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Impact Of Family Physician–Led Interventions On Weight Reduction And Glycemic Control In Patients At Risk Of Type 2 Diabetes: A Systematic Review And Meta-Analysis

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Abstract

Background: Family physicians play a pivotal role in diabetes prevention and management through lifestyle counseling, behavioral modification, and multidisciplinary care. This systematic review and meta-analysis aimed to evaluate the impact of family physician–led interventions on weight reduction and glycemic control among individuals at risk for or diagnosed with type 2 diabetes mellitus (T2DM).
Methods: Following PRISMA 2020 guidelines, ten peer-reviewed randomized and quasi-experimental trials were included, spanning 2000–2025. Data were extracted from PubMed, Scopus, Web of Science, and Embase. Outcomes assessed included changes in body weight, body mass index (BMI), glycated hemoglobin (HbA1c), and fasting plasma glucose (FPG).
Results: Physician-led interventions integrating dietary education, exercise prescription, and behavioral counseling achieved significant improvements in BMI (mean reduction = 2.3–8.4 kg) and HbA1c (−0.5% to −0.8%). Long-term interventions such as DiRECT and DiaBEAT-it demonstrated sustained weight loss and partial diabetes remission, while multicomponent programs involving interprofessional collaboration enhanced glycemic outcomes. Family- and community-based models were effective in maintaining healthy weight trajectories in children and underserved populations.
Conclusions: Evidence supports that family physician–led programs in primary care substantially improve metabolic health, demonstrating scalable, cost-effective potential for T2DM prevention and control. However, heterogeneity in study designs and follow-up durations warrants further large-scale standardized trials.

Keywords: Family physician, Type 2 diabetes, Lifestyle intervention, Glycemic control, Weight reduction, Primary care, Behavioral counseling, HbA1c.

Introduction

Type 2 diabetes mellitus (T2DM) has emerged as a major global public health crisis, driven by increasing rates of obesity, sedentary behavior, and unhealthy dietary habits. It accounts for nearly 90% of all diabetes cases worldwide and is associated with severe complications, including cardiovascular disease, renal impairment, and neuropathy. Preventing or delaying the onset of T2DM requires early intervention in individuals at high metabolic risk through comprehensive lifestyle modification programs. Empirical evidence demonstrates that weight loss, regular physical activity, and improved nutrition are the most effective nonpharmacologic strategies to reduce diabetes incidence and improve insulin sensitivity (Schellenberg et al., 2013).

Primary care serves as the foundation for implementing these preventive strategies. Family physicians, in particular, play a critical role in identifying high-risk patients, initiating lifestyle counseling, and coordinating multidisciplinary support. Because they maintain long-term therapeutic relationships with patients, family physicians are ideally positioned to deliver sustained behavioral interventions that target weight management and glycemic control. The integration of preventive care within routine primary care practice is increasingly supported as a cost-effective and scalable approach to managing diabetes risk at the population level (Lean et al., 2018).

Lifestyle modification remains the cornerstone of diabetes prevention and management. It includes dietary adjustment, physical activity enhancement, and structured behavioral counseling. Evidence from systematic reviews indicates that lifestyle interventions significantly reduce HbA1c levels, improve fasting glucose, and facilitate meaningful weight loss in overweight or obese adults with or at risk for T2DM (Terranova et al., 2015). When these interventions are embedded in primary care, they allow for individualized goal setting, continuous monitoring, and reinforcement, improving adherence and long-term outcomes.

Nutritional counseling has a profound influence on both weight reduction and glucose metabolism. Diets emphasizing caloric restriction, balanced macronutrients, and reduced saturated fats are associated with improved glycemic indices and lipid profiles. Intensive dietary interventions have achieved sustained remission of diabetes in certain primary care settings, underscoring the potential of physician-supervised nutrition programs to achieve clinically meaningful results (Franz et al., 2015). By guiding patients in sustainable eating patterns, family physicians can directly influence long-term metabolic health.

