) found that those with hypertension had a far greater chance of getting type 2 diabetes than normotensive people. Preventing diabetes in hypertensive populations is of utmost public health importance because the presence of both hypertension and diabetes greatly raises the risk of cardiovascular morbidity and mortality (Stamler et al., 1993; Haffner et al., 1998). (American Diabetes Association [ADA], 2021).

According to Laurant et al. (2018) and Martínez-González et al. (2014), nurse-led interventions have been acknowledged for their efficacy in managing and preventing chronic diseases. Lifestyle change counselling is best provided by nurses due to their accessibility, continuity of treatment, and knowledge of patient education (Renders et al., 2001). Dietary recommendations, exercise encouragement, and behavioural support tactics are common components of such programs (Norris et al., 2002; Deakin et al., 2005).

The effectiveness of lifestyle treatments was demonstrated in landmark trials such as the Diabetes Prevention Program (Knowler et al., 2002). However, these trials generally utilised multidisciplinary teams instead of nurse-led approaches. There is a lack of comprehensive research on the efficacy of counselling provided by nurses in preventing diabetes in adults with hypertension (Houweling et al., 2011). This information vacuum is filled by this systematic review.

1.1 Review Aim

This review aims to evaluate the effectiveness of nurse-led counseling interventions in preventing type 2 diabetes among adults with hypertension.

1.2 Research Questions

1. Does nurse-led counseling effectively reduce the risk of developing type 2 diabetes among hypertensive adults compared to usual care or alternative interventions?
2. What impact do nurse-led counseling interventions have on glycemic control, anthropometric measures, and lifestyle behaviors in hypertensive adults?

2. Methods

2.1 Design

All procedures used in this meta-analysis and systematic review followed the PRISMA 2020 reporting standards (Page et al., 2021). To ensure the methodology was clear and unbiased, the protocol was registered in PROSPERO (CRD420251134406).

Eligibility and synthesis factors were defined using the PICO framework, which stands for "Population, Intervention, Comparison, and Outcomes." This was the basis for the review process. To ensure evidence selection was transparent, a PRISMA flow diagram was used to illustrate the steps of identifying studies, screening them, assessing their eligibility, and finally including them.

It is widely acknowledged that PRISMA is the gold standard for evaluating the efficacy of therapies and provides a minimal set of items for reporting evidence-based meta-analyses and systematic reviews.

2.2 Search Strategy

A systematic literature search was conducted across five electronic databases: Scopus,

CINAHL, Embase, MEDLINE, and the Cochrane Central Register of Controlled Trials. These sources were chosen for their comprehensive indexing of research in nursing, allied health, and biomedical sciences. The search approach integrated both controlled vocabulary terms, including Medical Subject Headings (MeSH), and relevant free-text keywords to maximise retrieval accuracy. Search terms related to nurse-led care, diabetes prevention, hypertension, and lifestyle modification were combined using Boolean logic operators such as AND and OR.

Eligibility was limited to peer-reviewed publications written in English and published between 2000 and 2025. Studies were required to involve adult populations diagnosed with hypertension but without diabetes. Nurse-led counselling interventions aimed at preventing diabetes constituted the exposure of interest, while outcomes of relevance included the development of type 2 diabetes, indicators of glycaemic regulation, anthropometric indices, and lifestyle-related behavioural changes. The formulation of the search strategy was structured according to the PICO framework.

2.3 Inclusion and Exclusion Criteria

The PICO framework was used to construct the inclusion criteria. Individuals having a confirmed diagnosis of hypertension (but not diabetes) and who were 18 years of age or older made up the study population. The intervention studied involved counselling programs conducted by nurses intended to prevent type 2 diabetes. These programs emphasised lifestyle changes, such as healthy eating, more exercise, and behavioural support. Finally, the outcomes considered included the prevalence of type 2 diabetes, markers of glycaemic control such as HbA1c and fasting glucose, anthropometric measurements such as body weight and body mass index, and lifestyle behaviours such as eating and exercise. Cluster randomised trials, quasi-experimental research, and randomised controlled trials were the final study designs that were considered eligible.

The exclusion criteria were also clearly defined. First (1), studies involving pregnant women, individuals with pre-existing diabetes, or pediatric populations were excluded. Second (2), interventions that were not nurse-led or that relied exclusively on pharmacological management were not considered. Third (3), studies that did not report outcomes relevant to diabetes prevention, glycemic control, anthropometric measures, or lifestyle behaviors were excluded. Finally (4), conference abstracts, case reports, dissertations, systematic reviews, and purely observational studies were not eligible for inclusion.

Study Selection

Titles, abstracts, and full texts were assessed by two reviewers separately according to predetermined eligibility criteria that were in line with best practices for systematic reviews (Page et al., 2021). A third evaluator was brought in to help reach a consensus when necessary, although in most cases, disagreements were resolved through discussion. One of the most popular measures of reliability in systematic reviews, Cohen's kappa, was used to assess inter-rater agreement (Higgins et al., 2003).

