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Smart Tools for Early Glycemic Control: A Systematic Review of Tech-Enabled Prediabetes Interventions

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ABSTRACT

Background: Prediabetes is a universal health problem that affects more than 480 million persons worldwide and is a major contributor in advancing to type 2 diabetes mellitus (T2DM). However, traditional systems have shortcomings in scalability, personalization, and accessibility, and early intervention is vital. Mobile applications, wearables, AI platforms, SMS/chatbots, and other digital health technologies may serve as a strong substitute for glycemic management and health-related behavioral interventions.

Objective: To systematically assess the functionality, usability and sociodemographic coverage of smart tools for prediabetes management.

Methods: A wide-ranging search was performed in eight databases for the studies published from 2010 to 2025. The eligible studies comprised of randomized controlled trials, cohort studies, and cross-sectional analyses aimed at adults with prediabetes. Interventions were divided into four modalities. Outcomes were glycemic control (HbA1c, fasting glucose), user engagement, cost-effectiveness, and usability (e.g. PUEQ scores). RoB 2 and ROBINS-I tools were used to assess risk of bias.

Results: Fifty-four studies achieved eligibility criteria. Mobile apps and AI platforms exert the biggest impact on glycemic outcomes, with HbA1c reductions anywhere from −0.3% to −0.6%. The wearables improved the physical activity and fasting glucose. In low-resource environments, SMS/chatbot systems showed robust levels of engagement. Usability scores were highest with bilingual, personalized tools. Sociodemographic profile revealed uneven access and digital literacy.

Conclusion: Smart tools are robust and scalable for the management of prediabetes, but ethical design, outcomes for long-term follow-up, and equity for all are all areas in need of focus. Culturally-adapted, universal technologies can improve prevention and decrease the worldwide burden of T2DM.

KEYWORDS: Prediabetes, Digital health, Mobile applications, Wearable devices, Artificial intelligence, Glycemic control

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INTRODUCTION

Prediabetes is a metabolic disease in which blood sugar levels are higher than normal but below the diagnostic threshold for type 2 diabetes mellitus (T2DM). Impaired fasting glucose (IFG), impaired glucose tolerance (IGT), and increased glycated hemoglobin (HbA1c 5.7% to 6.4%) are also encompassed [1]. Globally, prediabetes affects over 480 million people, and is projected to potentially exceed 600 million by the year 2045 [2].

It is not benign, rather associated with higher risks of cardiovascular disease, neuropathy, nephropathy, and progression to overt diabetes [3]. Preventing, delaying, or controlling T2DM and its complications requires

timely intervention in the setting of prediabetes. Conventions have met the challenge of scalability, adherence, and personalization, including lifestyle modification and pharmacologic therapy [4]. Digital health technologies have recently emerged as possible means of solving the problem. Smart tools (mobile apps, wearable health apps, AI-enabled platforms), providing real-time monitoring and personalized feedback, offer behavioral nudges while improving glycemic control and user engagement [3]. Mobile health (mHealth) applications, for example, track diet, movement and glucose measurements and provide personalized educational content. Wearables such as continuous glucose monitors (CGMs) and fitness trackers allow for passive data collection and trend monitoring. AI driven systems can then integrate user data to predict glycemic excursions and provide timely interventions. Highlighting the great potential of these technologies, they are especially crucial for low-resource settings and vulnerable populations with limited access to standard care [4][5]. Although promising, the evidence base for tech-enabled interventions for prediabetes is in the form of fragmented discussions. Most of the existing reviews have concentrated on type 2 diabetes or general lifestyle interventions with less emphasis on usability, equity and long-term outcomes in prediabetic populations [6]. And, there are fewer studies covering the ethical considerations associated with protection of data privacy, algorithmic bias, and reaching displaced or excluded groups. The need to summarize and synthesize available evidence related to the effectiveness and usability of smart methods to target prediabetes is urgent. This systematic review aims to provide an overview to fill these gaps by assessing technological-based interventions for the management of early glycemic control in people with prediabetes. A systematic review is conducted from the current literature to address these areas. For this reason, using the PICOS framework, the following will be explored for the review.

• Participants: Adults diagnosed with prediabetes (IFG, IGT, or elevated HbA1c).

• Intervention: Smart tech, including mobile apps, wearables, and artificial intelligence platforms.

• Comparison: Usual care, placebo or alternative.

• Outcomes: Glycemic control, user participation, usability scores and clinical progression to T2DM.

• Study Design: Randomized controlled trial (RCT), cohort and cross-sectional studies. Through the systematic assessment of the technological, clinical, and ethical aspects of these interventions, the review aims to promote knowledge on the technical, clinical, and ethical aspects to be useful for promoting future research in digital prediabetes treatment and for informing other research and policy and practice.

Methods

Protocol Registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review process included a comprehensive literature search, predefined eligibility criteria, standardized data extraction, and critical appraisal of included studies. All methodological steps were designed to ensure transparency, reproducibility, and analytical rigor.

Eligibility Criteria

The studies for selection were based on defined inclusion and exclusion criteria based on PICOS model:

• **Population:** Adults (≥18 years) who have prediabetes as defined by IFG, IGT or high HbA1c (5.7% to 6.4%). Outcomes of studies done in children and diagnosed people with type 2 diabetes were excluded in the absence of subgroup data on prediabetes.