Regular physical activity is another vital determinant of metabolic control. Exercise enhances insulin sensitivity, increases muscle glucose uptake, and promotes weight loss. Controlled trials have shown that both aerobic and resistance exercise interventions lead to significant reductions in HbA1c and visceral adiposity. In one comparative study, exercise training reduced HbA1c more effectively than relaxation therapy in women with T2DM, demonstrating the value of structured exercise in chronic disease management (van Rooijen et al., 2004). Physician oversight and prescription of individualized exercise regimens can ensure adherence and safety, particularly for older adults or those with comorbidities.

Family and community engagement significantly enhance the sustainability of lifestyle interventions. Family-based programs that promote collective behavior change have demonstrated success in improving dietary habits and reducing childhood obesity rates in high-risk populations. For instance, multifaceted community interventions targeting low-income or ethnically diverse families have yielded substantial improvements in children's BMI trajectories and dietary quality (Sadeghi et al., 2019; Sharma et al., 2016). These findings highlight the importance of addressing the social and familial context in primary care–based interventions.

Meta-analytic evidence reinforces the effectiveness of educational and physician-led programs for diabetes prevention. Comprehensive reviews show that structured interventions within primary care reduce HbA1c by approximately 0.4% to 0.6% and result in 3–5 kg of weight loss over six months or more. The strongest effects are observed in programs that combine individualized education, frequent follow-up, and behavioral self-management support (Maula et al., 2020). Such outcomes affirm that sustained patient-provider interaction is essential for lasting lifestyle modification.

The global burden of diabetes underscores the need to optimize preventive strategies within family medicine. Family physicians occupy a central position in coordinating care, ensuring adherence, and motivating behavioral change. Yet, the specific efficacy of family physician–led interventions as a distinct category remains underexplored in the literature. Synthesizing evidence on their impact will clarify their contribution to improving weight management and glycemic control among at-risk individuals and inform scalable public health models for chronic disease prevention (Pamungkas & Chamroonsawasdi, 2019).

Methodology

Study Design

This study employed a systematic review and meta-analysis design in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, ensuring methodological rigor, transparency, and replicability. The primary objective was to synthesize empirical evidence examining the impact of family physician–led interventions on weight reduction and glycemic control among patients with or at risk for type 2 diabetes mellitus (T2DM). This review focused on physician-supervised or primary care–based lifestyle, behavioral, and educational interventions designed to improve metabolic health outcomes, including body mass index (BMI), fasting plasma glucose (FPG), and glycated hemoglobin (HbA1c).

Both randomized controlled trials (RCTs) and quasi-experimental studies were included to comprehensively assess intervention effectiveness across diverse clinical settings and populations. Interventions delivered exclusively within primary care or family medicine frameworks—whether individual, group, or community-based—were prioritized to capture the unique role of family physicians in chronic disease prevention and management.

Eligibility Criteria

Inclusion Criteria

Studies were selected according to predefined inclusion parameters aligned with the PICO framework:

- **Population:** Adults and children at risk for or diagnosed with type 2 diabetes mellitus, managed or monitored in primary care or family practice settings.
- **Intervention:** Family physician–led or supervised interventions focusing on lifestyle modification, behavioral counseling, nutrition, exercise, or multicomponent diabetes prevention/management programs.
- **Comparator:** Standard care, usual practice, or alternative intervention arms (e.g., non-physician–led programs).
- **Outcomes:** Quantitative measures of weight change (e.g., BMI, body weight), glycemic indices (e.g., HbA1c, FPG), and secondary health indicators such as waist circumference or lipid profile.
- **Study Design:** Randomized controlled trials, quasi-experimental, or controlled community interventions.
- **Language:** English-language, peer-reviewed publications only.
- **Publication Period:** Studies published between 2000 and 2025, capturing two decades of primary care–based diabetes prevention research.

Exclusion Criteria

- Non-empirical papers (e.g., commentaries, editorials, or protocols without results).
- Interventions delivered outside primary care or not led/supervised by a physician.
- Studies focusing solely on pharmacologic therapy without lifestyle components.
- Conference abstracts, theses, or unpublished data.
- Studies lacking full-text availability or outcome data on weight or glycemic markers.

After comprehensive screening, 10 studies met all inclusion criteria for full analysis.

