

Tailoring interventions to close gaps in diabetes mellitus care

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Abstract

Diabetes mellitus is one of the fastest-growing chronic medical conditions worldwide. It disproportionately affects some minoritized populations, including certain racial and ethnic groups, migrant populations, and rural communities. Disparities in diabetes mellitus prevalence, morbidity and mortality in minoritized populations are related to longstanding structural and social inequities and are closely tied to social factors. However, current interventions to improve diabetes mellitus outcomes among people from minoritized populations have primarily focused on trying to change individual behaviour, without sufficiently addressing the root structural barriers that drive disparities. Here, we aim to describe the structural inequities in the diagnosis, management and outcomes of minoritized people with diabetes mellitus and to discuss practical measures that can ensure equitable care for people in minoritized groups who have diabetes mellitus. Using a framework to examine diabetes mellitus disparities, we will consider interventions at system levels, including public health approaches, the endocrine healthcare workforce, care quality standards, access to high-quality care (including advanced technologies) and involvement in research. We will also discuss strategies to address intermediate factors, including food insecurity and literacy, and to improve diabetes mellitus care services among migrant and refugee populations and racial and/or ethnic minority communities.

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Key points

- The burden of disease and complications linked to diabetes mellitus for type 1 diabetes mellitus and type 2 diabetes mellitus in adult and paediatric populations is high, particularly for minoritized populations, often due to the social determinants of health.
- Using a conceptual framework and focusing on the structural, historical and community-based factors that drive disparities in diabetes mellitus care provides insight into closing these gaps.
- Multi-level interventions from the time of screening and diagnosis as well as during care delivery and prevention of complications are key to providing equitable care.
- Prioritization of appropriate workforce growth, expansion of insurance coverage, case management, diabetes mellitus education, nutrition services and specific research initiatives that centre on minoritized populations are needed.

Introduction

The worldwide burden of diabetes mellitus is high and predicted to continue to increase substantially over the next 30 years, with disproportionate effects on minoritized populations. For instance, in 2024, an estimated 589 million adults worldwide (11.1% of adults aged 20–79 years) had diabetes mellitus¹, and 3.4 million adults died from causes related to diabetes mellitus according to The Diabetes Atlas² of the International Diabetes Federation (IDF). In the same year, the North American and Caribbean region had the second-highest worldwide prevalence of diabetes mellitus among IDF regions (15.1% of the population), and outspent other regions on diabetes mellitus (approximately US\$ 7,800 per year per person), yet had the second-highest diabetes mellitus mortality of any region. According to the US Centers for Disease Control and Prevention National Diabetes Statistics Report³, American Indian, native Alaskan, Black, Asian and Hispanic populations in the USA have a higher prevalence of diabetes mellitus, are less likely to achieve glycaemic goals, are more likely to develop diabetes mellitus complications, and have higher diabetes mellitus mortality compared with the non-Hispanic white (NHW) population. Similar diabetes mellitus disparities affecting minoritized populations are seen globally.

These disparities are related to differences in the social determinants of health (SDOH)⁴. Therefore, targeted and timely interventions for diabetes mellitus that address SDOH risk factors should be an important focus of diabetes mellitus care and care delivery. However, many interventions and care delivery models have focused on the individual instead. This Review will discuss various potential systemic and intermediate-level interventions that can address SDOH-related risk factors and start to reduce disparity gaps. This approach requires the participation of multiple stakeholders, including healthcare (healthcare delivery organizations, clinicians and clinical staff, health plans and payors), government (policy-makers and legislators), industry (pharmaceutical, agriculture and food, health, and fitness) and non-profit (community-based and health professional organizations) stakeholders.

This Review focuses on systemic and intermediate-level approaches to reducing inequities in outcomes related to diabetes

mellitus in minoritized populations. Although many disciplinary theories have been used to describe the complex interplay between individual, intrapersonal, social–cultural, economic, political and geographic factors, this Review will use a conceptual framework combining a framework based on population health with a framework based on quality of care. We will focus on current literature, emphasizing work from 2022 to the present, thus building on work done by Walker et al.⁵. Although pilot studies test feasibility and inform future research, this Review will prioritize broader initiatives that demonstrate relevance and scalability across diverse populations.

