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USE OF TECHNOLOGY IN TYPE 1 DIABETES PATIENTS TO IMPROVE HEALTH LITERACY: LITERATURE REVIEW

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Abstract
This study aims to examine the role of technology use in improving health literacy in patients with type 1 diabetes mellitus (T1DM). The research methodology was guided by the PRISMA guidelines. A comprehensive search was conducted in five major databases (PubMed, Scopus, Web of Science, CINAHL, ScienceDirect), using a combination of keywords related to T1DM, technology (e.g. mobile applications, telemedicine, Continuous Glucose Monitoring, artificial intelligence), and health literacy. Primary studies in English/Indonesian published between 2020 and 2024 were selected based on strict inclusion and exclusion criteria. Data were extracted, assessed for quality, and synthesized narratively-thematically. The 7 articles analyzed showed that various technologies, including web applications, simulation tools, serious games, and personal robots, were effective in improving knowledge, self-management skills, and self-confidence in patients with T1DM through access to real-time information and feedback. However, patient digital literacy was identified as a key facilitator and significant barrier to technology adoption and effectiveness. A patient-centered approach is also essential for successful implementation. Although AI (*artificial intelligence)* shows potential, the accuracy of general generative AI tools in specific medical information still requires validation and professional guidance. In conclusion, technology has great potential to improve health literacy in people with T1DM, but its optimization requires increased digital literacy and user-centered design. Further research is needed for large-scale validation and comprehensive integration of technology in T1DM care.
Keywords: Diabetes, Health literacy, Health technology

Abstrak
Penelitian ini bertujuan mengkaji peran penggunaan teknologi dalam peningkatan literasi kesehatan pada penderita diabetes militus tipe 1 (DMT1). Metodologi penelitian ini berpedoman pada panduan PRISMA. Pencarian komprehensif dilakukan di lima database utama (PubMed, Scopus, Web of Science, CINAHL, ScienceDirect), menggunakan kombinasi kata kunci terkait DMT1, teknologi (misalnya aplikasi seluler, telemedisin, *Continuous Glucose Monitoring*, artificial intelligence), dan literasi kesehatan. Studi primer berbahasa Inggris/Indonesia yang diterbitkan antara 2020 hingga 2024 diseleksi berdasarkan kriteria inklusi dan eksklusi yang ketat. Data diekstraksi, dinilai kualitasnya, dan disintesis secara naratif-tematik. 7 artikel yang dianalisis menunjukkan bahwa beragam teknologi, termasuk aplikasi web, alat simulasi, *serious games*, dan robot pribadi, efektif meningkatkan pengetahuan, keterampilan *self-management*, dan kepercayaan diri pasien DMT1 melalui akses informasi dan umpan balik *real-time*. Namun, literasi digital pasien teridentifikasi sebagai fasilitator kunci sekaligus hambatan signifikan dalam adopsi dan efektivitas teknologi. Pendekatan berpusat pada pasien juga esensial untuk keberhasilan implementasi. Meskipun kecerdasan buatan menunjukkan potensi, akurasi alat AI (*artificial intelligence)* generatif umum dalam informasi medis spesifik masih memerlukan validasi dan pendampingan profesional. Kesimpulannya, teknologi berpotensi besar meningkatkan literasi kesehatan pada penderita DMT1, namun optimalisasinya menuntut peningkatan literasi digital dan desain yang berpusat pada pengguna. Penelitian lanjutan diperlukan untuk validasi skala besar dan integrasi komprehensif teknologi dalam perawatan DMT1.
Kata Kunci: Diabetes, Pengetahuan Kesehatan, Teknologi kesehatan

INTRODUCTION

Diabetes mellitus is a global health problem that continues to increase in prevalence. Among the various types of diabetes, Type 1 Diabetes (T1DM) is a chronic autoimmune condition in which the pancreas stops producing insulin, an essential hormone needed to convert sugar into energy (Ruissen et al., 2021). People with T1DM require strict and ongoing self-management throughout their lives. Self-management includes regular monitoring of blood glucose levels, administration of exogenous insulin, careful diet planning, and physical activity

(Akil et al., 2021), (Thomas et al., 2023). The complexity of this management demands a high level of understanding and skill from the patient (Carr et al., 2022), thus making health literacy a key factor in achieving optimal health outcomesHealth literacy is defined as the level of an individual's ability to obtain, process, and understand basic health information and services needed to make appropriate health decisions (Asharani et al., 2021). For people with DMT1, health literacy is very important to understand medical instructions, interpret blood glucose data, adjust insulin doses, recognize signs of complications, and actively participate in their treatment regimen (Esen & Aktürk Esen, 2020), (Naef et al., 2023). Low health literacy in this group is often associated with poor medication adherence, increased risk of acute and chronic complications, lower quality of life, and increased emergency department visits and higher health care costs (Mutlu et al., 2023). Therefore, innovative strategies to improve health literacy in people with DMT1 are urgently needed.