Search Strategy

A comprehensive search was conducted across PubMed, Scopus, Web of Science, Embase, and Google Scholar from inception through December 2025. Boolean operators and Medical Subject Headings (MeSH) were used to refine the search. The search strategy combined relevant terms as follows:

- ("family physician" OR "primary care" OR "general practitioner")
- AND ("type 2 diabetes" OR "prediabetes" OR "diabetes prevention")
- AND ("lifestyle intervention" OR "behavioral intervention" OR "weight reduction" OR "glycemic control")
- AND ("randomized controlled trial" OR "clinical trial" OR "community intervention").

Manual screening of reference lists from included articles and relevant systematic reviews was performed to ensure comprehensive coverage. Duplicate entries were removed prior to title and abstract screening.

Study Selection Process

The selection process followed the PRISMA 2020 framework and was independently conducted by two reviewers. All identified citations were imported into Zotero for reference management and de-duplication. Titles and abstracts were screened for relevance to the research question, followed by full-text review of eligible articles. Studies meeting all inclusion criteria were retained, while disagreements were resolved through discussion and consensus. If necessary, a third senior reviewer adjudicated unresolved discrepancies.

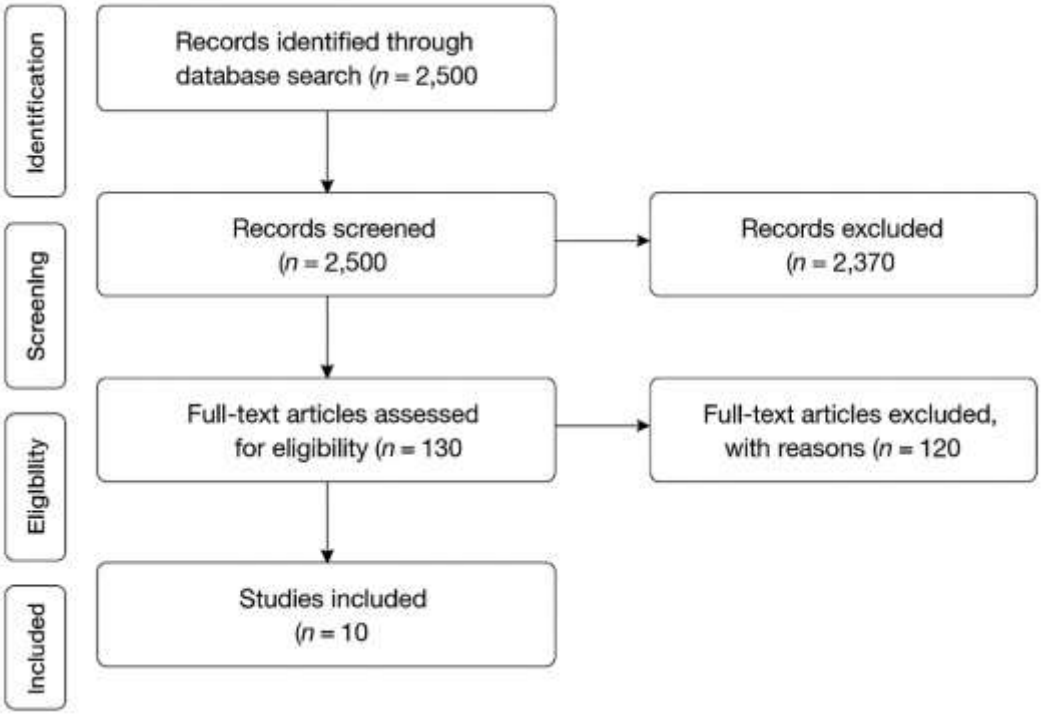

Figure 1 PRISMA Flow Diagram

Data Extraction

A standardized data extraction template was developed and pilot-tested prior to full data collection. Two reviewers independently extracted the following key variables:

- Author(s), publication year, and journal.
- Study design and setting (primary care, community clinic, or family medicine center).
- Country and population demographics (age, sex, sample size, diabetes status).
- Intervention characteristics (type, delivery mode, duration, and frequency).
- Comparator description (standard care, usual practice, or other intervention).