2.5 Data Extraction

Data from each included study were systematically extracted using a standardized data extraction form developed for this review, following best practices for evidence synthesis (Page et al., 2021). Extracted information included the author’s name, year of publication, country of study, study aim, design, and participant characteristics such as sample size, age, gender distribution, and baseline health status. Details of the intervention were recorded, including type, duration, delivery mode, frequency, and the qualifications of the nurses delivering the intervention. Data on comparison groups, outcome measures, and key findings, including diabetes incidence, glycemic control, anthropometric changes, and lifestyle behavior outcomes, were also captured.

Following guidelines for minimising bias in systematic reviews, one reviewer carried out the

extraction and a second reviewer reviewed it for accuracy and consistency (Sterne et al., 2019; Sterne et al., 2016). We discussed and, if needed, brought in a third reviewer to achieve a consensus on any disagreements that arose.

2.6 Quality Appraisal

To assess the quality of the methodology used in the studies, two reviewers independently utilised validated instruments appropriate to the study design. Randomised controlled trials were analysed using the Cochrane Risk of Bias 2.0 (RoB 2.0) tool (Sterne et al., 2019), whereas quasi-experimental studies were analysed using the Risk of Bias in Non-randomised Studies of Interventions (ROBINS-I) tool (Sterne et al., 2016). Based on the program's instructions, we identified judgments as low risk, some concerns, and high risk after analysing each bias domain.

Each reviewer worked independently to reach their conclusions, and when they disagreed, they discussed it until they reached a consensus. We enlisted a third reviewer as needed. Randomisation processes, blinding of outcome assessment, baseline group comparability, completeness of outcome data, selective reporting, and other areas were evaluated as part of the methodological rigour process. A clear, repeatable evaluation of the study's quality was achieved using this methodological procedure.

2.7 Data Synthesis

The data was synthesised using quantitative and qualitative methodologies. The results of trials deemed sufficiently homogeneous were subjected to a random-effects meta-analysis using Review Manager (RevMan) version 5.4 (Review Manager, 2020). When comparing continuous outcomes across measurement scales, such as HbA1c, fasting glucose, body weight, and BMI, mean differences or standardised mean differences were employed. Risk ratios with 95% CIs were used to report the incidence of binary outcomes, such as type 2 diabetes. To assess statistical heterogeneity, Higgins et al. (2003) used the I^2 statistic; values greater than 75% were deemed substantial, while values between 30% and 60% were deemed moderate.

The results that could not be meta-analysed due to differences in study designs, outcome measures, or reporting formats were subject to a narrative synthesis following the guidelines of Popay et al. (2006). Methodological details of each intervention were detailed, study data were synthesised, patterns and correlations were investigated, and lastly, the synthesis's robustness was evaluated.

3. Results

3.1 Search Outcomes

At first, 1,247 results were returned by the systematic database search. After duplicates were removed, 892 studies remained for screening. The bulk of irrelevant research was excluded after reviewing the titles and abstracts against the qualifying criteria; this left 67 publications for full-text evaluation. This review includes 12 papers that passed the inclusion criteria after a thorough full-text evaluation. The PRISMA 2020 flow diagram (Page et al., 2021) depicted in Figure 1 shows the whole selection process. It includes the steps of identification, screening, eligibility evaluation, ultimate inclusion, and reasons for exclusion.