In the last decade, rapid advances in technology have revolutionized many aspects of life, including the healthcare sector. Integration of technology into clinical practice and chronic disease management has opened up new opportunities to empower patients. Various technological innovations for T1DM patients, such as mobile applications (Karakuş et al., 2023), continuous glucose monitoring device (Continuous Glucose Monitoring/CGM) (Jiao et al., 2022), smart insulin pump (Schmidt et al., 2023), telemedicine platform (Lee et al., 2021), and artificial intelligence-based decision support systems. These devices and platforms not only facilitate monitoring and therapy delivery, but also provide instant access to relevant health information, interactive educational tools, and community support.

Given the great potential of technology in facilitating access to health information and education, the hypothesis arises that technology can play an important role in improving health literacy in people with DMT1 (Lee et al., 2021). Technology can present complex information in easier-to-understand formats, provide real-time feedback, and enable personalization of educational content to suit individual needs (Jansky, 2024). However, a comprehensive understanding is needed of how various forms of technology have been used and how effective their use is in improving health literacy in people with T1DM.

Therefore, this study aims to conduct a literature review to examine in depth the use of technology in people with type 1 diabetes and how the implementation of technology contributes to improving their health literacy. The results of this review are expected to provide a better understanding of best practices, challenges, and opportunities in this area, as well as inform the development of future technology-based interventions to support people with T1DM.

METHOD

This review was designed as a systematic literature review in accordance with PRISMA 2020, and the search strategy was reported according to PRISMA-S (Rethlefsen et al., 2021). Prior to the search, an a priori protocol was developed, including the research question, eligibility criteria, and synthesis plan; a condensed version of the protocol is available upon request. A comprehensive search was conducted in June 2025 in the following primary databases: MEDLINE via PubMed, Embase, CINAHL (EBSCOhost), and Cochrane Library CENTRAL. Scopus and Web of Science were used for forward–backward citation tracking and identification of additional studies, but not as primary sources. The year range was limited to 2020–2024, with the English language used.

The search strategy combined subject headings and free terms for three key concepts: Type 1 Diabetes population, diabetes technology/digital health, and health literacy outcomes. The strategy was tailored per database. Brief examples: PubMed: "Diabetes Mellitus, Type 1" OR "type 1 diabetes" OR T1D AND telemedicine OR "mobile application" OR smartphone OR

"continuous glucose monitoring" OR CGM OR "insulin pump" OR wearable OR "artificial intelligence" OR "decision support" AND "health literacy" OR "eHealth literacy" OR "patient education" OR "self-management" OR "diabetes knowledge". Embase: 'type 1 diabetes'/exp AND ('telemedicine' OR 'mobile application' OR 'continuous glucose monitoring' OR 'insulin infusion pump' OR wearable OR 'artificial intelligence') AND ('health literacy' OR 'patient education' OR 'self-management'). The complete string per database is provided in the appendix. There were no restrictions based on article access status; full-text acquisition efforts are made through institutional subscriptions or interlibrary loan services.

In addition to database searches, hand searches were conducted, including backward snowballing of included studies and key reviews, forward citation tracking through Scopus/Web of Science, scanning of key journals (e.g., Diabetes Care, Diabetic Medicine, Diabetes Technology & Therapeutics), and searching clinical trial registries (ClinicalTrials.gov and WHO ICTRP) for ongoing or completed studies. All records were exported to reference management software for deduplication, and the selection process was reported in a PRISMA diagram.

Screening was conducted independently by two researchers in two stages: title and abstract, then full text. Prior to screening, an initial calibration was conducted to standardize the interpretation of the criteria. Differences in decisions were resolved through discussion until consensus was reached, with a third researcher acting as an arbitrator if necessary. Reasons for exclusion at the full text stage were systematically recorded.

