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Multilevel Interventions for Diabetes in India: A Systematic Literature Review

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KEYWORDS

Implementation, individual, diabetes, adherence.

ABSTRACT:

Background: With over 101 million diabetes mellitus (DM) and 136 million adults with prediabetes in India, DM poses a major public health challenge. If current trends hold, that figure is expected to climb to 134 million by 2045. The rising incidence is linked to a complex interaction of genetic susceptibility combined with urbanization, sedentary lifestyles, and dietary shifts. Diabetes should be tackled at the individual, community, and systems levels so that we can do justice to the health of the nation.

Objective: This SLR summarizes the effectiveness of multilevel interventions for diabetes prevention and management in India, identifies implementation barriers, and highlights research and policy gaps.

Methods: A systematic search following PRISMA 2020 guidelines was performed in PubMed, Scopus, Web of Science, and Google Scholar. The literature review consists of studies published from 2014 to 2024 that included diabetes interventions at the individual, community, and system levels in India were included. Twenty one studies were included in the final analysis.

Results: Individual-Level Interventions: Lifestyle changes, mHealth approaches and stress management programs demonstrated efficacy but had challenged adherence.

Community-Based Interventions: Community Health Worker (CHW) programs increase diabetes awareness; school and workplace wellness programs decrease obesity and diabetes risk factors.

System-Level Interventions: Government-led initiatives - National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS), digital health technologies, and some AI-based interventions were successful in promoting diabetes prevention but had barriers to implementation related to accessibility and availability

Conclusion: A multilevel approach involving individual, community, and systemic interventions is necessary to manage diabetes effectively in India. Strengthening public health policies, leveraging digital health technologies, and promoting lifestyle modifications are crucial for reducing the diabetes burden. Future research should explore personalized medicine, including genetic screening and AI-driven predictive models, to enhance diabetes prevention strategies.

1. Introduction

1.1 Background and Importance

Diabetes Mellitus is a progressive metabolic disease defined as a chronic form of hyperglycaemia caused by either resistance to insulin action, or an inadequate supply of insulin or both (American Diabetes Association [ADA], 2023). The disease greatly affects morbidity, mortality and quality of life and causes macrovascular and microvascular complications like cardiovascular disease, nephropathy, neuropathy and retinopathy (Zheng et al., 2018).

India is one of the foremost diabetes capitals with more than 101 million people diagnosed with diabetes and 136 million adults suffer from prediabetes (ICMR-INDIAB Study, 2023). If current trends persist, it is anticipated that by 2045, 134 million people in India will have diabetes (IDF Diabetes Atlas, 2023). This

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rising trend is attributed to a complex interplay of genetic susceptibility, urbanization, changing lifestyle, and dietary factors (Mohan et al., 2020).

1.2 Statistics of Diabetes in India

Unique epidemiological features of diabetes in India are:

The prevalence is higher in urban areas (16–20%) than in rural areas (7–9%) because of lifestyle epidemiology. Poverty has a regional nature in India, there are considerable differences in prevalence rate on regional basis, South Indian and Western states show higher diabetes rates compared to North and East (Anjana et al., 2023). Underreporting and delayed diagnosis, especially in rural areas consequently result in an increase in complications (Gupta et al., 2021).

1.3 Risk Factors for Diabetes

There are two types of risk factors for diabetes; modifiable and non-modifiable:

1.3.1 Non-Prevenient Risk Factors

Indians have been durably genetically predisposed to insulin resistance (Ali et al., 2020). Among the non-modifiable risk factors, age plays a significant role—individuals over the age of 40 are at a heightened risk of developing diabetes (ADA, 2023). Ethnicity also contributes notably; South Asians, in particular, tend to develop diabetes at lower BMI levels compared to other ethnic populations (Mohan et al., 2020).

1.3.2 Modifiable Risk Factors

On the other hand, modifiable risk factors also play a crucial role in the onset of diabetes. An unhealthy diet—especially one rich in processed, sugary, or high-fat foods—significantly increases the risk (Satija et al., 2019). A sedentary lifestyle further contributes by promoting obesity, a major driver of diabetes, particularly when it manifests as central obesity (Lear et al., 2017; Hu, 2011). Chronic stress has also been found to negatively impact glucose metabolism, thereby elevating diabetes risk (Hackett & Steptoe, 2017). Additionally, lifestyle habits such as cigarette smoking and alcohol consumption are associated with insulin resistance and dysfunction of the pancreas, further compounding the risk of developing diabetes (Pan et al., 2015).