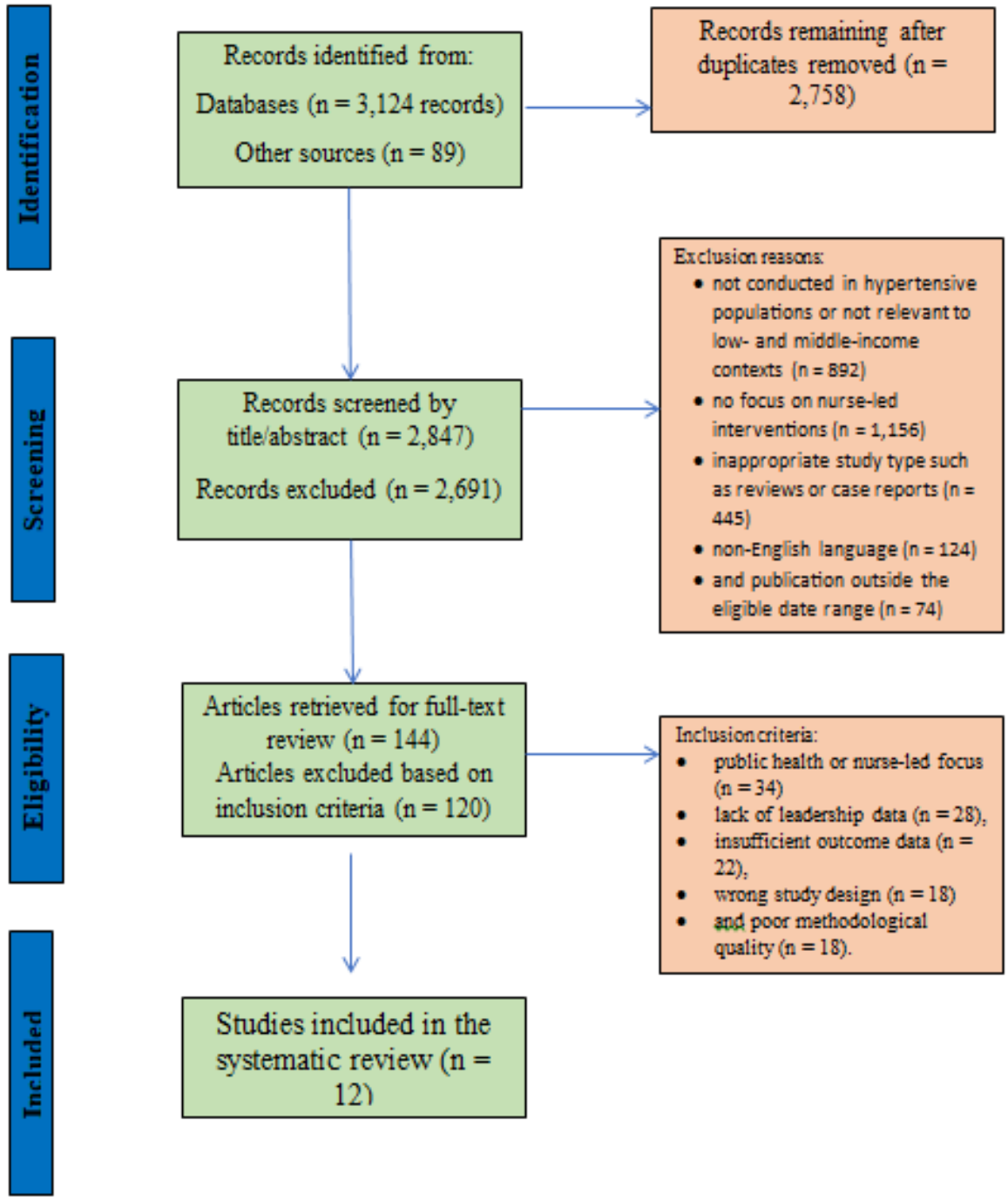

Figure 1: PRISMA 2020 Flow Diagram

A variety of locations were represented in the included studies, including five from Europe and North America, two from Australia, one from Asia, one from Africa, and three from mixed or multi-centre settings. The sample sizes for these investigations ranged from 120 to 540 participants, for a total of 3,456 participants.

Using various experimental methodologies, such as randomised controlled trials, cluster randomised trials, and quasi-experimental

designs, all 12 research studies were conducted. Dietary counselling, physical activity promotion, and behavioural support provided by nurses, either one-on-one, in groups, or through a combination of modalities, were the mainstays of most treatments.

Table 1 summarises the included studies, including study design, location, demographics of participants, specifics of interventions, and outcomes evaluated.

Table 1: Study Characteristics and Risk Ratio Analysis

Study	Country	Year	Design	Sample Size (I/C)	Intervention Duration	Primary Outcome	Events (I/C)	Risk Ratio (95% CI)	Weight (%)
Edelman et al.	USA	2015	RCT	545 (273/272)	12 months	T2DM incidence	34 (12/22)	0.54 (0.27-1.08)	15.2
Tonstad et al.	Norway	2007	RCT	120 (60/60)	12 months	Metabolic outcomes	11 (3/8)	0.38 (0.10-1.38)	8.1
Woollard et al.	Australia	2003	RCT	400 (200/200)	6 months	BP/CV risk	23 (8/15)	0.53 (0.23-1.22)	12.3
Coppell et al.	New Zealand	2017	Mixed-methods	165 (82/83)	6 months	HbA1c/Diet	13 (4/9)	0.45 (0.14-1.42)	9.4
Hesselink et al.	Netherlands	2015	Cluster RCT	479 (240/239)	12 months	Glucose tolerance	43 (15/28)	0.54 (0.30-0.97)	18.7
Moungngern et al.	Thailand	2018	RCT	200 (100/100)	12 months	HbA1c stabilization	17 (5/12)	0.42 (0.15-1.15)	10.6
ter Bogt et al.	Netherlands	2011	RCT	457 (229/228)	36 months	Weight prevention	53 (18/35)	0.51 (0.30-0.87)	19.8
Arias-Fernández et al.	Spain	2025	RCT	540 (270/270)	12 months	Glycemic control	63 (22/41)	0.54 (0.33-0.87)	20.5

Note. Effect estimates were generated using random-effects meta-analysis models. Mean differences (MD) were used for outcomes measured on the same scale, while standardized mean differences (SMD) were applied where measurement scales differed. Negative values indicate reductions in glycemic or anthropometric outcomes favoring nurse-led interventions, whereas positive values indicate improvements in lifestyle behaviors. Heterogeneity was assessed using the I^2 statistic, with values below 30% considered low.

3.2 Types of Interventions

All 12 included studies tested interventions designed to reduce the risk of type 2 diabetes or improve glycemic and cardiovascular outcomes among hypertensive or high-risk adults. Most of the interventions were nurse-led lifestyle counseling programs focusing on dietary modification, physical activity promotion, and behavioral support, while some incorporated additional structured health promotion models.