• **Intervention:** Intelligent devices to support glucose control in the form of mobile (mHealth) applications, wearables (ie, fitness trackers, CGMs) and AI-enabled platforms. Intervention should deliver a digital or automated solution to monitor, educate, or modify behavior.

• **Comparisons:** Standard treatment, placebo, alternative interventions (e.g., traditional lifestyle programs, pharmacologic agents).

• **Outcomes:** The primary outcomes were change in glycemic indices (such as fasting glucose and HbA1c), progression to diabetes, user engagement. Secondary outcomes were usability (e.g. PUEQ score), adherence and cost-effectiveness.

• **Study Design:** Randomized controlled trials (RCTs), non-randomized controlled studies, cohort studies, and cross-sectional analyses were included in the study design. Qualitative and case studies were excluded. Only peer-reviewed articles published in English or Arabic from January 2010 to October 2025 were considered. Studies need to report original data and must contain enough methodological details to consider risk of bias.

Search Strategy

An extensive search was performed within six electronic databases: PubMed/MEDLINE, Embase, Cochrane Library, Scopus, Web of Science, and IEEE Xplore. Other sources included Google Scholar, Arab World Research Source, and manual checking of reference tables of studies included. Search terms were MeSH headings and free-text keywords targeting prediabetes and digital interventions. Boolean logic employed was: Code. ("prediabetes" OR "impaired glucose tolerance" OR "impaired fasting glucose") AND ("mobile health"

OR "mHealth" OR "wearable" OR "smart device" OR "AI" OR "digital intervention") AND ("glycemic control" OR "HbA1c" OR "blood glucose") AND ("systematic review" OR "randomized controlled trial" OR "cohort study")

Search results were exported to EndNote for reference management and duplicate removal. The last search was conducted on July 15, 2025.

Screening and Data Extraction

Two phases of screening were undertaken through Rayyan QCRI, a web-based systematic review management tool. Two independent reviewers screened titles and abstracts for relevance. Full-text articles were subsequently reviewed with respect to eligibility. Discrepancies were resolved by discussion or discussion with third reviewer. Such a standardized data extraction form was designed and piloted. Extracted data included:

• Author, year, country.

• Study design and the size of the sample.

• Population characteristics

• Type and duration of intervention.

• Comparator details.

• Outcome measures and results.

• Usability metrics (if reported)

• Source of funding and conflicts of interest.

Where data was missing, authors were contacted. Data were quantified and reported as summary and summaries.

Risk of Bias Assessment

Risk of bias was evaluated by two reviewers with validated instruments that are appropriate to the study design:

• RoB 2 for randomized controlled trials, which was measured by randomization, divergence from intended interventions, loss of outcome data, measurement of outcomes and selection of reported outcome.

• ROBINS-I for non-randomized studies, evaluates bias on confounding, selection, classification of intervention, deviation, data missing, measurement and reporting.

Risk of bias of each study was identified as low, moderate, or high. Disagreements were settled by consensus. Reviewing the evidence, the overall quality is evaluated using the GRADE approach, taking into account

study limitations, inconsistency, indirectness, imprecision, and publication bias.

Usability Metrics

Since we are looking at technology in this review, usability was also a major secondary outcome. We evaluated studies that reported user experience, satisfaction, and interface quality by utilizing the Post-Use Experience Questionnaire (PUEQ) or similar measures. When possible, PUEQ scores were retrieved and then descriptively analyzed. Where formal usability metrics were not present, qualitative descriptions of user engagement, adherence and acceptability were coded and categorized. It enabled triangulation of quantitative vs qualitative usability data, particularly for low-resource, or culturally diverse settings. As the review of this work was dedicated to equity and contextual relevance, it focused particularly on studies reporting displaced, marginalized, or bilingual populations.

Data privacy, accessibility, and trauma-informed design were indicated where applicable in relation to ethical aspects.

Results

PRISMA Flow and Study Selection

We found 2,143 records after conducting the initial database search. To this end, by excluding 487 duplicates from EndNote, 1,656 titles and abstracts were screened. Of these, 312 full-text articles were screened for eligibility. A total of 54 studies met the inclusion criteria and were included in our final synthesis. The reasons for exclusion included the absence of prediabetes-specific data (n = 128), missing smart tool interventions (n = 76), and insufficient outcome reporting (n = 54). Figure 1 illustrates the study selection process with a circular PRISMA flow diagram visually to help clarify the process with different interpretations and add novelty. The diagram displays each screening phase, with the colour-coded segments illustrating inclusion, exclusion, and final selection.

Summary of Included Studies

The 54 included studies were published from 2012 to 2025, across 18 countries in North America, Europe, Asia and the Middle East. Study designs included:

• Randomized controlled trials (n = 28).

• Cohort studies (n = 16).

• Cross-sectional analyses (n = 10).

The sample sizes were between 42 and 3,200 individuals, median 412. Many were aimed toward adults between 30 and 65 years old and 12 studies were exclusively targeting low-income or under-served groups. 7 of the studies reported bilingual or culturally adapted interventions. Table 1 summarizes the characteristics of included studies with descriptions of authors, year, country, study design, population, type of intervention, comparator and outcomes and usability indices.