Framework to examine diabetes mellitus disparities

In the USA, the Department of Health and Human Services describes SDOH as the conditions in which people are born, grow, work, live and age, and it is categorized as healthcare access and quality, education access and quality, social and community context, economic stability, and neighbourhood and built environment. These factors mediate diabetes mellitus disparities and lead to higher levels of HbA_{1c} and higher rates of acute and chronic complications in type 1 diabetes mellitus (T1DM), a higher incidence and prevalence of type 2 diabetes mellitus (T2DM), higher risks of undiagnosed diabetes mellitus, and higher mortality and lower quality diabetes care for both T1DM and T2DM in those adversely affected by disparities than in those unaffected by disparities⁴ (Fig. 1).

Adapted from a previously proposed framework⁶, an Endocrine Society scientific statement from 2012 proposed a conceptual framework combining “a population health framework with a quality of care framework to elucidate the causes of disparities in endocrine conditions and to guide our approach to understanding and eliminating these disparities”⁷. In 2023, a further Endocrine Society scientific statement used a similar framework to examine endocrine health disparities in paediatric and LGBTQIA+ populations⁸, and another paper used the World Health Organization (WHO) SDOH framework, which added socioeconomic and political systems and racism as upstream drivers of SDOH⁹. Subsequent work added social and caregiver isolation to an examination of cardiovascular risk among adults with diabetes mellitus and associations with SDOHs¹⁰. In 2025, the Diabetes Index for Social Determinants of Health was developed, incorporating the principal SDOH categories outlined by the American Diabetes Association (ADA)¹¹, yet the model does not include such systems as socioeconomic, political or historical contexts. Other models explore the individual frameworks and include a diabetes mellitus distress measure¹², and question the utility of previous guidelines or recommendations¹³.

Studies performed in an international context, not necessarily with respect to diabetes mellitus, have also provided insight into other contributing factors such as migration¹⁴, acculturation¹⁵ and austerity measures¹⁶. In one framework⁷, systemic-level or distal concerns included factors such as governmental and economic policies, public health programmes (including screening and health education), representation in research (including healthcare implementation and outcomes), workforce capacity, environmental or climate factors, and considerations for the care of vulnerable populations (which include migrant, geriatric, paediatric, disabled and incarcerated people). Importantly, when examining systemic-level factors, a historical context of policies and events that have shaped each community-level factor must be understood. Individual SDOH factors are often shaped by allostatic load, which is the compendium of physiological dysregulation caused by life course stressors and can be measured as weathering

(the process whereby systemic disadvantages lead to more rapid ageing and development of age-related conditions). Molecularly, consistent exposure to stressors leads to elevations in levels of cortisol and inflammatory cytokines (such as IL-6), which induce epigenetic modifications of DNA that lead to dysregulation and altered expression of genes in the pancreas, adipose tissue, liver and vasculature¹⁷. These epigenetic changes can be sustained throughout an individual's life or even passed through generations as a form of metabolic memory¹⁸. Accordingly, we aim to highlight systemic and community-based interventions centring race and ethnicity within these systems. This proposed framework could be used to design and deliver tailored programmes to minoritized communities with diabetes mellitus and work to affect improved clinical outcomes (Fig. 2).

Disparities in T2DM

T2DM accounts for more than 90% of all cases of diabetes mellitus worldwide, disproportionately affecting communities on the basis of socioeconomic status, race, ethnicity, geographic location and other demographic factors¹⁹. Globally, the majority of people with T2DM live in low-income or middle-income countries (LMICs), where delayed diagnosis and inadequate treatment are widespread due to insufficient public health and healthcare infrastructures, high medication costs, low health literacy, and socioeconomic disadvantages²⁰. Minoritized populations in high-income countries face similar barriers despite much larger investments in healthcare by these countries than by LMICs²⁰. China, India and the USA have the highest number of estimated incident cases of T2DM, with rapidly increasing incidences in the Near East and Middle East regions¹. An increased prevalence and rising incidence of T2DM are also observed in Indigenous groups and among people of Asian or African American descent. In the USA, T2DM has an increased prevalence among Native American, Black and Hispanic populations¹.