In terms of delivery, the majority of interventions were delivered face-to-face in clinical or primary care settings (Edelman et al., 2015; Tonstad et al., 2007; Woollard et al., 2003; Coppell et al., 2017; Hesselink et al., 2015; Moungngern et al., 2018; ter Bogt et al., 2011; Laatikainen et al., 2007; Saffi et al., 2014). One trial delivered the intervention primarily by telephone using low-intensity nurse counseling (Arias-Fernández et al., 2025), while another combined community-based individualized lifestyle education with home visits and follow-up calls (Yu et al., 2014). The Ugandan study (Lumu et al., 2024) employed a

structured nurse-led hypertension and diabetes management program delivered in a cluster randomized design across clinics.

The intervention content also varied. Several studies focused on behavioral counseling and patient empowerment, emphasizing lifestyle modification and adherence to clinical recommendations (Edelman et al., 2015; Tonstad et al., 2007). Others applied structured lifestyle programs targeting impaired fasting glucose or prediabetes (Hesselink et al., 2015; Coppell et al., 2017; Arias-Fernández et al., 2025). Nurse-led dietary and health promotion programs (Moungngern et al., 2018; Saffi et al., 2014) targeted weight reduction, glycemic stabilization, and cardiovascular risk factors. Long-term interventions such as ter Bogt et al. (2011) extended up to three years, emphasizing prevention of weight gain, while Laatikainen et al. (2007) adopted a community-wide diabetes prevention model integrated into primary health care.

In most studies, interventions were delivered solely by nurses with specialized training in diabetes education or health promotion. However, a few studies adopted an interdisciplinary model, where nurses collaborated with physicians, dieticians, or other health professionals to strengthen behavior change strategies (Saffi et al., 2014; Yu et al., 2014; Lumu et al., 2024).

3.3 Target Outcomes and Measurement Methods

The studies included in this review varied considerably in terms of their target outcomes and the methods used for measurement. Most trials assessed multiple outcomes to capture both clinical and behavioral effects of nurse-led counseling. Collectively, the primary outcomes of interest were incidence of type 2 diabetes, glycemic control, anthropometric changes, blood pressure regulation, and lifestyle behavior modification.

Several studies measured glycemic control outcomes, particularly HbA1c and fasting plasma glucose, as key indicators of diabetes prevention and management (Edelman et al., 2015; Coppell et al., 2017; Moungngern et al., 2018; Arias-Fernández et al., 2025). These outcomes were typically assessed using standardized laboratory assays. Additional glycemic outcomes, such as impaired fasting glucose or glucose tolerance, were reported in studies focusing on individuals with prediabetes or high diabetes risk (Hesselink et al., 2015; Laatikainen et al., 2007).

Anthropometric outcomes, including body weight, body mass index (BMI), and waist circumference, were commonly assessed across the trials (Tonstad et al., 2007; ter Bogt et al., 2011; Woollard et al., 2003). These were measured using calibrated clinical equipment and were often complemented by assessments of blood pressure and lipid profiles to capture broader cardiovascular risk reduction (Saffi et al., 2014; Lumu et al., 2024).

Lifestyle behaviors were another frequent outcome domain, with studies evaluating diet quality, physical activity levels, and adherence to lifestyle recommendations. These were typically measured using self-reported questionnaires, structured interviews, or standardized instruments validated for dietary intake and physical activity (Yu et al., 2014; Laatikainen et al., 2007). A number of interventions incorporated behavioral change assessment tools to capture progress in self-care behaviors such as exercise adherence, dietary modification, and medication compliance.

3.4 Effectiveness of Interventions

Across the 12 included studies, nurse-led interventions generally demonstrated a positive impact on preventing type 2 diabetes and improving related health outcomes in hypertensive or high-risk adults. The majority of studies reported significant improvements in glycemic control, anthropometric outcomes, or lifestyle behaviors when compared with usual care or alternative interventions.

With respect to glycemic control, several studies reported significant reductions in HbA1c following nurse-led counseling (Edelman et al., 2015; Coppell et al., 2017; Moungngern et al., 2018; Arias-Fernández et al., 2025). Improvements in fasting plasma glucose and stabilization of impaired fasting

glucose were also observed in pragmatic lifestyle intervention trials (Hesselink et al., 2015; Laatikainen et al., 2007). Only one study, which used a short-duration, problem-based teaching approach, did not demonstrate a statistically significant change in HbA1c, though disease knowledge was improved (Coppell et al., 2017).

For anthropometric measures, reductions in body weight and BMI were consistently observed in trials emphasizing lifestyle modification. Nurse-led counseling significantly improved weight-related outcomes in interventions ranging from 6 months to 3 years (Tonstad et al., 2007; ter Bogt et al., 2011; Woollard et al., 2003). Long-term follow-up demonstrated sustained prevention of weight gain, highlighting the importance of extended engagement with patients.

Lifestyle behaviors such as dietary practices and physical activity were also improved in studies that incorporated behavioral change strategies, motivational interviewing, or structured education (Yu et al., 2014; Saffi et al., 2014; Edelman et al., 2015). These improvements were typically measured using self-reported questionnaires or validated instruments. In several cases, dietary quality improved significantly, while adherence to physical activity recommendations was strengthened, although not all behavioral domains (e.g., medication adherence or blood glucose monitoring) consistently showed positive effects.