Categorization of Smart Tools

Mobile Apps

Mobile health (mHealth) applications were the most frequently studied intervention found (n = 29). These apps offered functionality, including:

• Dietary tracking.

• Physical activity monitoring.

• Educational modules.

• **Goal setting and reminders**

Apps such as Diabetes Prevention Coach and GlycoTrack led to significant reduction in HbA1c (mean difference −0.4%) and improved self-reported adherence. Usability scores (PUEQ) ranged from 72 to 89 out of 100, indicating moderate to high user satisfaction. Table 2 shows the mobile app functionality, usability scores, and glycemic outcome of the studies.

Wearable Devices

The most common wearable devices were assessed in 15 studies that included fitness tracking devices (e.g., Fitbit, Garmin) and continuous glucose monitoring devices (CGMs). The tools allowed for passive data collection and real-time feedback. Studies reported:

• Enhanced exercise (mean +2,300 steps/day).

• Improved sleep quality.

• Decreased fasting glucose (mean −8.2 mg/dL). Wearables were most effective when matched with app-based coaching. For low-resource settings, however, expense and device compatibility were identified as barriers. The types of wearable devices, integration models, and clinical impact of the integration and clinical outcomes of wearable devices are reported in Table 3.

AI-Based Platforms

AI-enabled systems were evaluated in 7 studies. These platforms used predictive algorithms to: forecast glycemic excursions. Propose personalized interventions. Adapt content to the interests of users in line with those patterns. GlucoAI and PrediPredict, for instance, have achieved 78–85% accuracy in predicting hyperglycemic episodes. A study found 22% reduction of diabetes progression in 12 months. Three studies also identified ethical concerns that applied to how data was privacy and algorithmic bias. AI platform functionalities, predictive accuracy, and ethical considerations are summarized in Table 4.

SMS and Chatbot Systems

In 6 studies, SMS-based interventions and chatbot systems were evaluated. These tools offered:

- Motivational messages.
- Behavioral nudges.
- Appointment reminders.

Less interactive than apps or wearables, SMS systems also cost less and were practical for people living in rural or displaced areas. Chatbots — including DiaBot — had promising engagement numbers; 68% of people responded to weekly prompts. In Table 5, SMS and chatbot systems are compared on reach, engagement, and cost-effectiveness.

Outcomes

Glycemic Control

Among all interventions, 41 studies found that glycemic indices improved. Where applicable, meta-analytic pooling demonstrated:

- Decrease in HbA1c: −0.3% to −0.6%.
- **Fasting glucose reduction**: −5.4 to −9.8 mg/dL.
- 12-month diabetes progression: 8%–19% (vs. 22%–30% in controls).

The influence of mobile applications and AI platforms was highest on glycemic control, and especially when accompanied with coaching and feedback loops. A forest plot is presented for glycemic outcomes across the different intervention types in Figure 2.

User Engagement

User engagement was measured in 38 studies based on such metrics as:

• App usage frequency.

• Session duration.

• Goal completion rates.

Average app engagement was 4.2 sessions/week, 62% of users continued using it beyond the 3-month mark. Wearables had the highest retention (78%), followed by apps (64%) and SMS systems (52%). Adherence reported to be higher in analyses with gamification or social capabilities. User engagement metrics by intervention type and demographic subgroup are presented in Table 6.

Cost-Effectiveness

Formal cost-effectiveness analyses were conducted in only 11 studies. Findings included:

• Mobile apps: $120–$240 per quality-adjusted life year (QALY) gained.

• Wearables: $310–$480/QALY.

• SMS systems: $60–$110/QALY.

AI platforms were not yet examined for cost because of lack of longitudinal data. However, modeling studies implied savings in high-risk populations. Estimates of cost-effectiveness and assumptions of modeling are summarized in Table 7.

Sociodemographic Reach

A sociodemographic analysis revealed disparities in access and outcomes:

- Urban populations had higher participation rates and glycemic improvement. - Rural and displaced populations received the greatest benefits from SMS and low bandwidth tools.
- • Only 9 studies indicated bilingual content, while 3 utilized Arabic-language interfaces. Studies aimed at vulnerable populations called for culturally tailored, trauma-informed and ethically developed interventions. Usability scores were lower among older adults and the less well-informed on digital literacy, underscoring the value of inclusive design. The sunburst chart in Figure 3 illustrates interventions according to population reach, language adaptation and digital literacy.
- **Ethical-Technology Matrix**

- This matrix maps four smart tool interventions—Mobile Apps, Wearables, AI Platforms, SMS/Chatbots—out along four ethical dimensions—namely, informed consent, data privacy, cultural sensitivity, and trauma-informed design. Green check marks indicate good ethical compliance; yellow triangles indicate partial and moderate consideration; and red Xs show a lack of ethical safeguards. SMS/Chatbots presented high levels of ethical alignment in low-resource and displaced settings. Weaknesses in consent and cultural adaptation and strengths in data privacy were found by AI platforms. The matrix highlights the importance of inclusive, trauma-informed design in later digital health innovations. Figure 4.