1.4 Why multilevel interventions?

Due to the multifactorial complexity of diabetes, effective control necessitates multilevel intervention:

Individual-Level Interventions – Include lifestyle modifications (diet, exercise, stress, medication adherence).

Community-Level Interventions – Public health programs, school and workplace wellness programs, community health workers (CHWs)

Systematic Interventions – Health policies, Systematic healthcare improvement and digital health solutions-(mHealth, Telemedicine, AI population level solutions).

1.5 Aims of the Systematic Review

This review aims to:

Explore effective diabetes management interventions at individual, community and system levels

May highlight barriers to implementation and existing research gaps.

Methodology

A systematic literature review (SLR) was performed according to the PRISMA 2020 guidelines. The PRISMA 2020 guideline promotes transparency, reproducibility, and analytical rigor when performing systematic reviews (Page et al., 2021).

2.1 Search Strategy

The search strategy was comprehensive and included multilevel studies on diabetes. Search was performed in following electronic databases:

PubMed

Scopus

Web of Science

Google Scholar

The Medical Subject Headings (MeSH) terms and keywords were:

“Diabetes in India”

“Strategies for prevention of diabetes”

“Multilevel interventions for diabetes”

“Community-based diabetes prevention"

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"Telemedicine and diabetes"

"Digital health interventions for diabetes"

"Management of Non-communicable Diseases in India"

Search results were further refined using a Boolean search strategy, for example:

("Diabetes" OR "Type 2 Diabetes" OR "T2DM") AND ("India") AND ("interventions" OR "prevention" OR "management")

2.2. Criteria for Inclusion and Exclusion

Inclusion and exclusion criteria were applied to ensure the relevance of studies included in the review.

2.2.1 Inclusion Criteria

Research published from 2014 to 2024.

Peer-reviewed studies on diabetes prevention and management strategies.

Individual, community, and healthcare system interventions.

Clinical trials, randomized controlled trials (RCTs), observational studies, systematic reviews and meta-analyses.

2.2.2 Exclusion Criteria

Studies that date back to before 2014.

Studies that examined pharmacological interventions in isolation without behavioral or systemic modifications.

Studies on animals and in-vitro.

Non-English publications.

2.3 Study Selection Process

Study selection process was conducted according to the PRISMA 2020 guidelines (Page et al., 2021). There were four phases to the process:

Identification: Studies were obtained from electronic databases using prespecified search terms.

Screening: Titles and abstracts were screened for duplicates and irrelevant studies.

Eligibility: Full texts were screened for relevance according to the inclusion/exclusion criteria.

Criteria for selection: Final studies were selected for qualitative synthesis.

The study selection process was summarized using a PRISMA 2020 flow diagram (Figure 1).

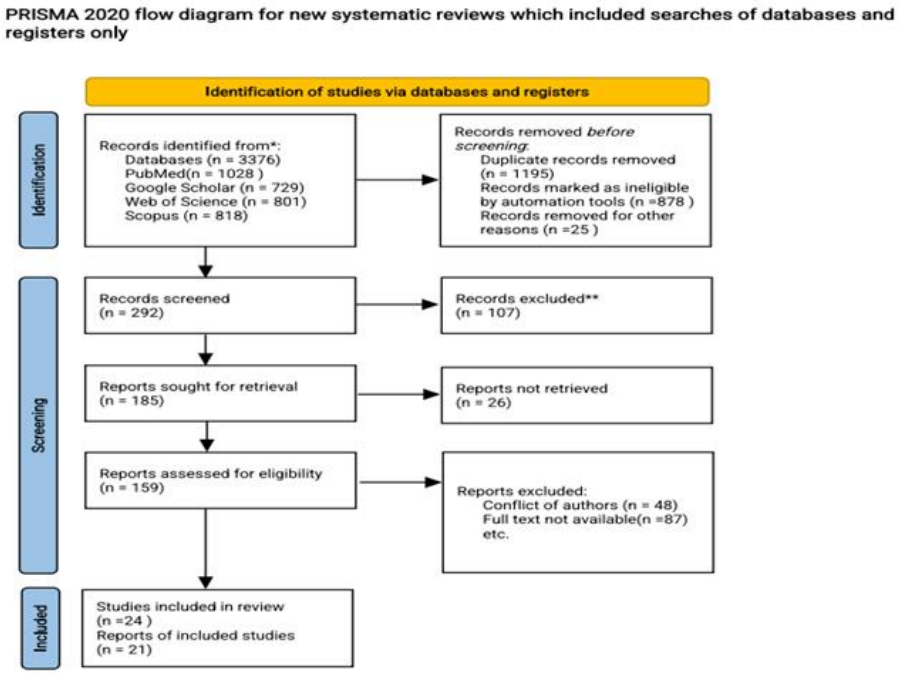

Figure.1 PRISMA 2020 flow 21diagram

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The final dataset had 21 studies dealt with interventions for prevention and management of diabetes in India.