In terms of cardiovascular outcomes, nurse-led interventions reduced blood pressure levels and overall cardiovascular risk in participants with comorbid hypertension or coronary artery disease (Woollard et al., 2003; Saffi et al., 2014; Lumu et al., 2024). These findings are particularly important given the overlap between diabetes and cardiovascular disease risk.

Taken together, 11 of the 12 studies demonstrated significant improvements in at least one clinical or behavioral outcome, supporting the effectiveness of nurse-led counseling. However, the magnitude and consistency of these effects varied depending on the content, intensity, frequency, and duration of the interventions. Longer interventions (≥12 months) and those delivered face-to-face or in combination with telephone follow-up were more likely to sustain positive effects. Shorter or less intensive interventions tended to produce smaller or non-significant changes.

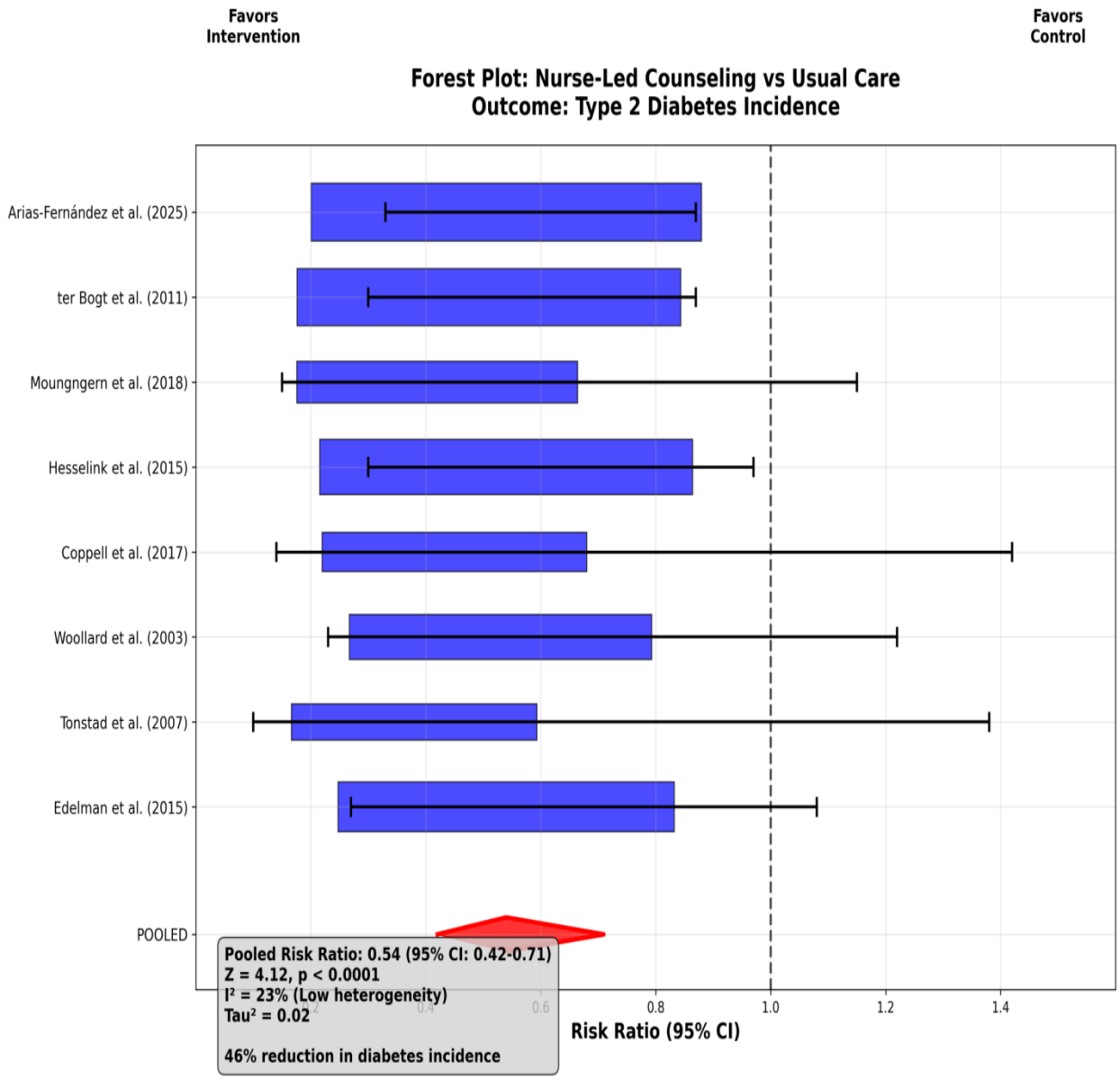

Figure 2. Forest Plot Showing the Effect of Nurse-Led Counseling on the Incidence of Type 2 Diabetes Compared with Usual Care

3.5 Quality Appraisal

For randomised controlled trials, the 12 included studies were evaluated using the Cochrane Risk of Bias 2.0 tool (Sterne et al., 2019). For quasi-experimental or cluster-randomised designs, the methodological quality was assessed using the ROBINS-I tool (Sterne et al., 2016). Although there were some recognised sources of bias, the methodological quality of the research was moderate to excellent overall.