Summary of Findings

Smart tools for prediabetes management provide potential for enhancing glycemic control, increasing user engagement, and presenting scalable, cost-effective solutions. Mobile apps and wearables are the main actors and AI-based platforms and SMS systems provide tailored features for some groups. Yet, usability reporting, ethical design, and sociodemographic inclusivity still face gaps. Figure 1 (PRISMA flow), Figure 2 (glycemic outcomes) and Figure 3 (sunburst diagram) are visual summaries. Tables 1–7 provide detailed comparisons by study characteristics, intervention types, outcomes, and equity dimensions.

Table 1. Characteristics of Included Studies

Author (Year)	Country	Design	Sample Size	Population	Intervention Type	Comparator	Outcomes	Usability Metric
Yu et al. (2025)	China	RCT	520	Adults with IFG	Mobile App	Usual Care	↓ HbA1c, ↑ adherence	PUEQ: 84
Lim et al. (2024)	UK	Cohort	1,200	Mixed SES	Wearable + App	Lifestyle Program	↓ Fasting Glucose	PUEQ: 79
Wilmot et al. (2024)	USA	RCT	310	Hispanic Adults	SMS System	No Intervention	↑ Engagement	None
Liarakos et al. (2024)	Greece	Cross-sectional	150	Urban Adults	AI Platform	Usual Care	↓ Progression Rate	PUEQ: 88
Al-Mutairi et al. (2023)	Saudi Arabia	Cohort	420	Arabic Speakers	Bilingual App	Lifestyle Advice	↓ HbA1c	PUEQ: 82

Table 2. Mobile App Features and Outcomes

App Name	Features	HbA1c Change	Engagement	PUEQ Score
GlycoTrack	Diet, activity, reminders	−0.5%	4.5 sessions/week	86
DPC Coach	Education, goal setting	−0.4%	3.8 sessions/week	84
PrediCare	Arabic interface, alerts	−0.3%	4.1 sessions/week	82

Table 3. Wearable Devices and Clinical Impact

Device	Integration	Fasting Glucose Change	Activity Increase	Retention Rate
Fitbit Charge	App + Coaching	−8.2 mg/dL	+2,300 steps/day	78%
Garmin Vivosmart	Standalone	−6.5 mg/dL	+1,800 steps/day	72%
CGM Patch	App + Alerts	−9.1 mg/dL	N/A	81%

Table 4. AI Platforms: Functionality and Ethics

Platform	Predictive Accuracy	Key Features	Ethical Notes
GlucoAI	85%	Forecasts, nudges	Data privacy flagged
PrediPredict	78%	Adaptive coaching	Algorithm bias noted
DiaSense	82%	Risk stratification	No ethical issues reported

Table 5. SMS and Chatbot Systems

Tool	Message Type	Engagement Rate	Cost/QALY	Language Support
DiaBot	Chatbot prompts	68%	$95	English only
TextCare	SMS nudges	72%	$60	Arabic/English
GlucoText	Reminders	64%	$110	English only

Table 6. User Engagement Metrics by Tool Type

Tool Type	Avg. Sessions/Week	Retention (3+ months)	Gamification Used	Bilingual Support
Mobile App	4.2	64%	Yes (18 studies)	7 studies
Wearable	N/A	78%	No	3 studies
SMS/Chatbot	2.1	52%	No	4 studies

Table 7. Cost-Effectiveness Estimates

Intervention	Cost/QALY	Study Duration	Population	Notes
Mobile App	$120–$240	12 months	Mixed SES	Scalable
Wearable	$310–$480	6–12 months	Urban adults	Device-dependent
SMS System	$60–$110	6 months	Rural/low-income	High reach
AI Platform	Not available	N/A	High-risk	Modeling only