Inclusion criteria: primary studies or systematic reviews/meta-analyses in individuals with Type 1 Diabetes (all ages) that evaluated the use of relevant technologies for education, monitoring, decision support, or self-management (e.g., mobile apps, telemedicine, CGM, insulin pumps, wearable devices, decision support systems, or AI), and reported measurable health literacy outcomes or proxies such as eHEALS, HLQ, Newest Vital Sign, Diabetes Knowledge Test, self-management indicators, or diabetes knowledge. Peer-reviewed publications, 2020–2024, in English or Indonesian. Exclusion criteria: Type 2/gestational studies without Type 1 sub-analysis, not involving a technology component, not reporting health literacy/proxies, non-research reports (editorials, opinion pieces, conference abstracts without full articles).

RESULTS DAN DISCUSSION

Results

Figure 1 below is the result of work using the PRISMA framework, the findings of articles based on the entire database are 1.902 articles. Selection based on title and abstract produced 1.052 articles, then selection of article content based on exclusion criteria produced 392 articles, the last selection is based on exclusion criteria produced 7 relevant articles.

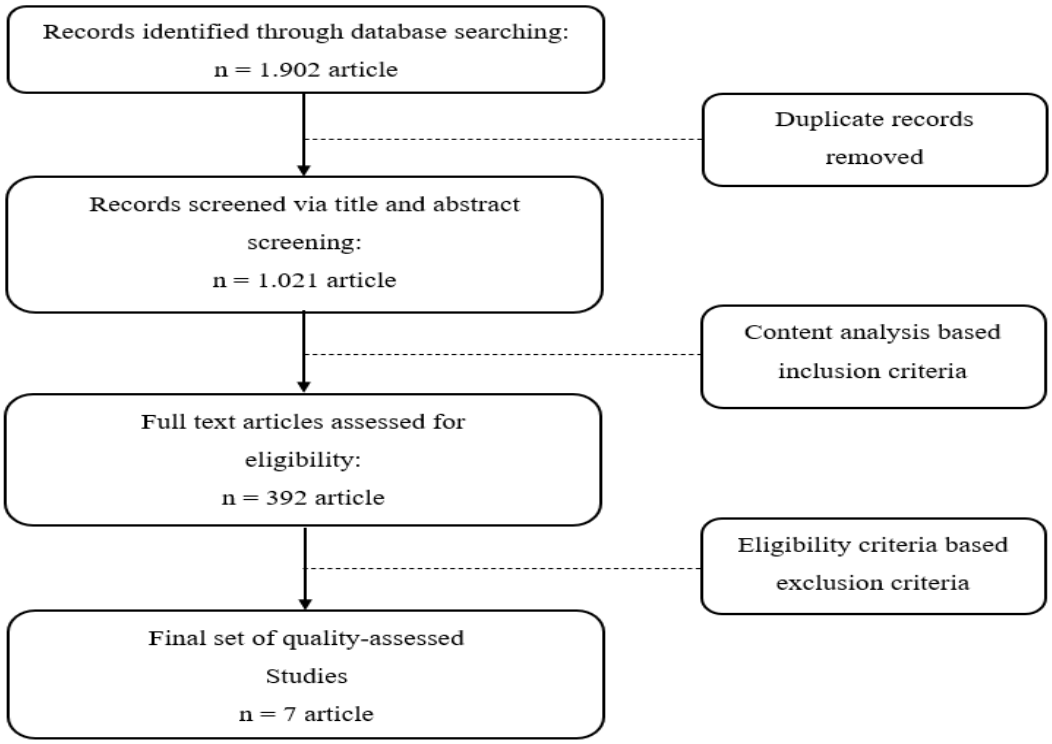

Figure 1. Research framework

Then, after the article is worthy of analysis, the next stage is analysis based on each article. Below is table 1 of article analysis.

Table 1. Results of review of eligible articles

Title (author and year)	Method of collecting data	Characteristics of Technology	Research Findings	Research Gaps and Expectations
Blood glucose monitoring and sharing amongst people with diabetes and their facilitators: Cross-sectional study of methods and practices (Jamal et al., 2021)	Cross-sectional study, questionnaire for SMBG (Self-Monitoring of Blood Glucose) practice	Digital devices (laptop, smartphone) for recording and sharing blood glucose data	45% of patients use digital devices; digital data is shared more frequently. Digital literacy can improve SMBG practices	Diabetes self-management programs should integrate digital technologies into training; emphasize the use of electronic devices to share data.