Although the pathogenesis of T2DM is not completely understood, known risk factors (including polygenic and environmental triggers, overweight, obesity and family history) might contribute to observed disparities in the incidence of the disease. The global increasing incidence of diabetes mellitus has been attributed to changes in food quality and availability and to increasingly more sedentary lifestyle practices²¹. Exposure to endocrine-disrupting chemicals, commonly found in many materials, including plastics, has also been identified as an important emerging risk factor for developing diabetes mellitus²² and probably disproportionately affects low-income communities. Symptomatic presentation, ranging from mild to severe, and risks of microvascular and macrovascular complications also seem to have discrepancies based on racial and/or ethnic classifications, which is probably related to differences in the SDOH^{23–25}.

Disparities in T2DM care also exist and are associated with disparities in diabetes mellitus morbidity and mortality. In an analysis of diabetes mellitus care quality in the USA, Black adults were less likely to achieve treatment goals for HbA_{1c} than white adults, and lack of health insurance and low socioeconomic status were strong predictors of poor-quality diabetes mellitus care across all populations²⁶. Global disparities in diabetes mellitus care also exist²⁷, including high medication out-of-pocket costs in countries such as the USA²⁸, low access to medications in sub-Saharan Africa²⁹, therapeutic inertia in parts of Europe³⁰ and mistrust of allopathic medicines in India³¹. These and other barriers to care are most likely to affect people in LMICs and minoritized populations in high-income countries.

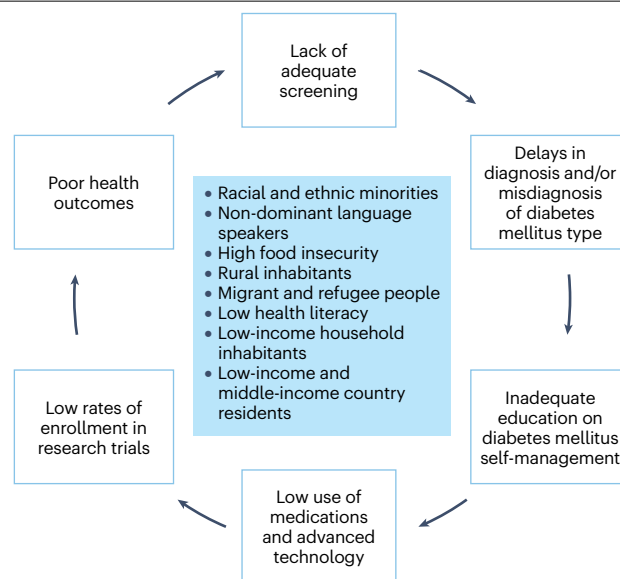


Fig. 1 | Factors in populations at the highest risk of diabetes mellitus disparities throughout the diabetes mellitus care continuum. This figure outlines some of the factors associated with diabetes mellitus disparities (central blue box) and some of the implications of these disparities (boxes with a blue outline).

Disparities in T1DM

T1DM occurs in individuals of all ages: globally, 40% of patients with T1DM are diagnosed before they are 20 years old, and the remainder are diagnosed in adulthood^{32,33}. Worldwide, the incidence and prevalence of T1DM are steadily increasing across all regions³⁴. In the USA, the largest increases in T1DM incidence have occurred in individuals from racial and/or ethnic minorities, yielding a more diverse population of people living with T1DM than previously³⁵. The IDF Diabetes Atlas estimated that 9.2 million people were living with T1DM in 2024 (ref. 34), with 22% living in LMICs³². Life expectancy varies considerably with socioeconomic factors, with markedly short lifespans in the lowest resourced countries, which is probably related to lack of appropriate care and misdiagnosis or non-diagnosis of T1DM^{34,36}. However, even within the highest-resourced countries, there is still a socioeconomic gap in life expectancy and complication rates^{37,38}.

Globally, T1DM health outcomes vary considerably by SDOH, and individuals with socioeconomic disadvantages and from minority race and ethnicity groups have worse glycaemic control and greater rates of acute and chronic disease complications than people in other groups^{39–42}. Data from the T1D Exchange in the USA highlighted differences in average glycaemic control across the lifespan by race and/or ethnicity, with higher HbA_{1c} levels in Hispanic and Black people than in NHW people⁴¹. These differences persisted for Black people with the highest household income levels, which suggests that structural racism has a role in propagating health disparities and in increasing the risk of chronic complications^{43,44}.