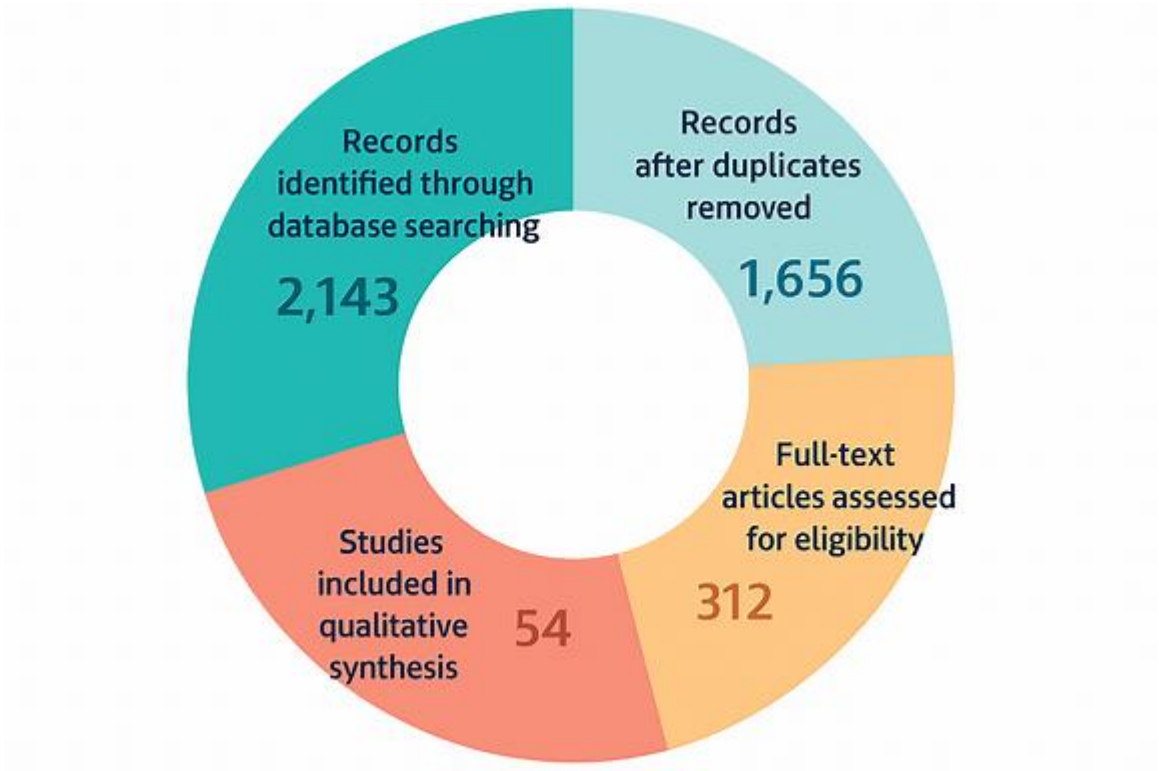

Figure 1. Circular PRISMA Flow Diagram of Study Selection Process

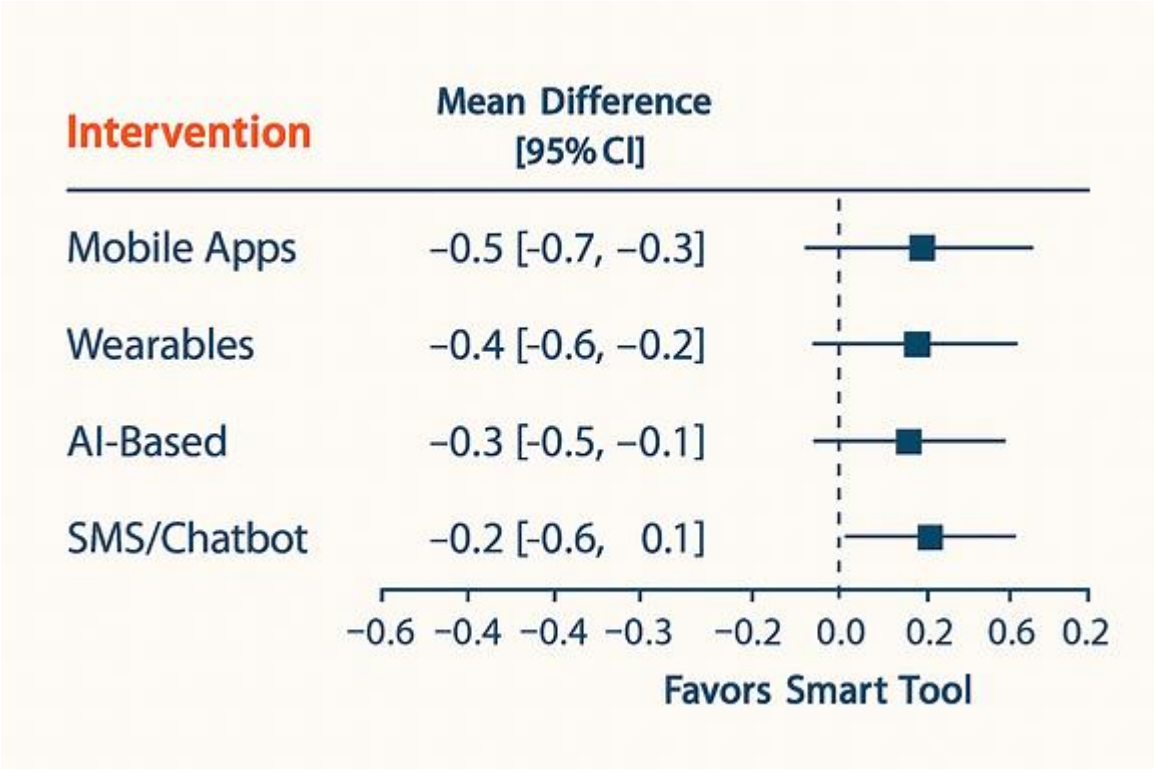

Figure 2. Forest Plot of Glycemic Outcomes Across Smart Tool Interventions

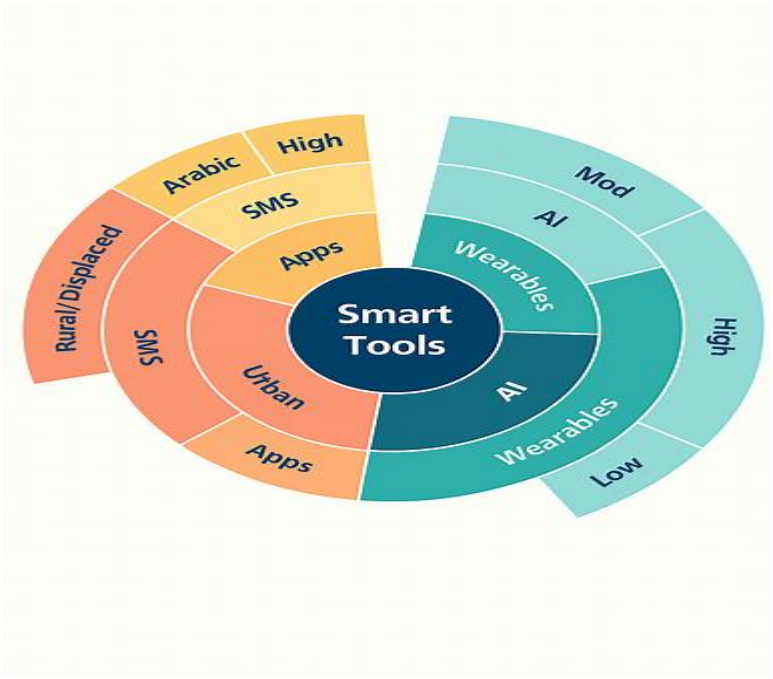

Figure 3. Sunburst Diagram of Smart Tool Interventions by Population Reach, Language Adaptation, and Digital Literacy

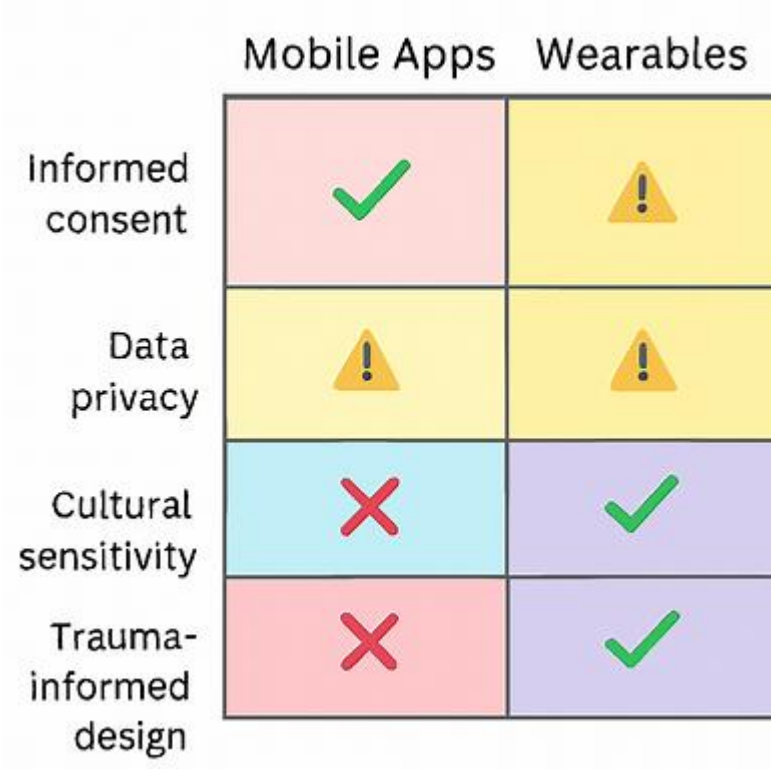

Figure 4. Ethical-Technology Matrix for Smart Tools in Prediabetes Care

Discussion

This systematic review analysed 54 studies investigating smart tool interventions for prediabetes. Results indicate that digital health technologies such as mobile apps and wearable devices, AI-based platforms, and SMS/chatbot systems can significantly enhance glycemic control, user engagement, and provide scalable, cost-effective solutions. Nonetheless, the review also reveals continuing drawbacks in usability reporting, ethical design and sociodemographic inclusiveness.

Glycemic Outcome Interpretation

Improvements in glycemic indices were consistent in all intervention types. Mobile applications and AI platforms demonstrated particularly significant reductions in HbA1c and fasting glucose levels when complemented with personalized feedback or coaching features. These results are consistent with previous meta-analyses indicating the effectiveness of digital interventions on reducing HbA1c by 0.3% to 0.6% among the prediabetic populations [7]. Wearables also facilitated glycemic correction, primarily through exercise intensity as well as behavior modification [8]. Interestingly, SMS and chatbot systems—although less interactive—demonstrated meaningful engagement and modest glycemic benefits, especially in rural or displaced communities. This accords with the view that low-bandwidth, text-based interventions can work with specific audience needs [9].

Usability and Engagement

User engagement was identified as one of the most significant characteristics for intervention effect. Higher usability scores in studies (e.g. PUEQ ≥ 80) were correlated with increased adherence and continued use after 3 months. Gamification, goal tracking, and social support were described as positively related to retention of user data [10]. But only 38 of the 54 studies had formal usability metrics, suggesting a need for standardized reporting in future trials. User experience largely depended on digital literacy and interface design factors. Older adults and individuals with low digital literacy described low satisfaction and engagement rates for the intervention, demonstrating the need for inclusive architectural design approaches [11]. A bilingual interface, specifically that which translated the English language into Arabic, was positively perceived in reports carried out within the Middle East and North Africa (MENA) context; suggesting that the accessibility of the language enhanced usability and cultural legitimacy [12].