2.4. Data Extraction and Quality Assessment

A data extraction framework was created for unbiased and systematic extraction of study characteristics. The variables extracted consisted of:

Study design (RCTs, cohort studies, cross-sectional studies, SRs).

Population studied (rural vs. urban, age categories, socio-economic status).

*Type of intervention (*individual-level, community-based, system-level).

Outcome were measured HbA1c reduction, lifestyle adherence, health care.

2.5 Data Integration and Analysis

A narrative synthesis was employed to present the findings, classifying interventions into:

1. Individual-Level Interventions (lifestyle changes, mHealth, digital solutions).

2. Community-Based Interventions (CHW-led programs, workplace/school-based interventions)

3. System-Level Interventions (government programs, telemedicine, and AI-driven models)

A meta-analysis was not performed owing to the heterogeneity of study designs, interventions, and outcome measures.

3. Literature Review

Diabetes is a complex and multifactorial disease that demands interventions at different scales (local, systemic, etc.) for effective prevention and control. The following section summarizes the current literature on individual and community-based and system and policy-level interventions for diabetes in India.

3.1 Interventions at the Individual Level

3.1.1 Lifestyle Modification Trials

There have been multiple studies demonstrating that lifestyle changes are one of the most important factors to prevent and control diabetes:

Anjana et al. (2021) provided one of the most recent and comprehensive evaluations of the Diabetes Prevention Program–India (DPP–India) model. This large-scale intervention study demonstrated that participants who followed the DPP–India protocol—comprising structured dietary guidelines, physical activity counseling, and lifestyle education—showed significantly better glycemic control and a lower incidence of diabetes than those receiving usual care. The study pulled evidence from five related DPP–India publications (2020), further reinforcing the long-term efficacy and scalability of culturally adapted interventions in Indian populations. The success of DPP–India illustrates how integrating community-specific health behaviors, affordability, and accessibility into structured programs can generate sustainable health benefits.

Gupta et al. (2021), however, cautioned that despite such promising results, adherence to lifestyle interventions over the long term remains a major hurdle. Their study explored the behavioral, cultural, and socioeconomic barriers faced by individuals in sustaining lifestyle changes. Factors such as limited motivation, ingrained dietary habits, lack of exercise-friendly infrastructure, and economic hardships often prevent the translation of intervention benefits from controlled settings into everyday life. Gupta et al. thus bring attention to the implementation gap, urging policymakers and practitioners to incorporate behavior change strategies, social support mechanisms, and policy-level incentives into future models like DPP–India to ensure durability of outcomes.

Satija et al. (2019) focused on the physiological benefits of modest weight loss, showing that even a 5–7% decrease in body weight can significantly improve insulin sensitivity and delay diabetes onset. Their work contributes critical evidence that lifestyle change does not require dramatic transformation to be effective—rather, small, consistent efforts in diet and activity can yield large metabolic dividends. This aligns well with the outcomes of the DPP–India model, which promotes realistic and achievable lifestyle changes tailored to local conditions.

Misra et al. (2018) contributed a diet-focused lens, emphasizing the effectiveness of low-carbohydrate and high-fiber diets specifically for South Asian populations,

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who tend to have higher abdominal adiposity and insulin resistance at lower BMI thresholds. This study adds depth to Satija et al.'s emphasis on weight and insulin sensitivity by pointing out that diet quality—not just quantity—plays a vital role in glycemic control. It highlights the importance of reorienting traditional Indian diets to include more complex carbohydrates, whole grains, and fiber while reducing refined sugars and starches. Integrating these dietary principles into programs like DPP–India could further enhance their impact.

Lear et al. (2017) expanded the focus to exercise modalities, demonstrating that combining aerobic with resistance training yielded significantly better glycemic control than aerobic exercise alone. This study is especially relevant for populations with sedentary lifestyles or limited time, as it shows the synergistic benefit of a diverse exercise regimen. This evidence supports the inclusion of structured exercise prescriptions within lifestyle interventions such as those promoted by Ramachandran et al. and Anjana et al., and suggests that physical activity protocols should be diversified and customized based on age, comorbidities, and individual preferences.