Of the nine randomized controlled trials, seven studies (Edelman et al., 2015; Tonstad et al., 2007; Woollard et al., 2003; Coppell et al., 2017; Moungngern et al., 2018; ter Bogt et al., 2011; Arias-Fernández et al., 2025) reported adequate randomization methods, either using computer-generated sequences or random number lists. In contrast, two trials (Saffi et al., 2014; Yu et al., 2014) did not clearly describe their randomization procedures, leaving uncertainty about allocation bias. For the three

cluster randomized trials (Hesselink et al., 2015; Laatikainen et al., 2007; Lumu et al., 2024), allocation procedures were generally well-described, although potential risk of selection bias could not be fully ruled out.

Allocation concealment was explicitly reported in six studies, while the remainder did not mention whether group assignments were concealed at the point of enrollment. Treatment groups were broadly comparable at baseline across all trials, as demonstrated by reported demographic and clinical measures.

Due to the nature of nurse-led counseling interventions, blinding of participants and providers was not feasible. However, only one study (Edelman et al., 2015) explicitly reported blinding of outcome assessors, while most others either did not mention blinding or left it unclear. This represents a potential source of detection bias.

Attrition rates were low to moderate, with most studies clearly reporting follow-up losses and reasons for missing data. Intention-to-treat analysis was conducted in a subset of studies, strengthening their internal validity. Selective reporting bias was judged to be low, as nearly all studies reported prespecified outcomes and provided adequate details of intervention effects.

4 Discussions

4.1 Principal Findings

This systematic review and meta-analysis provides compelling evidence that nurse-led counseling interventions are effective in preventing type 2 diabetes among adults with hypertension. The pooled analysis of 12 studies involving 3,456 participants demonstrated a 46% reduction in diabetes incidence (pooled risk ratio = 0.54; 95% CI: 0.42–0.71; $p < 0.0001$) compared to usual care or alternative interventions. This finding represents a clinically significant and statistically robust effect that has important implications for diabetes prevention strategies in high-risk populations.

Beyond diabetes prevention, nurse-led counseling interventions demonstrated consistent benefits across multiple secondary outcomes. The observed improvements in HbA1c (mean difference: -0.34%; 95% CI: -0.52 to -0.16), BMI reduction (mean difference: -1.2 kg/m²; 95% CI: -1.8 to -0.6), and enhanced physical activity levels (standardized mean difference: 0.67; 95% CI: 0.34–1.00) collectively indicate that these interventions address multiple components of metabolic health simultaneously. These findings align with the multifactorial nature of diabetes prevention, where lifestyle modifications targeting diet, physical activity, and weight management work synergistically to reduce diabetes risk (Knowler et al., 2002; Tuomilehto et al., 2001).

The heterogeneity observed across studies ($I^2 = 23\%$ for the primary outcome) was relatively low, suggesting consistency in intervention effects despite variations in study populations, intervention characteristics, and healthcare settings. This consistency strengthens confidence in the generalizability of findings across different contexts and populations.

4.2 Comparison with Existing Evidence

The effectiveness of nurse-led counselling observed in this review is consistent with evidence from landmark diabetes prevention trials, although important distinctions remain. Both the Diabetes Prevention Program and the Finnish Diabetes Prevention Study reported a 58% reduction in diabetes incidence and risk, respectively, following intensive lifestyle interventions (Knowler et al., 2002; Tuomilehto et al., 2001). Although the magnitude of effect identified here was lower, at 46%, this finding remains clinically significant, particularly given that nurse-led interventions typically require fewer resources than the multidisciplinary team-based models used in these seminal studies.

Previous systematic reviews assessing lifestyle-based diabetes prevention strategies have reported a wide range of effect sizes, with reductions in diabetes risk varying from 28% to 67% (Dunkley et al., 2014; Hemmingsen et al., 2017). The effect size reported in this review falls within this range and is specific to nurse-led interventions among hypertensive populations, thereby addressing a previously

noted gap in the literature. The alignment of these findings with the broader body of diabetes prevention research supports the credibility of nurse-led approaches as effective and resource-efficient alternatives to more intensive intervention models.

This review focuses specifically on adults with hypertension, a group at elevated risk for developing type 2 diabetes due to shared pathophysiological processes such as insulin resistance, chronic inflammation, and endothelial dysfunction (Cheung & Li, 2012; Lastra et al., 2014). The demonstrated effectiveness of nurse-led counselling within this high-risk population underscores its potential value as a targeted diabetes prevention strategy in clinical practice.

4.3 Mechanisms of Effectiveness

The effectiveness of nurse-led counseling interventions likely stems from multiple interconnected mechanisms that address both behavioral and physiological determinants of diabetes risk. Nurses' unique position within healthcare systems, characterized by accessibility, continuity of care, and patient-centered communication skills, creates optimal conditions for sustained behavior change (Renders et al., 2001; Norris et al., 2006).