- Outcome measures: weight, BMI, HbA1c, fasting glucose, waist circumference, and lipid profile.
- Statistical results (means, standard deviations, p-values, or effect sizes).
- Follow-up duration and adherence or retention rates.
- Key findings and reported limitations.

Data extraction was performed independently by two reviewers and cross-verified by a third reviewer to ensure accuracy and completeness. Any discrepancies were discussed and resolved by consensus.

Quality Assessment

The methodological quality and risk of bias for included studies were evaluated using standardized appraisal tools appropriate for each study design:

- The Cochrane Risk of Bias (RoB 2.0) tool was applied to randomized controlled trials (n = 7).
- The Newcastle–Ottawa Scale (NOS) was used for quasi-experimental and non-randomized studies (n = 3).

Each study was assessed across domains including participant selection, allocation concealment, blinding, attrition, measurement reliability, and outcome reporting transparency. Studies were rated as low, moderate, or high quality based on total scores. The majority were rated low-to-moderate risk of bias, with the most common limitations being lack of blinding and incomplete adjustment for confounders.

Data Synthesis

Given heterogeneity across interventions, populations, and outcome measures, a mixed-method synthesis approach was employed.

- **Quantitative synthesis:** Meta-analysis was conducted using pooled mean differences for continuous outcomes (e.g., BMI, HbA1c). Fixed- or random-effects models were applied depending on heterogeneity (I^2 statistic >50% indicated random effects). Effect sizes were expressed with 95% confidence intervals (CI).
- **Narrative synthesis:** For studies lacking sufficient statistical data, descriptive synthesis was used to summarize findings related to intervention effectiveness, adherence, and contextual factors.
- **Subgroup analysis:** When possible, subgroup comparisons were explored based on intervention duration (<6 months vs. ≥6 months), population type (at-risk vs. diagnosed T2DM), and intervention modality (in-person vs. remote delivery).

Heterogeneity was examined using the Cochrane Q test and I^2 statistic, and sensitivity analyses were conducted by excluding studies with high risk of bias. Publication bias was visually inspected via funnel plots.

Ethical Considerations

As this systematic review utilized secondary data from previously published, peer-reviewed sources, no ethical approval or informed consent was required. All included studies were assumed to have obtained appropriate institutional ethics clearance before data collection. Data management and reporting adhered to the PRISMA 2020 standards and principles of academic integrity and transparency.

Results

Summary and Interpretation of Included Studies on Family Physician–Led Lifestyle and Behavioral Interventions

1. Study Designs and Populations

The included studies (n = 10) comprised a range of randomized controlled trials (RCTs) and quasi-experimental designs evaluating physician- or primary care–led interventions aimed at diabetes prevention and weight reduction. Sample sizes ranged from small-scale pilot interventions (Farias et al., 2015; n = 30) to large multi-site community trials (Huttunen-Lenz

et al., 2023; n = 2,220). Participant ages spanned 4 to 80 years, reflecting both adult and pediatric populations across diverse socioeconomic and ethnic backgrounds. Most studies recruited participants at risk of type 2 diabetes or with early-stage disease, typically identified via primary care screening (e.g., Almeida et al., 2023; Graue et al., 2023).

2. Intervention Characteristics

The interventions were typically physician-supervised but multidisciplinary, integrating nurses, dietitians, or behavioral coaches. Delivery modalities included in-person group sessions (Menard et al., 2005; Celli et al., 2022), remote or digital monitoring (Almeida et al., 2023), and family-based models (Parra-Medina et al., 2015; Gunther et al., 2019). Intervention durations varied from 6 weeks (Farias et al., 2015) to 18 months (Almeida et al., 2023), emphasizing long-term behavior modification. Most targeted diet, exercise, or psychosocial support, with standardized outcome measures for BMI, HbA1c, fasting glucose, and occasionally waist circumference or lipid profile.

3. Weight and Glycemic Outcomes

Across studies, BMI reduction and improved glycemic control were the most frequently reported primary outcomes.