Does telemedicine work well to support adolescents with type 1 diabetes?: A qualitative study with parents and diabetes care team members (Malik et al., 2021)	Qualitative study, eight focus groups with parents and diabetes care teams	Telemedicine (video conferencing technology)	Telemedicine is useful; adolescent literacy with videoconferencing technology is a facilitator. Barriers: physical examination, data availability, confidentiality of communication. Hybrid models are useful	Clinics need to address issues of accessibility, appointment preparation, and confidential communication in telemedicine.
Current Provision and HCP Experiences of Remote Care Delivery and Diabetes Technology Training for People with Type 1 Diabetes in the UK during the COVID-19 Pandemic (Forde et al., 2022)	Survey (48-questions) of healthcare professionals (HCPs)	Remote care (telephone, video), insulin pump training	Telephone consultations are dominant. Key barriers: patient familiarity with technology (digital literacy) and access to patient device data. Decreased pump initiation/renewal	Need to address patient digital literacy to improve the effectiveness of virtual care and device training
THE ENDORSE FEASIBILITY PILOT TRIAL: ASSESSING THE IMPLEMENTATION OF SERIOUS GAMES STRATEGY AND ARTIFICIAL INTELLIGENCE- BASED TELEMEDICINE IN GLYCEMIC	Two-phase pilot trial (pre-pilot data presented), observations, engagement tracking	Integrated ENDORSE platform (AI, gamification, serious games, mobile technology, glucose sensor, smart insulin pen)	It is expected to improve diabetes management through training, monitoring and feedback	It is necessary to consider the level of digital literacy and internet access to increase compliance and acceptance of the platform

CONTROL IMPROVEMENT (Vasilakis et al., 2022)				
Evaluation of a Web-Based Simulation Tool for Self-Management Support in Type 1 Diabetes: A Pilot Study (Colmegna et al., 2023)	Pilot clinical trial, questionnaires (Technology Acceptance, Diabetes Distress Scale), interviews	Web-Based Simulation Tool (WST) for patient data interaction, supporting self-management	WST is useful and reliable, there is a learning curve. Potential to increase diabetes literacy and reduce emotional burden	Implications for larger, longer-term studies for further validation
Mixed-methods study protocol to identify expectations of people with type 1 diabetes and their caregivers about voice-based digital health solutions to support the management of diabetes distress: The PsyVoice study (Vergara et al., 2023)	Mixed-methods study protocol (semi-structured interviews, e-Health literacy questionnaire	Voice-based digital health solutions	Identifying user expectations towards voice technology and its impact on e-Health literacy	The need to develop voice-based digital health interventions tailored to users' digital health expectations and literacy
Adolescents with type 1 diabetes' perspectives on digital health interventions to enhance health literacy: a qualitative study (Naef et al., 2024)	Qualitative study, semi-structured individual interviews with adolescents (n=20)	Digital health interventions (general) for information access, peer-to-peer interactions, and doctor-patient communication	Digital interventions are underutilized or inadequately implemented; lack of patient-centered approach	There is a need to focus on increasing capacity, promoting digital health literacy, and fostering a participatory culture to optimize technology and improve health literacy.

Source: data proceed

Discussion

Based on the results of the researcher's review, it consistently shows the potential of technology in improving health literacy and self-management skills in people with T1D. Studies

such as those conducted by Colmegna et al. (2023) who evaluated the Web-Based Simulation Tool (WST) reported that the tool was not only useful and reliable, but also had the potential to improve diabetes literacy. Similarly, a personal robot-based intervention that played an educational game on diabetes self-management in children with T1D (Naef et al., 2024) showed a significant increase in diabetes knowledge. These findings are supported by the development of a web-based application for diabetes self-management that has been shown to be effectively used by individuals with varying levels of literacy, serving as a logbook and educational resource to improve self-management skills (Type I diabetes self-management: Developing a web-based telemedicine application),

Furthermore, the positive impact of technology on improving health literacy extends across multiple platforms. Integrated platforms such as ENDORSE (Vasilakis et al., 2022) which leverage artificial intelligence (AI) and gamification, explicitly aim to facilitate training and monitoring, which directly contributes to health literacy by providing real-time information and feedback to patients. The broader context of the effectiveness of technology in health education is also supported by an integrative review Moreira et al. (2023), which comprehensively concluded that the use of digital educational technology is beneficial and effective in improving the knowledge of patients and health professionals about diabetes management. Although in Type 2 patients, the study by Leong et al. (2022) also emphasized that social media-based educational programs can improve knowledge, attitudes, and self-management activities, even in individuals with low initial health literacy.