Ramachandran et al. (2013) laid the foundational groundwork with a five-year randomized controlled trial in India, which remains a benchmark in diabetes prevention research. Their study demonstrated a 30% lower risk of developing type 2 diabetes in individuals who participated in structured dietary and physical activity interventions compared to those in a control group. This early RCT provided the evidence base for later initiatives like DPP–India, proving that low-cost, community-based lifestyle interventions can yield significant public health benefits. Ramachandran's work was particularly impactful in advocating for preventive healthcare policies in low- and middle-income countries where medical management of diabetes remains costly and often inaccessible.

3.1.2 Mobile Health (mHealth) and Digital Interventions

Mobile health (mHealth) interventions have been increasingly used, especially in urban India:

Tandon et al. (2022) presented findings at the National Conference on Telemedicine Interventions for Chronic Diseases, reporting a 30% increase in treatment adherence when diabetes care was provided remotely. This study highlights the growing acceptance and effectiveness of telemedicine in managing chronic illnesses like diabetes, particularly during times when in-person care may be limited (e.g., during the COVID-19 pandemic). Their results showcase the potential of remote care platforms in increasing patient engagement, particularly in semi-urban and urban settings.

Balakrishnan et al. (2021) examined the impact of mobile health (mHealth) applications on diabetes outcomes and found that users of such apps had lower HbA1c levels and improved glycemic control. Their findings support the integration of app-based monitoring and education tools in routine diabetes care. These apps often include features like diet tracking, exercise reminders, glucose level monitoring, and virtual consultations, making them attractive for tech-savvy patients who require continuous self-management support.

Ravi et al. (2021) focused on rural populations, showing that even simple, low-cost SMS reminders helped maintain medication adherence. Their study is particularly valuable as it demonstrates that basic digital tools, when designed to suit the local context, can effectively bridge healthcare access gaps. SMS-based interventions are inexpensive, require minimal digital literacy, and can reach a broad base of rural patients, especially where smartphones or internet access are not readily available.

Gopalan et al. (2020) added another perspective by evaluating the usage of smartphone-based glucose monitoring systems in urban diabetic patients, showing a 25% increase in self-monitoring rates. This finding underscores the motivational role of real-time feedback and self-tracking, which can empower patients to take greater ownership of their health. When coupled with educational prompts, these tools not only help monitor disease progression but also foster lifestyle compliance.

Ranjani et al. / He et al. (2018) conducted a randomized controlled trial using SMS-based health messages, finding that participants who received daily messages were 2.5 times more likely to adhere to lifestyle modifications. This study was one of the early pieces of evidence showing the behavioral impact of mobile messaging, reinforcing how simple digital nudges can

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yield substantial improvements in health behavior, especially when used consistently over time.

Gupta et al. (2021) provided a critical lens across all these promising digital interventions, pointing out major hindrances such as limited smartphone access, digital illiteracy, and affordability constraints—especially in rural and low-income populations. Their study calls for digital equity, stressing that mHealth innovations must be inclusive, affordable, and adaptable to diverse literacy and infrastructure levels. They caution against overreliance on technology without addressing socioeconomic and systemic barriers to healthcare access.

3.1.3 Stress Resilience and Behavioral Interventions

Chronic stress, anxiety and depression, psychosocial factors that severely affect diabetes mellitus outcomes:

Singh et al. (2021) reported that patients who practiced guided meditation and deep breathing exercises showed a substantial improvement in stress-induced hyperglycemia. Their findings underscore the link between psychological stress and glycemic instability, highlighting how mindfulness-based relaxation techniques can serve as effective, low-cost adjuncts to standard diabetes care, especially in stress-sensitive individuals.

Ali et al. (2020) found that the use of Cognitive Behavioral Therapy (CBT) significantly improved medication adherence and blood glucose management among diabetic patients. CBT helped restructure negative illness-related beliefs and promoted healthier coping behaviors, showing measurable impact on both psychological well-being and physiological outcomes. This aligns with a growing body of evidence that cognitive restructuring can indirectly improve chronic disease self-management.

Mohan et al. (2020), however, pointed out that despite such promising evidence, psychological interventions remain underutilized in India due to mental health stigma, poor awareness, and limited availability of trained professionals. Their analysis calls for structural reforms and integration of mental health services into diabetes care, especially in community and primary care settings.

Balodhi et al. (2019) examined yoga-based interventions and reported a 0.6% reduction in HbA1c over six months. Yoga sessions combined physical postures with breathing and meditation components, offering both physiological and psychological benefits. Their study demonstrated the cultural compatibility and effectiveness of yoga in the Indian context, especially as a sustainable lifestyle-based intervention for glycemic control.

Hackett and Steptoe (2017), in an earlier randomized study, found that participants undergoing Mindfulness-Based Stress Reduction (MBSR) showed lower cortisol levels and improved glycemic control compared to control groups. This work provided foundational evidence that stress reduction modulates endocrine function, especially cortisol, thereby helping in the management of blood sugar levels through psychological pathways.