Diabetic ketoacidosis (DKA), a potentially fatal complication associated with poor long-term glycaemic control and an increased risk of adverse cognitive outcomes^{45,46}, has been persistently associated with socioeconomic disadvantage. Published in 2022, a systematic review of studies from patients living in 47 countries found an increased risk of DKA at the time of T1DM diagnosis in youth belonging to an ethnic

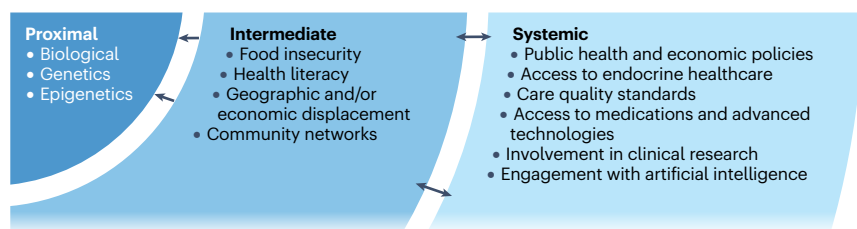


Fig. 2 | Schematic of intermediate-level and systemic-level factors that mediate the outcomes of the proximal factors of an individual with diabetes mellitus.

Designing interventions at the systemic levels should be informed by the intermediate factors. Vice versa, intermediate-level interventions require systemic-level support.

minority population and, among youth in the USA, in those without private health insurance; conversely, high parental education and regular access to primary healthcare were protective against DKA³⁹. Death from DKA as a result of new-onset T1DM not being diagnosed is most common in under-resourced countries and could be the leading cause of death for young people with T1DM globally³².

Regional deprivation indices, which are based on multidimensional measures of socioeconomic disadvantage by location of residence⁴⁷, have been applied to assess disparities in many chronic diseases and go beyond simply equating socioeconomic deprivation with racial or ethnic minority populations. In a study published in 2024, the application of deprivation indices to more than 21,000 children from five national paediatric T1DM registries (from Germany, the USA, Wales, New Zealand and Slovenia) and a clinical cohort in the USA revealed an association between regional social deprivation and the likelihood of DKA at the time of diagnosis⁴⁸. Given the presence of several robust T1DM registries, such as the Diabetes Prospective Follow-Up Registry in Germany, Austria, Switzerland and Luxembourg⁴⁹ and the T1D Exchange Quality Improvement Collaborative in the USA⁵⁰, further elucidation of the complex interplay between comprehensive country-specific deprivation indices and clinical T1DM outcome measures is anticipated. Indeed, continual efforts are under way to standardize data across regions and registries as well as to promote international collaboration and improve health outcomes across diverse populations of patients⁵¹.

Systemic-level factors and potential interventions

Healthcare, socioeconomic and policy environments are embedded in regional and national historical underpinnings. For example, in the USA, the increased incidence of T2DM in the Indigenous population is directly tied to laws, such as the Homestead Act of 1862 and the Desert Land Act of 1877, that negatively influenced the environment, domiciles and dietary sources of these communities⁸. These laws resulted in the displacement of Indigenous populations and water scarcity, leading to dependence on ultra-processed foods. In the Gila River Indian Community, cycles of drought brought food scarcity and famine, which have been associated with the development of adverse metabolic profiles⁵². Studies of the Pima community, living in the Gila River Indian Community, have consistently reported a statistically significantly high incidence and prevalence of T2DM; the US National Institutes of Health has conducted a longitudinal study of the epidemiology of T2DM in this population, starting in 1965 (refs. 53,54). The rates of T2DM increased over time in the population, disproportionately affecting offspring of women with diabetes mellitus during pregnancy, thus promoting a feedforward generational effect⁵⁵. Some studies have proposed that the feedforward effect can be partially explained by epigenetic changes⁵⁶. To be effective, interventions must consider historical context, recognizing the increased allostatic load and resulting weathering that

have contributed to rising T2DM rates across generations in affected communities.

In 1997, the **Special Diabetes Program for Indians** was established by the US Congress as a grant programme for the prevention and treatment of diabetes mellitus in Native American communities; this community-driven programme was administered by the Indian Health Service. It was adapted to support more than 300 Indian Health Services in both rural and urban areas, including the Gila River Indigenous Community. Aggregate results from these programmes (1997–2019) noted a reduction in the average HbA_{1c} from 9% to 8%, a 54% decrease in newly diagnosed diabetic nephropathy, and a 50% reduction in the incidence of diabetic retinopathy⁵⁷. Assessment of the effectiveness of the various community-based programmes was not performed owing to the locally driven and thus heterogeneous nature of each intervention. Systemic-level interventions have the potential to reach large numbers of individuals but are also arguably more difficult to implement and might have a smaller individual effect than intermediate-level interventions. One limitation of the Special Diabetes Program for Indians is that it does not include larger policy changes such as taxes on sugar-sweetened beverages and changes to the built environment of the various locales⁵⁷. In short, global, national, regional and local policies influence diabetes mellitus inequities directly and indirectly, and there is a critical need for updated policies.