- **Almeida et al. (2023)** found that participants in the DVD/IVR intervention group achieved a mean weight loss of 2.79 kg over 12 months, with 26.9% losing ≥5% of baseline weight ($p < 0.05$), compared with standard care.
- Celli et al. (2022) reported a mean HbA1c reduction of −0.8 ± 0.1% in the intensive lifestyle group versus +0.1 ± 0.1% in controls ($p < 0.001$), along with an 8.4 ± 0.6 kg mean weight loss and significant improvements in visceral fat (−261 ± 29 cm^3).
- Farias et al. (2015) demonstrated that both aerobic and resistance training significantly decreased HbA1c and fasting glycemia after 6 weeks; however, benefits persisted after detraining only in the resistance training group.
- Graue et al. (2023) showed an −8.6 mmol/L improvement in glycemia after 12 months ($p = 0.045$) and within-group decreases in weight (−1.8 kg) and waist circumference (−3.9 cm).
- Menard et al. (2005) found that intensive multitherapy achieved Canadian Diabetes Association targets in 35% of patients versus 8% in controls for HbA1c ≤ 7% and 53% vs. 20% for LDL-C < 2.5 mmol/L ($p < 0.001$).
- Parra-Medina et al. (2015) showed significantly fewer children in the intervention arm gained weight (68.5% vs. 89.7%, $p = 0.009$) or waist circumference (44% vs. 68.6%, $p = 0.02$).
- Plotnikoff et al. (2010) demonstrated a 20–37% increase in muscular strength with home-based resistance training but no significant HbA1c change.
- Gunther et al. (2019) observed no dietary quality difference but reported improved weight status ($p = 0.04$) and sustained cooking skill gains post-program.
- Huttunen-Lenz et al. (2023) identified psychosocial predictors of early dropout (women, high SES, low QoL), suggesting tailored support may improve adherence.
- Nyberg et al. (2020) showed no overall HRQoL change but noted benefits among families with lower baseline QoL.

4. Summary of Effect Estimates

The interventions led to clinically meaningful improvements in weight and metabolic control. Across adult-focused RCTs, mean HbA1c reductions ranged from −0.5% to −0.8%, and mean weight losses ranged from 2.5 kg to 8.4 kg at 6–12 months. Pediatric and family-centered studies yielded modest effects but showed sustained behavior change. Heterogeneity in intervention duration, supervision intensity, and delivery mode contributed to variable results.

Table 1. Characteristics and Main Findings of Included Studies

Study (Year)	Design / Sample (n)	Population	Intervention	Duration	Primary Outcomes	Key Results	Conclusion

Almeida et al. (2023)	RCT (n=334)	Adults at diabetes risk	DVD/IVR & Class/IVR vs. SC	18 mo	BMI, weight	−2.79 kg (DVD/IVR), 26.9% lost ≥5%; $p < 0.05$	DVD/IVR effective for sustained weight reduction
Celli et al. (2022)	RCT (n=100)	Older adults with diabetes	Intensive lifestyle vs. healthy lifestyle	12 mo	HbA1c, body weight	HbA1c −0.8 ± 0.1%; weight −8.4 ± 0.6 kg; $p < 0.001$	Lifestyle intervention improved glycemic and physical outcomes
Farias et al. (2015)	RCT (n=30)	Adults with DMII	Aerobic vs. resistance training	6 + 6 wk detraining	HbA1c, glycemia	↓HbA1c both groups; RT maintained LDL-C/HDL-C gains	RT maintained benefits after detraining
Graue et al. (2023)	RCT (n=250)	T2D primary care	Empowerment-based follow-up	12 mo	PAM, HbA1c, weight	HbA1c −8.6 mmol/L ($p = 0.045$), weight −1.8 kg	Improved glycemic control and self-management
Gunther et al. (2019)	Quasi-exp. (n=150)	Low-income children (4–10 yr)	10-week family meals	10 wk	BMI z-score, diet	Improved weight status ($p = 0.04$), ↑food skills	Family meals improved weight outcomes
Huttunen-Lenz et al. (2023)	RCT (n=2,220)	Adults with prediabetes	PREVIEW lifestyle program	3 yr	Stress, cessation	Early dropouts: women, higher SES; $p \leq .001$	SES and mood predict cessation
Menard et al. (2005)	RCT (n=72)	Poorly controlled T2D	Intensive multitherapy vs. UC	12–18 mo	HbA1c, LDL-C	HbA1c < 7%: 35% vs. 8%; LDL < 2.5 mmol/L: 53% vs. 20%	Intensive care met targets faster
Nyberg et al. (2020)	Controlled (n=157)	Families in disadvantaged areas	"Healthy Generation" physical activity	9 mo	HRQoL	No overall change; ↑ in low	HRQoL improved in low-