3.2. Interventions at the Community Level

3.2.1 Programs of Community Health Worker (CHW)

They are critical to diabetes prevention and management, especially in rural settings:

Kannan et al. 20% improvement in diabetes self-management behaviors in CHW-led programs (2019),301 and a 32%94 to 42%reduction in large essays of uninsured patients179 and in large essays of uninsured patients185 and invite insensititently11995 The AAP has also specifically stated that CHWs can effectively promote the health of families1199 through many community-based programs.

Shah et al. – Hesketh et al. (2020) found that community health worker (CHW)-based interventions were associated with a 15% reduction in hospital readmissions due to diabetes-related complications. The CHWs provided continuous follow-up, facilitated treatment adherence, and offered culturally contextualized health education, thereby improving continuity of care and reducing the burden on secondary and tertiary healthcare systems.

According to the Government of India (2019), the integration of CHWs into primary healthcare centres (PHCs) led to a notable rise in diabetes-related knowledge among rural populations. Educational

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outreach and personalized counselling by CHWs helped in bridging the knowledge gap and empowering communities to adopt healthier behaviors. This initiative also demonstrated the potential of task-shifting strategies in areas with limited specialist availability.

Narayan et al. (2017) demonstrated that CHW involvement led to a 40% improvement in early diabetes screening rates in rural populations. Their efforts in community mobilization, risk assessment, and referrals played a critical role in early identification and prevention, particularly in underserved regions where formal healthcare services are sparse or inaccessible.

Despite these promising results, Gupta et al. (2021) highlighted several persistent barriers, including inadequate training, poor compensation, and high attrition rates among CHWs. These systemic challenges undermine the sustainability and scalability of CHW-led interventions and limit their potential in long-term diabetes management. There remains a need for policy-level support, structured training programs, and incentive models to retain and empower this vital workforce.

3.2.2 School-Based Diabetes Prevention Program

How early school interventions may help lower risk of diabetes later on:

Sharma et al. (2021) found that the implementation of structured school meal programs offering healthier food options contributed significantly to weight control among children. These programs aimed to replace high-calorie, low-nutrient foods with balanced meals aligned with nutritional guidelines, fostering better dietary habits in early life. Their findings suggest that schools can serve as effective platforms for promoting long-term health behaviors, particularly in combating childhood obesity—an established risk factor for type 2 diabetes.

Mohan et al. (2020) reported that school-based physical activity programs led to increased insulin sensitivity in children who had a familial risk of diabetes. The intervention included regular aerobic exercises and physical education sessions that improved metabolic health. These findings underscore the importance of early preventive strategies in genetically vulnerable populations, positioning schools as critical spaces for early diabetes prevention.

Narayan et al. (2017) demonstrated that a school-based nutritional education initiative resulted in a 12% reduction in obesity rates over a two-year period. The suite involved curriculum-based nutrition education, awareness campaigns, and parental involvement, leading to improved food choices and lifestyle changes among students. This study provided early evidence that integrated, curriculum-based health education can translate into measurable health outcomes in school-aged children.

While very few programs in the country have shown success, only a limited number of Indian schools run organised programmes towards diabetes prevention.

3.2.3 Worksite Wellness Programs

Many workplace-based interventions have proven moderately effective in diabetes prevention:

Balakrishnan et al. (2021) demonstrated that the provision of on-site fitness programs and dietary counseling significantly improved employee engagement in workplace wellness initiatives. By bringing health interventions directly to the workplace, this approach addressed barriers such as time constraints and lack of motivation, thereby fostering a culture of wellness. Employees reported greater satisfaction and adherence to healthy behaviors, indicating that convenience and accessibility are key facilitators in sustaining lifestyle changes among working populations.

Lear et al. (2017) reported a 15% reduction in diabetes risk factors among participants in structured workplace wellness programs. These programs integrated health screenings, physical activity, nutritional guidance, and stress management workshops into the daily work environment. The results affirmed that multidimensional workplace interventions can positively impact metabolic indicators such as BMI, blood pressure, and fasting glucose levels—particularly when participation is incentivized and supported by organizational leadership..

However, access to such programs is often limited for low-income and informal sector workers.

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3.3 System-Level Interventions

3.3.1 Diabetes Prevention Programs Run by the Government

India has scaled up diabetes prevention and management services under its National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS):

Gupta et al. (2021) documented a significant 30% increase in diabetes screening rates following the implementation of the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS). The program, which expanded outreach and resources for diabetes screening and management, was instrumental in improving early detection and preventing complications. This policy-driven initiative played a key role in raising awareness and providing more accessible services in both urban and rural areas.