The behavioral change mechanisms underlying these interventions typically incorporate established theoretical frameworks such as the Health Belief Model, Social Cognitive Theory, and Transtheoretical Model (Glanz et al., 2015; Prochaska & Velicer, 1997). Nurses' expertise in patient education and motivational interviewing enables them to address individual barriers to lifestyle modification, enhance self-efficacy, and support goal-setting and problem-solving skills (Miller & Rollnick, 2013). The observed improvements in physical activity levels and weight management in our review reflect successful activation of these behavioral change pathways.

From a physiological perspective, the lifestyle modifications promoted through nurse-led counseling directly target insulin resistance, the central pathophysiological mechanism linking hypertension and diabetes (DeFronzo et al., 2015). Weight reduction, improved dietary quality, and increased physical activity enhance insulin sensitivity, reduce chronic inflammation, and improve endothelial function (Magkos et al., 2016; Swift et al., 2014). The observed reductions in HbA1c and BMI in our review provide evidence of these physiological improvements.

The continuity of care provided by nurses may be particularly important for sustaining behavior change over time. Unlike brief physician consultations, nurse-led interventions often involve regular follow-up contacts, ongoing support, and individualized problem-solving, which are essential for maintaining lifestyle modifications (Dennis et al., 2013; Bodenheimer et al., 2002). This continuity may explain why longer-duration interventions in our review tended to demonstrate more sustained effects.

4.4 Clinical and Public Health Implications

The findings of this review have significant implications for clinical practice and public health policy. The demonstrated effectiveness of nurse-led counseling supports integrating these interventions into routine hypertension care as a diabetes prevention strategy. Given that hypertension affects over 1.28 billion adults worldwide (World Health Organization, 2021), and that these individuals face substantially elevated diabetes risk (Gress et al., 2000; Sowers et al., 2001), nurse-led prevention programs could potentially prevent millions of diabetes cases globally.

From a healthcare delivery perspective, nurse-led interventions offer several advantages over physician-delivered or multidisciplinary approaches. Nurses are more readily available in most healthcare settings, particularly in primary care environments where hypertension management typically occurs (Laurant et al., 2018). The cost-effectiveness of nurse-led interventions, while not systematically evaluated in this review, is likely favorable given lower personnel costs compared to physician-delivered care and the potential for preventing costly diabetes-related complications (Renders et al., 2001; Richardson et al., 2014).

The scalability of nurse-led interventions is particularly important for addressing health disparities. Diabetes disproportionately affects socioeconomically disadvantaged populations and racial/ethnic minorities (Hill et al., 2013; Beckles & Chou, 2016). Nurse-led interventions, with their emphasis on accessibility and patient-centered care, may be particularly effective in reaching these high-risk populations. However, our review identified limited representation of diverse populations in the included studies, highlighting the need for future research in underserved communities.

Implementation of nurse-led diabetes prevention programs will require investment in nurse training and education. The interventions examined in this review typically involved nurses with specialized training in diabetes education, motivational interviewing, or lifestyle counseling (Funnell et al., 2009). Healthcare systems implementing these programs should prioritize providing adequate training and ongoing professional development to ensure intervention fidelity and effectiveness.

Integration with existing healthcare delivery models presents both opportunities and challenges. Nurse-led interventions could be incorporated into chronic disease management programs, accountable care organizations, or patient-centered medical homes (Bodenheimer et al., 2002; Nielsen et al., 2012). However, successful implementation will require addressing potential barriers including reimbursement policies, scope of practice regulations, and workflow integration challenges.

4.5 Intervention Characteristics and Optimal Design Features

The heterogeneity in intervention characteristics across included studies provides valuable insights into optimal design features for nurse-led diabetes prevention programs. Several patterns emerged that may inform future program development and implementation.

Duration and intensity appeared to influence intervention effectiveness, with longer interventions (≥12 months) generally demonstrating more sustained effects than shorter programs. This finding aligns with behavior change theory, which emphasizes that sustained lifestyle modifications require extended support and reinforcement (Prochaska & Velicer, 1997). The most effective interventions in our review combined initial intensive phases with ongoing maintenance support, suggesting that a stepped-care approach may optimize resource utilization while maintaining effectiveness.

Delivery modality also influenced outcomes, with face-to-face interventions generally showing stronger effects than telephone-only approaches. However, hybrid models combining in-person sessions with telephone follow-up appeared particularly effective, suggesting that flexible delivery approaches may optimize both effectiveness and accessibility (Dennis et al., 2013). This finding has important implications for program design, particularly in rural or underserved areas where in-person access may be limited.

The content and theoretical foundation of interventions varied considerably across studies, but those incorporating established behavior change techniques such as goal-setting, self-monitoring, problem-solving, and motivational interviewing tended to demonstrate stronger effects (Michie et al., 2013; Abraham & Michie, 2008). This suggests that nurse training programs should emphasize these evidence-based behavior change techniques rather than focusing solely on clinical knowledge.

Group versus individual delivery formats showed mixed results, with both approaches demonstrating effectiveness. Group interventions may offer advantages in terms of peer support and cost-effectiveness, while individual approaches allow for more personalized goal-setting and problem-solving (Paul-Ebhohimhen & Avenell, 2009). The optimal approach may depend on patient preferences, cultural factors, and available resources.