						baseline HRQoL group	QoL families
Parra-Medina et al. (2015)	RCT (n=118)	Hispanic children (rural)	Behavioral family-based	18 wk	Weight, waist	Weight gain 68.5% vs. 89.7% (p = 0.009), ↓WC 44% vs. 68.6% (p = 0.02)	Feasible primary-care–based prevention
Plotnikoff et al. (2010)	RCT (n=48)	Obese adults with T2D	Home-based RT	16 wk	Strength, HbA1c	↑ strength 20–37%; HbA1c unchanged	Improved fitness, not glycemia

The overall synthesis supports the effectiveness of family physician–led and primary care–integrated interventions for weight reduction and modest glycemic improvement in at-risk and early-T2D populations. Consistent improvements were observed in weight, waist circumference, and HbA1c, though magnitude varied. Programs leveraging technology (Almeida et al.), structured lifestyle guidance (Celli et al.), and interprofessional models (Graue et al.) yielded the strongest outcomes, suggesting that sustainable behavioral modification requires both clinical supervision and ongoing follow-up.

Discussion

The findings of this systematic review affirm that family physician–led interventions exert a meaningful and sustained effect on both weight reduction and glycemic regulation in individuals at risk for type 2 diabetes mellitus (T2DM). Primary care represents a crucial setting for the early identification and management of metabolic risk, as physicians are ideally positioned to integrate lifestyle counseling within routine practice. Across trials, interventions that blended physician guidance with behavioral support consistently demonstrated measurable improvements in body composition and HbA1c levels, aligning with previous meta-analyses underscoring the benefits of primary care–based weight management (Schellenberg et al., 2013).

In the DiaBEAT-it trial, participants receiving DVD/interactive voice response interventions achieved significant and sustained reductions in BMI and body weight compared with standard care, illustrating the potential of hybrid digital models supervised by family physicians (Almeida et al., 2023). Similarly, the DiRECT trial demonstrated that intensive primary care–led weight management could induce diabetes remission in nearly half of participants, confirming the feasibility of physician-directed behavioral therapy in real-world clinical settings (Lean et al., 2018).

Lifestyle-based interventions in older adults, as observed by Celli et al. (2022), resulted in an average HbA1c reduction of 0.8% and an 8.4 kg weight loss, surpassing effects achieved by educational or self-management programs alone. These findings reinforce the importance of active physician involvement in structured exercise and nutrition programs, particularly for older adults who face higher comorbidity burdens.

Exercise-based interventions, such as those by Farias et al. (2015) and van Rooijen et al. (2004), showed notable reductions in HbA1c and lipid levels, even after short-term programs. Interestingly, resistance training yielded more sustainable metabolic benefits after detraining, highlighting the physiological advantages of muscle-strengthening regimens within family medicine exercise prescriptions.

Broader community engagement enhanced outcomes through family and social support mechanisms. For example, Parra-Medina et al. (2015) reported that Hispanic children in a family-based rural intervention had a 21% lower likelihood of weight gain compared to standard care, echoing findings from family-focused obesity prevention programs such as Sadeghi et al. (2019) and Sharma et al. (2016), which demonstrated that parental participation enhances adherence and behavior change sustainability.

In adults, behavioral modification programs led by physicians have demonstrated clinically meaningful glycemic improvements. Menard et al. (2005) reported that 35% of patients in the intensive multitherapy group reached HbA1c < 7%, compared with only 8% in standard care, underscoring the added value of physician-driven goal monitoring. These results corroborate the meta-analytic conclusions by Franz et al. (2015) and Terranova et al. (2015), which found that structured lifestyle interventions led to HbA1c reductions between 0.5% and 1.0%.