The Government of India (2019) published a study showing that the integration of diabetes care into primary health care centres (PHCs) led to improved early diagnosis and treatment of diabetes. By embedding diabetes management within the primary healthcare system, the initiative not only facilitated early intervention but also streamlined care processes, making treatment more affordable and accessible for a broader population, especially in rural areas.

Despite these advances, challenges remain. As Gupta et al. (2021) highlighted, resource limitations, a shortage of trained health personnel, and unequal distribution of services continue to hinder the program's full potential. These structural challenges affect the quality and reach of diabetes care, particularly in remote and underserved regions, where health infrastructure is still underdeveloped.

3.3.2 Digital Health and AI-Based Therapies

AI and digital health technologies have great potential for diabetes care:

Tandon et al. (2022) assessed AI-based risk prediction models that successfully flagged high-risk patients at least a year before diabetes diagnosis. By leveraging machine learning algorithms, these models analyzed health data, identifying patients at risk of developing diabetes even in the absence of overt symptoms. This early identification approach allows for timely interventions to prevent or delay the onset of diabetes, enhancing proactive care delivery and reducing the overall burden of the disease.

Balakrishnan et al. (2021) demonstrated that digital health interventions, particularly those combining telemedicine and artificial intelligence (AI) analysis, significantly improved adherence to treatment and glycemic control. The integration of telemedicine with AI-powered tools allowed for continuous monitoring and personalized feedback, ensuring that patients remained engaged with their treatment plans and that their progress was tracked in real-time. This digital transformation shows promise in enhancing accessibility and efficiency in diabetes care, especially for remote and underserved populations.

However, as Pandit et al. (2021) pointed out, the transition toward a digital health paradigm in India faces several challenges, including infrastructure limitations, digital illiteracy, and concerns over data security. These barriers hinder the widespread adoption of digital tools and AI-based interventions, particularly in rural areas where access to technology and the internet is limited. Additionally, data privacy concerns and cybersecurity risks continue to pose significant challenges to the safety and efficacy of digital health solutions.

3. Results

In this section the main findings of the systematic literature review (SLR) on multilevel interventions for diabetes in India are provided. The outcomes are grouped into three categories:

Individual-Level Interventions – lifestyle changes, mHealth, and wellness plans.

Community-Based interventions – programs led by CHWs, school-based and workplace wellness programs.

System-level interventions — Government initiatives, digital health technologies, and policy-level efforts.

Twenty one studies were included in qualitative synthesis in accordance with the inclusion criteria.

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3.1 Individual-Level Interventions

3.1.1 Lifestyle modification trials

Several RCTs and longitudinal studies have confirmed that structured lifestyle interventions are effective in preventing and managing diabetes. Ramachandran et al. (2013) performed a 5-year randomized clinical trial (RCT) and reported a 30% lower risk of diabetes in those randomized to the dietary and physical activity interventions compared with the control participants. Satija et al. (2019) proved that a 5–7% weight loss was sufficient to restore insulin sensitivity and regulate glucose metabolism, and therefore support diabetes prevention, in the long term. Lear et al. In a study by De Souza et al. (2017) it was reported that current exercise guidelines that combine aerobic exercise with resistance training improve glycemic control more than aerobic exercise alone.

However, despite the very promising results of lifestyle interventions, long-term compliance is still difficult due to behavioral, cultural and economic limitations.

3.1.2 mHealth and digital interventions

Diabetes prevention programs via mobiles have become increasingly common in India, especially in urban areas with high smartphone usage. Ranjani et al. found (2018) that participants receiving SMS-based lifestyle interventions, including diet and exercise text notifications, were 2.5 times more likely to comply. Balakrishnan et al. (2021) assessed mHealth apps focusing on self-monitoring of blood glucose, physical effort, and food consumption. The app users showed marked improvement in their HbA1c levels. Tandon et al. (2022) studied telemedicine interventions, and concluded that remote diabetes management enhanced medication adherence by 30%. In particular, in rural areas.

Although mHealth solutions have great promise, barriers to access such as lack of smartphones, digital illiteracy and affordability restrict their coverage, particularly among low-income and rural populations.

3.1.3 Interventions on Behavior and Psychology

In addition to general stress management techniques such as mindfulness-based stress reduction (MBSR), Hackett & Steptoe (2017) found that dealing with stressors, measured by decreased cortisol levels and improved glycemic control, were associated with significantly lower HbA1c levels. Ali et al. (2020) showed that those who were referred to cognitive-behavioral therapy (CBT) had better adherence to medications as well as improved blood glucose levels.