Public health approaches and economic policies

Most countries include diabetes mellitus in their national non-communicable disease policies or as a standalone policy or plan to facilitate a coordinated, multisectoral response. In its 2016 Global Report on Diabetes⁵⁸, the WHO recommended implementation of whole-of-government and whole-of-society approaches with multisectoral engagement, policy coherence and mutual accountability among different spheres of policy-making that influence non-communicable diseases such as diabetes mellitus.

Such an approach is being tested in Singapore with the War on Diabetes⁵⁹. The War on Diabetes policy is a multisectoral, population-based approach initiated by the Singapore Ministry of Health to reduce the prevalence of modifiable T2DM risk factors (overweight, obesity, physical inactivity and unhealthy diet). A range of stakeholders are engaged in the programme, including government officials, healthcare providers, food and beverage manufacturers, producers and retailers, professional associations, academic institutions, and the general public. Inclusion of the general public was a crucial step to developing an intervention that would be embraced by populations most likely to benefit. Policy actors cited multiple reasons for introducing the War on Diabetes policy, including rising diabetes mellitus prevalence, an ageing population, increased life expectancy, increasing comorbidities and escalating healthcare costs, along with concerns about the financial burden of diabetes mellitus on the working class

and its potential negative effect on society. One year after the rollout, seven beverage companies signed a pact pledging to reduce the sugar level in their beverages to 12% or less by 2020. The Singapore Ministry of Health made it possible for the food and beverage industry to use Singapore as a regional headquarters to sell their healthier products to other markets in Asia, supporting the sustainability of the change. Despite challenges, such as misinformation, unclear messaging, and high costs for food and beverage innovation, research and marketing, overall, whole-of-government and whole-of-society approaches show promise as systemic-level interventions.

Public health and educational campaigns to increase recognition of T1DM can improve prompt and accurate diagnosis, enabling initiation of insulin therapy and reducing DKA risk. Early detection of T1DM auto-antibodies through research trials markedly reduces the risk of DKA at clinical diagnosis⁶⁰. In 2023, Italy was the first country to institute law-mandated universal screening for T1DM auto-antibodies across its population of children and adolescents aged 1–17 years⁶¹. General screening initiatives also include, for example, EDENT1F1, a multinational European study pursuing general population auto-antibody screening of children to further early detection, develop biomarkers of disease progression, and provide broad education and support to all families⁶². Although not yet available, research on how regional deprivation and socioeconomic factors influence acceptance, use and outcomes of early detection programmes could guide future improvements and targeted outreach. Educational outreach and social campaigns can be designed in culturally and linguistically congruent ways across populations to maximize their effects.

Similarly, efforts to increase awareness of and screening for pre-diabetes can lead to increased participation in evidence-based T2DM prevention programmes and eventually reduce the prevalence of T2DM. Evidence-based consensus guidelines from major diabetes mellitus organizations (such as the ADA, European Society for Paediatric Endocrinology and International Society for Paediatric and Adolescent Diabetes) inform clinical care and serve as a call to action to shape research priorities and advocate for policy change. For example, the ADA Standards of Care section entitled 'Improving Care and Promoting Health in Populations' discusses the importance of tailoring treatment for social context and capturing SDOH as part of routine diabetes mellitus care⁶³. Public health agencies, such as the US Centers for Disease Control and Prevention and WHO, further drive policy change by capturing key epidemiological and cost data that determine funding and inform government priorities. Furthermore, patient and healthcare professional advocacy groups, such as Breakthrough T1D and IDF Europe, have a key role in raising awareness and shaping legislative priorities.