However, effective implementation of technology is highly dependent on patients' digital literacy levels, which is often a significant barrier. Survey of healthcare professionals in the UK (Forde et al., 2022) consistently highlight that low patient familiarity with technology and digital literacy are major barriers to successful remote consultations and training on advanced technology devices such as insulin pumps. These barriers not only complicate technology adoption but also directly impact patient access to interventions that can improve their self-management.

On the other hand, when digital literacy is adequate, technology can be a powerful enabler. A cross-sectional study by Jamal et al. (2021) showed that patients who used digital devices to record blood glucose were more likely to share data with their providers, indicating that digital literacy may improve self-monitoring of blood glucose (SMBG) practices and care communication. Similarly, Malik et al. (2021) qualitative study of telemedicine in T1DM adolescents identified "adolescent literacy with videoconferencing technology" as a key enabler. These findings underscore that to maximize the benefits of technology, digital literacy enhancement programs should be integrated into diabetes care strategies, in line with clinical guidelines such as those issued by the AACE (Grunberger et al., 2021) that emphasize the need for knowledge of device functionality and expertise to provide relevant education to patients.

The importance of a patient-centered approach in the development and implementation of digital health interventions cannot be overstated. A qualitative study by Naef et al. (2024) clearly found a lack of a patient-centered approach in existing digital health interventions for adolescents with T1DM, leading to underutilization of the technology. This underscores that the effectiveness of technology lies not only in its capabilities, but also in how well it is tailored to the user's needs, preferences, and digital health literacy levels. Study protocols such as PsyVoice (Vergara et al., 2023) that aim to identify user expectations for voice-based solutions are a step in the right direction towards more patient-responsive design.

Despite the promise of many technologies, significant gaps exist in how these technologies are integrated into clinical practice and how patients are optimally empowered. A scoping review by Racey et al. (2023) highlighted the need to equip healthcare professionals with the knowledge and skills to deliver technology-enabled integrated care. Challenges also

arise for specific subpopulations, such as older adults, who require an adaptive approach to technology integration (Huang et al., 2023). This highlights the complexity of incorporating digital innovation into existing healthcare frameworks.

Overall, the use of technology promises significant transformation in improving health literacy and self-management in people with T1DM. However, its successful implementation depends on a deep understanding of users' digital literacy, patient-centered design, and robust research to fill the gaps. While artificial intelligence shows potential in facilitating diabetes management, it is important to note that general generative AI tools such as Bard and ChatGPT still have limitations in the accuracy of specific medical knowledge (Meo et al., 2023), suggesting that their use as a direct source of information should be cautious and guided.

Identified limitations of this study include: (1) Large-scale, long-term pilot studies are needed to validate the effectiveness of technology interventions in improving health literacy sustainably and with significant clinical outcomes; (2) Development of proven strategies to improve digital literacy in different subpopulations of people with T1DM, including adolescents and older adults; (3) Further investigation of best practices in integrating technology into clinical workflows and hybrid care models; and (4) Further research into the development and validation of customized and verified AI tools for health education in T1DM.

CONCLUSION

This systematic literature review highlights that technology plays a significant role in improving health literacy and self-management skills in people with Type 1 Diabetes (T1DM). Innovations ranging from web applications, simulation tools, serious games, to personal robots have demonstrated effectiveness in enhancing patient knowledge, self-management skills, and self-confidence. These technologies facilitate access to information and provide adaptive feedback, empowering individuals to better manage their chronic condition. However, the success of technology implementation is highly influenced by the patient's digital literacy level. Low digital literacy has been shown to be a major barrier to technology adoption and utilization, while adequate literacy serves as a key facilitator. Furthermore, technology development centered on patient needs and preferences is crucial to ensure the relevance and acceptability of digital interventions. It is also important to note that while artificial intelligence offers potential, the accuracy of medical information from common generative AI tools still requires validation and professional guidance. Future research should focus on large-scale intervention studies to validate long-term effectiveness and identify comprehensive technology integration strategies into healthcare systems. In doing so, technology can fully realize its potential as a powerful tool to empower people with T1DM towards better health literacy and optimal clinical outcomes.

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Conflict of Interest

The authors of this study declare that they have no conflicts with other authors.

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