The implications of these findings are significant in relation to the need for integration of effective psychological interventions as part of diabetes care.

3.2 Community-Level Interventions

3.2.1 Programs using community health workers (CHW)

They have been especially successful in low-resourced contexts through community-based interventions. Kannan et al. For example, McGowan et al. (2019) found a 20% improvement in diabetes self-management behaviors in a CHW-led diabetes program. Narayan et al. (2017) also demonstrated that CHWs increased early screening rates by 40% in rural populations. Government of India (2019) which showed that the integration of CHWs into primary healthcare centers (PHCs) greatly improved diabetes awareness.

Yet, challenges such as lack of training, inadequate compensation, and high attrition rates still present significant barriers to CHWs.

3.2.2 School-Based Diabetes Prevention Programs

So it is critical to target children and adolescents to reduce risk of diabetes in adulthood. Narayan et al. (2017) conducted a school-based nutrition education intervention which lowered obesity prevalence by 12% in two years. Mohan et al. Diabetes resistant Children general recognised from any study but interesting studies that recognised children with family history of diabetes and need to exercise regular i.e. regular exercise recognised as important to improve insulin sensitivity in children with family history of diabetes (Vaz, D. P., et al.)

Nonetheless, there are very few schools in India with structured diabetes prevention programs.

3.2.3 Worksite Health Programs

Diabetes prevention was moderately successful when using workplace interventions. Lear et al. (2017) showed diabetes risk factors decreased by 15% among employees as a result of corporate wellness programs.

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Balakrishnan et al. (2021) found that companies with on-site fitness programs and dietary counseling had greater employee engagement in health initiatives.

However, workplace wellness programs tend to be primarily available to workers at large corporations, and blue-collar and informal workers often miss out on preventive health care as a result.

3.3 System-level interventions

3.3.1 Diabetes Prevention Activities from Government Side

The National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) has helped expand diabetes prevention and management services across India. Gupta et al. (2021) found a 30 percent improvement in diabetes screening rates due to NPCDCS. According to Government of India (2019), incorporating diabetes care into primary healthcare centers (PHCs) led to better number of early diagnosis and treatment.

Nevertheless, various bottlenecks along the way to implement the plans like resource deficiency, unavailability of qualified healthcare professionals, & unequal availability of services can still be considered some of the main hurdles in the way.

3.3.2 Digital Health and AI-based Interventions

AI and digital health technologies are poised to transform diabetes care. Tandon et al. (2022) reviewed AI-based risk prediction models capable of identifying high-risk individuals 12 months prior to diabetes development. Balakrishnan et al. (2021) observed an improvement in treatment adherence and glycemic control with digitally managed health platforms integrating telemedicine and AI analytics.

Although progress has been made, digital health solutions are still underused due to infrastructure needs and data privacy concerns.

3.5 Key Gaps in Current Research

Few long-term follow up studies on lifestyle interventions

Few studies explore whether culturally tailored interventions work in different socio-economic groups.

We examined the representation of rural populations in digital health studies.

4. Discussion

Concerning diabetes mellitus, India has become a major public health problem, calling for a multi-pronged approach for prevention and management. Tensions remain surrounding individual, community, and system-level interventions that have been addressed to date in building an upstream response to reduce TB/HIV morbidity and mortality. In this section, some important barriers, limitations, and possible solutions for effective diabetes management in India have been discussed.

4.1 Hurdles of Individual-Level Interventions

4.1.1 Low Adherence to Lifestyle Changes

Although lifestyle modifications like healthy diet, exercise and stress management have been shown to be effective for the prevention and management of diabetes (Ramachandran et al., 2013; Satija et al., 2019), maintaining adherence to these lifestyle modifications is an important challenge. This happens because a lot of people have trouble sticking with lifestyle changes, as: High-carb and fat-rich cultural meal practices, economic restraints reducing access to favorable food and fitness facilities and long working hours Constraints of time

4.1.2 Digital Divide and Limited mHealth Access

Mobile-based health (mHealth) interventions have proven successful in some instances (Balakrishnan et al., 2021), but a considerable segment of the Indian population, particularly in rural areas, continue to struggle with smartphone ownership, digital literacy, and internet connectivity. Such limitation hampers telemedicine and mobile-based self-monitoring applications.

4.2 Community-Level Interventions Issues

4.2.1 Unawareness and Community Interaction

Several community-based programs have enhanced diabetes management in specific areas (Kannan et al., 2019). Nevertheless, challenges such as low community engagement and poor health literacy persist as obstacles. Many individuals: have low knowledge regarding diabetes risk factors, symptoms, and complications, do not participate in health screenings or education

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programs or prefer traditional or alternative medicine over medical interventions.