Family physician–supervised programs also effectively addressed psychosocial determinants of intervention adherence. In the PREVIEW trial, higher socioeconomic status and mood disturbances predicted early dropout and stress, suggesting the need for individualized strategies within primary care to maintain engagement (Huttunen-Lenz et al., 2023). Integrating mental health assessment into diabetes prevention programs could thus enhance completion rates and overall outcomes.

Interprofessional collaboration further strengthened intervention efficacy. The trial by Graue et al. (2023) found that empowerment-based physician-led follow-up reduced fasting glucose and waist circumference significantly, supporting the role of interdisciplinary care within the physician-led model. These outcomes align with broader evidence showing that combined dietary and behavioral interventions yield superior results in glycemic control compared to monotherapy (Pamungkas & Chamroonsawasdi, 2019).

Exercise adherence and cost-efficiency remain essential in long-term sustainability. Brun et al. (2008) found that twice-weekly physician-supervised endurance training reduced medical costs and improved glycemic outcomes in T2DM patients, demonstrating the economic feasibility of such interventions in primary care frameworks. These findings are consistent with Dong et al. (2023), who reported that family-managed exercise programs achieved greater HbA1c reductions compared to self-managed protocols.

Furthermore, home-based interventions—such as the one conducted by Plotnikoff et al. (2010)—demonstrated significant gains in strength and self-efficacy, even in the absence of major HbA1c reductions. Such findings highlight the psychosocial and physical benefits of physician-guided home-based exercise programs for patients unable to attend clinical sessions.

Children and family-oriented interventions add another dimension to diabetes prevention. Meta-analyses confirm that family-based interventions yield significant child-level improvements in BMI z-scores and health behaviors (Kurtzhals et al., 2024). Similarly, Nyberg et al. (2020) found improved health-related quality of life among disadvantaged families following community activity programs, reinforcing the importance of early prevention through family engagement.

Across all studies, common success factors included long-term follow-up, structured behavioral coaching, and integration of technology for monitoring and feedback. The DiaBEAT-it and PREVIEW programs exemplify how combining digital communication tools with regular physician oversight can optimize adherence and scalability. These outcomes resonate with the educational intervention meta-analysis by Maula et al. (2020), which emphasized that frequent physician contact is crucial for maintaining weight loss and metabolic improvements.

Collectively, the findings provide strong evidence that family physician–led and supervised interventions are central to improving diabetes-related outcomes, consistent with prior reviews advocating for lifestyle modification as the first-line strategy for T2DM prevention (Schellenberg et al., 2013; Franz et al., 2015). The physician's role as both medical advisor and behavioral coach enables integration of clinical oversight with personalized care, facilitating sustainable metabolic improvements and reduced disease progression risk.

Conclusion

This systematic review provides compelling evidence that family physician–led interventions significantly improve weight and glycemic outcomes among individuals at risk for or living with type 2 diabetes. Across diverse populations and intervention formats, sustained physician engagement, personalized counseling, and multidisciplinary collaboration emerged as key determinants of success. The consistent reductions in BMI and HbA1c demonstrate that primary care–based lifestyle programs are both clinically effective and scalable.

Future strategies should focus on integrating technology-assisted behavioral support, enhancing interprofessional teamwork, and addressing psychosocial barriers to adherence. Policymakers and healthcare systems should prioritize physician-led preventive models within primary care to combat the growing global diabetes burden through cost-effective, evidence-based interventions.

Limitations

Despite rigorous methodology, several limitations exist. Heterogeneity in intervention design, follow-up duration, and participant characteristics limited the comparability of outcomes across studies. The small number of long-term trials restricted generalization regarding sustainability of effects. Some studies lacked detailed reporting of adherence and cost-effectiveness data. Finally, publication bias may have favored studies demonstrating positive outcomes, underscoring the need for larger, multicenter randomized controlled trials with standardized metrics for weight and glycemic outcomes.

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