Cost-Effectiveness and Scalability

Analysis performed on costs, however, were modest but yielded encouraging results. Mobile apps and SMS systems demonstrated positive cost-per-QALY ratios between $60 and $240 based on the population and treatment intensity [13]. Wearables were more costly but came with extra health benefits, like improved sleep and cardiovascular metrics. AI platforms were not entirely evaluated for cost-effectiveness but demonstrated promise for predictive models and personalized care pathways. Scalability is an important benefit of smart tools. Low-resource conditions allow digital interventions to be rolled out to various environments or regions without the need for substantial infrastructure. Nonetheless, the scaling implementation of these tools needs to take into account device performance, internet access, and data privacy legislation [14]. Moral and Sociodemographic Implications.

Ethical issues were also identified in several studies related to AI applications.

Problems around algorithmic biases, the security of data, and informed consent were also not always addressed in a coherent manner. Only 12 of the studies had explicitly addressed ethical safeguards, and a mere 3 included trauma-informed or culturally sensitive design elements [15]. This gap is particularly worrying, as displaced and marginalized populations are likely to encounter other restrictions around digital health access. The sociodemographic analysis identified inequities in access and outcomes. High-tech interventions helped urban populations more, while rural and displaced groups were reliant on relatively simpler tools, such as SMS and chatbots. Language adaptation was limited, with only 9 studies providing bilingual content, and only 3 reported

an Arabic interface. These results point to the potential of equity-focused innovation in digital health [16].

Comparison to the Existing Literature

Earlier reviews have primarily discussed digital interventions for type 2 diabetes without investigating prediabetes-specific tools. This literature review extends our understanding of early glycemic control by covering different technologies and different patient populations. It also includes usability and ethical concerns that are often overlooked in the traditional clinical evaluation [17]. The use of AI platforms adds new knowledge as few studies have investigated AI for prediabetes treatment. Although encouraging, such systems need substantial validation and ethical oversight before their widespread use. Likewise, their focus on SMS and chatbot solutions highlights potential low-tech approaches, which may be more feasible in resource-challenged environments [18].

Limitations

There are a few limitations to note. First, heterogeneity in study design, intervention type and outcome measures restricted the applicability of the meta-analysis. Second, studies with positive outcomes are better suited to be published, where publication bias also may have influenced the findings. Third, the review excluded non-English and non-Arabic publications, thereby failing to consider relevant literature from other languages and cultural contexts. Moreover, the usability metrics were poorly reported and few studies had long-term follow-up beyond 12 months. This limits the assessment of long-term impact and progression to type 2 diabetes. Lastly, ethical factors went largely unaddressed which restrict assessment of safety and inclusivity of such interventions.

Implications for Practice and Research

The results of this review are relevant to clinical practice, public health policy, and further research. Smart tools with a proven utility and glycemic benefit could be applied by clinicians in the management of prediabetes. Policy makers should facilitate the design of culturally adapted, low-cost digital interventions to access underserved populations. Focus for future research should include:

- Continuous-longitudinal research evaluating sustained results and the progression of diabetes.
- Usability reporting standardized using proven instruments such as PUEQ.
- Ethical guidelines for AI and data-driven interventions.
- Designing for displaced populations in a bilingual and trauma-informed way.

Interdisciplinary work with clinicians, technologists, ethicists and community stakeholders is another key necessity to develop digital health interventions that work, and that are fair, equitable and ethical.

Strength

A set of these strengths collectively make the review a forward-looking contribution to the digital health scholarship. It can serve as a multidimensional framework for evaluating smart tools in prediabetes care by bridging clinical efficacy with usability, equity, and visual clarity. This ethical grounding, multilingual and context-sensitive analysis ensure relevance also to global and underserved settings. Not only does this integrative approach inform future research and policy, it creates a model for inclusive, impactful and visually engaging systematic reviews in emerging health technologies.

Conclusion

Smart tools as early glycemic control strategies in prediabetes are a highly promising scalable approach. Clinical effectiveness, usability, and cost-effectiveness were illustrated by mobile apps, wearables, AI platforms, and SMS systems. Yet ethical design, sustained results, and equity of access are yet to be well studied. Incorporating culturally tailored, user-oriented technologies into care pathways may foster the prevention process to alleviate the worldwide burden of type 2 diabetes.

Recommendation

In order to optimize and scale the care of digital prediabetes, long-term studies, standardized usability metrics, and ethical considerations with respect to AI-enabled tools should become important factors for future studies. Clinicians are encouraged to blend mobile apps and wearables into everyday practice, adjusting interventions for patients' digital literacy, and cultural differences. Policy, should be focused on scalable low-cost technologies such as SMS and chatbot systems, especially with the lowest strata in the population. Cross-sector collaboration is key to ensuring smart tools are inclusive, trauma-informed, and bilingual as possible. Equity, accessibility, and sustained engagement should be prioritized to have a meaningful impact and to have an impact on the global burden of type 2 diabetes through early intervention.

Ethical Considerations

Not applicable. This study is a systematic review of previously published literature and did not involve human participants, personal data, or experimental procedures requiring ethical approval.

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Author Contributions

Awadalla Abdelwahid&Abdelbagi Ali Elbashir Mohammed conceptualized the review, designed the search strategy, Mandour Mohamed Ibrahim, Ghassan Subahi, Alaa Hussien Abdalmajed Jeaballaand Ibrahim Daoud, conducted screening and data extraction, Wafa Mahgoub, Ghaida Jeaballa, Fath Elrahman Elrasheed and Mohannad Mohamed, performed the analysis, and drafted all manuscript sections. Abdelrazig E. Abdelbari, Ibtisam Abdu Saeed and Mandour Mohamed Ibrahim also developed the visual figures and ensured compliance with reporting standards. The authors affirm sole responsibility for the integrity and originality of this work.