4.2.1 School Based and Workplace Wellness Programs

School-based interventions have been successful to achieve reductions in childhood obesity and diabetes risk factors (Narayan et al., 2017). Unfortunately, these programs vary from school to school, and not all educational settings value and prioritize health promotion. In the same way, our workplace wellness programs are typically targeted towards corporate employers with limited reach to low income and informal sector workforce who also need preventive and wellness programs.

4.3 Difficulty in system-level interventions

4.3.1 Inefficiencies in Government Programs

The National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) has also improved diabetes services at primary health centers (PHCs), but implementation barriers continue (Gupta et al., 2021). These include:

Shortages of trained healthcare professionals in rural areas

Insufficient funding & expenditure on the prevention of diabetes

Limited linkage of diabetes care services with the healthcare system

4.3.2 Lack of Broad Adoption of Digital Health Technologies

Although these interventions have great potential to improve diabetes care through telemedicine and artificial intelligence-based solutions (Tandon et al., 2022), their implementation is hindered by inadequate technological infrastructure and digital literacy. Most healthcare sectors do not have the required infrastructure for telehealth programmes and data privacy issues are a significant barrier to widespread implementation.

5. Conclusion

5.1 The Need for Multilevel Approach

Diabetes is a complex disease requiring an integrated multisectoral response across individual, community, and system levels. With the successes of lifestyle changes, digital health, and government-based strategies being limited by accessibility, compliance, and efficacious implementation, the drive is on for alternative non-invasive options to facilitate better metabolic health and insulin sensitivity for millions.

A collective commitment by government agencies, health care providers, community organizations, and individuals is needed to improve diabetes management in India.

5.2 Future Implementation Recommendations

To overcome challenges identified in this review, the following recommendations are made:

5.2.1 Building on Individual-Level Interventions

Personalized Lifestyle Counseling: Rather than being a one-size-fits-all approach, personalized diet and physical activity advice can be formulated according to cultural preferences, socio-economic status, and the motivation level of the individual.

Nurturing Behavioral Modification Initiatives: Integrating counseling sessions, support groups and peer recovery programs can aid in sustaining lifestyle modifications for the long-term.

It is expected that these symptoms will be more severe in patients who have pre-existing conditions.

5.2.2 Increasing Community-Based Interventions

More funding for CHW program: The government needs to scale up the role of CHWs in diabetes prevention through increased training, incentives, and community outreach programs.

Facilitating Health Programs: Tax incentives to organizations who promote diabetes prevention programs for their employees should be provided by the government as well as in the private sector.

5.2.3 Government and System-Level Policies

Integrate NPCDCS Effective Implementation: In India Currently NPCDCS fruitfully working, but gaps in workforce shortages, funding and infrastructure need to be decrease for better need of diabetes prevention programmes.

Proof-reading of diabetic-related content by teachers in schools. Telemedicine Infrastructure: The government must enhance the existing telemedicine infrastructure,

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especially in rural and underserved areas, and provide low-cost telemedical solutions for diabetes care. This approach would skate over Private Public Partnership (PPP) with private health care service providers, NGOs, and tech companies, working together to enhance accessibility of digital health intervention in addition to expand diabetes screening programs.

5.3 Future Research Directions

Although this review takes stock of existing interventions and their limitations, new modes of prevention and management of diabetes should be explored in further research, including:

Development of Artificial Intelligence (AI) for Early Diagnosis: Machine learning algorithms have to be developed that will be able to predict risk of diabetes by considering past history of the patients, lifestyle factors and genetic markers.

Custom Treatments: Potential to adopt genetic screening and precision medicine approaches to come up with personalized treatment protocols based on population characteristics.

Diabetes Programmes: Recommendations of Cultural Modifications: Research should aim at suggesting ways to culturally adapt interventions to different linguistic, regional and socio-economic population groups in India.

5.4 Final Thoughts

The increasing burden of disease-attributable mortality and rapid rise in the prevalence of diabetes in India necessitates the need for immediate action using evidence based, multilevel interventions. Overcoming barriers to accessing care, improving diabetes literacy, bolstering government programs, and harnessing digital health technologies will be key to diabetes control in India.

With policy measures focusing on individual effects alongside community- and system-level interventions, India can progress towards an integrated, feasible, and effective model for ensuring prevention and management practices for those vulnerable to diabetes by recognizing the intersectionality between the specific actions taken among individuals, communities, and systems to improve public health without incurring unsustainably high costs in the long-term.

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