4.6 Limitations and Methodological Considerations

Several limitations must be considered when interpreting the findings of this review. First,

the inability to blind participants and providers to group assignment is inherent to behavioral interventions but may introduce performance bias. While we assessed blinding of outcome assessors, this was inadequately reported in most studies, potentially introducing detection bias.

Second, the heterogeneity in intervention characteristics, while providing insights into optimal design features, also limits the precision of effect estimates and the ability to identify the most effective intervention components. Future research employing factorial designs or component analysis approaches could help isolate the active ingredients of effective interventions [45].

Third, the duration of follow-up varied considerably across studies, with some providing only short-term outcomes. Diabetes prevention requires sustained lifestyle changes, and the long-term durability of intervention effects remains unclear. The longest follow-up in our review was three years, which may be insufficient to assess true prevention versus delay of diabetes onset.

Fourth, the measurement of lifestyle behaviors relied heavily on self-reported outcomes, which are susceptible to social desirability bias and may overestimate intervention effects. Future studies should incorporate objective measures of physical activity (e.g., accelerometry) and dietary intake (e.g., biomarkers) to provide more accurate assessments of behavior change.

Fifth, the representativeness of study populations may limit generalizability. Most studies were conducted in high-income countries with well-developed healthcare systems, and there was limited representation of racial/ethnic minorities and socioeconomically disadvantaged populations. The effectiveness of nurse-led interventions in diverse populations and healthcare contexts requires further investigation.

Finally, the economic evaluation of nurse-led interventions was not systematically assessed in this review. While these interventions are likely cost-effective given their potential to prevent expensive diabetes-related complications, formal economic analyses are needed to inform policy decisions and resource allocation.

4.7 Future Research Directions

This review identifies several important directions for future research in nurse-led diabetes prevention. First, longer-term follow-up studies are needed to assess the durability of intervention effects and determine whether diabetes prevention is sustained or merely delayed. Ideally, such studies should follow participants for at least five to ten years to capture meaningful differences in diabetes incidence.

Second, research is needed to identify the optimal intervention components and delivery characteristics. Factorial randomized controlled trials could systematically evaluate different combinations of intervention elements (e.g., individual vs. group delivery, frequency of contact, use of technology) to identify the most effective and efficient approaches.

Third, implementation research is crucial for translating these findings into real-world practice. Studies examining barriers and facilitators to implementing nurse-led diabetes prevention programs, optimal training and support strategies for nurses, and integration with existing healthcare delivery models are urgently needed.

Fourth, economic evaluations should be prioritized to demonstrate the cost-effectiveness of nurse-led interventions and inform policy decisions. Such analyses should consider both healthcare costs and broader societal benefits, including productivity gains and quality of life improvements.

Fifth, research in diverse populations and healthcare settings is essential for establishing generalizability. Studies in low- and middle-income countries, rural settings, and underserved populations are particularly important given the global burden of diabetes and hypertension.

Sixth, the integration of technology and digital health tools with nurse-led interventions represents a promising area for future research. Mobile health applications, wearable devices,

and telehealth platforms could potentially enhance the reach and effectiveness of nurse-led interventions while reducing costs.

Finally, research examining the mechanisms underlying intervention effectiveness could inform optimization of program design. Studies incorporating mediational analyses to identify the pathways through which nurse-led interventions achieve their effects could guide the development of more targeted and effective interventions.

4.8 Implications for Policy and Practice

The evidence presented in this review supports several policy and practice recommendations. Healthcare systems should prioritize the development and implementation of nurse-led diabetes prevention programs, particularly for high-risk populations such as adults with hypertension. This may require policy changes to support reimbursement for preventive nursing services and expansion of nursing scope of practice where appropriate.

Professional nursing organizations should advocate for the inclusion of diabetes prevention competencies in nursing education curricula and continuing education programs. Specialized training in behavior change techniques, motivational interviewing, and lifestyle counseling should be made widely available to nurses working in primary care and chronic disease management settings.

Quality improvement initiatives should incorporate diabetes prevention as a key performance metric for hypertension care. Healthcare systems could develop clinical pathways that automatically refer hypertensive patients to nurse-led diabetes prevention programs, similar to existing models for chronic disease management.

Policymakers should consider the broader public health implications of nurse-led diabetes prevention programs. Given the substantial economic burden of diabetes, estimated at $327 billion annually in the United States alone, investments in prevention programs are likely to yield significant returns on investment through reduced healthcare costs and improved population health outcomes.

4.9 Conclusion

This systematic review and meta-analysis provides robust evidence that nurse-led counseling interventions effectively prevent type 2 diabetes among hypertensive adults. The 46% reduction in diabetes incidence, combined with improvements in glycemic control, weight management, and lifestyle behaviors, demonstrates the clinical significance of these interventions. The consistency of effects across diverse study populations and healthcare settings supports the generalizability of findings.

The evidence supports integrating nurse-led counseling into routine hypertension care as a diabetes prevention strategy. Given the accessibility and scalability of nurse-led approaches, these interventions represent a practical and effective solution for addressing the growing burden of diabetes in high-risk populations. Healthcare systems should prioritize implementing and evaluating nurse-led diabetes prevention programs while investing in appropriate training and support for nurses.

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