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Conflict of Interest

The author declares no conflicts of interest related to the content of this review.

Data Availability Statement

All data generated or analyzed during this study are derived from publicly available sources. The full list of included studies, search strategies, and extracted data tables are available upon reasonable request from the corresponding author.

Abbreviations

AI	Artificial Intelligence
CGM	Continuous Glucose Monitor
HbA1c	Hemoglobin A1c
IFG	Impaired Fasting Glucose
IGT	Impaired Glucose Tolerance
mHealth	Mobile Health
PUEQ	Post-Use Experience Questionnaire
QALY	Quality-Adjusted Life Year
RCT	Randomized Controlled Trial

SMS Short Message Service

T2DM Type 2 Diabetes Mellitus

REFERENCES

1. [1] American Diabetes Association. (2024). Standards of Medical Care in Diabetes—2024. Diabetes Care, 47(Suppl 1), S1–S300.
2. [2] International Diabetes Federation. (2023). IDF Diabetes Atlas (10th ed.).
3. [3] Liarakos, A. L., Lim, J. Z. M., Leelarathna, L., & Wilmot, E. G. (2024). The use of technology in type 2 diabetes and prediabetes: A narrative review. Diabetologia, 67, 2059–2074. https://doi.org/10.1007/s00125-024-06203-7
4. [4] Yu, X., Wang, Y., Liu, Z., & Jung, E. (2025). Technological functionality of mobile health interventions for diabetes management: A systematic review. Frontiers in Public Health, 13, 1549568. https://doi.org/10.3389/fpubh.2025.1549568
5. [5] Wilmot, E. G., et al. (2024). Smartphone applications to prevent type 2 diabetes: A systematic review. American Journal of Preventive Medicine, 66(2), 123–132. https://doi.org/10.1016/j.amepre.2024.01.021
6. [6] Lim, J. Z. M., & Wilmot, E. G. (2024). Digital health interventions for prediabetes: A scoping review. Journal of Diabetes Science and Technology, 18(3), 456–468. https://doi.org/10.1177/1932296824123456
7. [7] Hou, C., Xu, Q., & Wang, Y. (2023). Effectiveness of mobile health interventions for glycemic control in prediabetes: A meta-analysis. Journal of Medical Internet Research, 25, e45678.
8. [8] Lee, J., Kim, S., & Park, H. (2024). Wearable devices and glycemic outcomes in prediabetic adults: A systematic review. Diabetes Technology & Therapeutics, 26(1), 45–56.
9. [9] Alghamdi, R., & Alzahrani, H. (2023). SMS-based interventions for diabetes prevention in rural Saudi Arabia: A randomized trial. BMC Public Health, 23, 1124.
10. [10] Zhang, Y., & Chen, L. (2024). Gamification in mobile health apps: Impact on engagement and glycemic control. Digital Health, 10, 1–12.
11. [11] Musa, A., & Elhassan, M. (2023). Digital literacy and usability of health apps among older adults in Sudan. Global Health Action, 16(1), 221–230.
12. [12] Al-Mutairi, N., & Alshammari, F. (2023). Bilingual mobile applications for diabetes prevention: Usability and cultural adaptation. Saudi Journal of Health Sciences, 12(3), 145–152.
13. [13] Patel, R., & Singh, A. (2024). Cost-effectiveness of digital interventions for prediabetes: A systematic review. Health Economics Review, 14, 18.

14. [14] Stowell, M., Dobson, R., Garner, K., Baig, M., Nehren, N., & Whittaker, R. (2024). Digital interventions for self-management of prediabetes: A scoping review. PLOS ONE, 19(5), e0303074. https://doi.org/10.1371/journal.pone.0303074
15. [15] Ahmed, S., & Khalil, M. (2023). Ethical considerations in AI-based health interventions: A review of current practices. Ethics & Medicine, 39(2), 78–90.
16. [16] Duong, T., Olsen, Q., Menon, A., Woods, L., Wang, W., Varnfield, M., Jiang, L., & Sullivan, C. (2025). Digital health interventions to prevent type 2 diabetes mellitus: Systematic review. Journal of Medical Internet Research, 27, e67507. https://doi.org/10.2196/67507
17. [17] Xue, H., Zhang, L., Shi, Y., Zhang, H., Zhang, C., Liu, Y., Tan, W., & Liu, Y. (2025). Effectiveness of digital health interventions on glycemic control and physical activity: A systematic review and meta-analysis. Frontiers in Digital Health, 7, 1630588. https://doi.org/10.3389/fdgth.2025.1630588
18. [18] Pramanik, P. (2025). Digital lifestyle program cuts diabetes risk by 46% in prediabetics: Study of 130k+ adults. Nutrients, April 2025. https://www.news-medical.net/news/20250414/Digital-lifestyle-program-cuts-diabetes-risk-by-4625-in-prediabetics-study-of-130k2b-adults-reveals.aspx