Access to quality care and the endocrine workforce

The balance of healthcare supply and demand reflects broader social, economic and policy conditions that directly affect the workforce, which is evident in the global shortages and uneven distribution of paediatric and adult endocrinologists that limit access to adequate care. The UN Sustainable Development Goals and the WHO Health Workforce 2030 strategy identified human resources for health as vital in providing universal health coverage worldwide. Globally, areas with the lowest densities of human resources for health are North Africa, sub-Saharan Africa, South Asia and the Middle East⁶⁴. The highest density of physicians is seen in central and eastern Europe and central Asia, with 38.3 physicians per 10,000 people, whereas sub-Saharan Africa has the lowest coverage, with 2.9 physicians per 10,000 people, which

equates to a 10-fold difference⁶⁴. In 2022, an [Association of American Medical Colleges Report](#) released projections of a shortage of physicians in the USA, ranging between 37,800 and 124,000 by 2034, both in primary and specialty care⁶⁵.

Furthermore, the geographic distribution of adult endocrinologists to patients needing endocrine care is often mismatched, with the fewest endocrinologists available in rural areas⁶⁶. In the USA, as of 2020, there are 1.8 paediatric endocrinologists per 100,000 children⁶⁷. Distance to travel to a paediatric endocrinologist can range from 5.3 miles in Rhode Island, USA, to 132.4 miles in North Dakota, USA, with an average driving distance of 20.4 miles for patients in the USA⁶⁸. As paediatric diabetes mellitus rates rise, particularly among youth from minoritized communities, there is a critical need for more paediatric endocrine physicians who reflect the racial, ethnic and geographic diversity of the populations they serve. Although there has been an increase in paediatric endocrine trainees from historically minoritized populations, the workforce is still not reflective of census data in the USA; for example, 5.5% of 2018 fellows identified as Black versus 13.5% of people identifying as Black in the USA census⁶⁹. Similar workforce capacity limitations exist for the growing population of adult individuals with T1DM and those with T2DM requiring specialty management. Although ethnic and racial concordance between patients and providers is not essential for high-quality care, it has been associated with improved medication adherence⁷⁰.

Tactics to attract future endocrinologists include incentive loan-forgiveness programmes, with two examples from the USA being the Paediatric Subspecialty Loan Repayment Program⁶⁹ and the Health Resources & Services Administration National Health Service Corps, which includes a programme specific to providers working in rural communities. For LMICs, programmes such as the Paediatric Endocrinology Training Center for Africa improved access to quality healthcare by educating paediatricians in paediatric endocrinology; between 2008 and 2015, the programme trained 54 fellows in 12 African countries, which led to improvements in screening for diabetes mellitus and obesity-associated disorders⁷¹.

Electronic consultations (eConsults) are virtual communications between primary care providers and subspecialists that occur without the patient being physically present. These consultations offer a promising solution to the limited availability of in-person endocrinology appointments. By allowing specialists to provide guidance remotely, eConsults help ensure that clinic visits are reserved for patients who truly require face-to-face evaluation, improving access and efficiency in specialty care. This approach enables endocrinologists to assess urgency and determine necessity, so they can triage referrals accordingly⁷². Telehealth for education on diabetes mellitus self-management and clinical support can complement in-person visits to optimize glycaemic management^{73–76}. This use of telehealth is safe in people with diabetes mellitus living in rural areas or areas of low diabetes mellitus prevalence, in individuals with suboptimal glycaemic control, and in those requiring flexibility due to scheduling conflicts^{73–76}. A systematic review and meta-analysis found that telemedicine reduced HbA_{1c} levels and improved glucose self-monitoring in children and adolescents with diabetes mellitus⁷⁷, and telehealth has been used successfully in school settings to reduce demands on the family and to use school-based internet access⁷⁸. Access to telehealth is challenged by a lack of access to high-speed internet, which disproportionately affects people in rural areas⁷⁹, and a lack of privacy for individuals living in overcrowded or multigenerational homes⁸⁰. Policies and funding initiatives, such as the US Federal Government's [Internet for All](#) initiative

by the National Telecommunications and Information Administration, can help address some of these inequities.

Telehealth services require clinical infrastructure and resources; these services, especially for technology support and education in diabetes mellitus, are not always reimbursed by insurers and might strain health systems. To ensure the continued use of widespread telemedicine options, public policy of government-funded health insurance would need to guarantee adequate oversight and reimbursement. Though high-visibility, high-impact programmes that streamline state-to-state variability in regulations and provide reasonable reimbursement for telehealth services are still lacking, progress in the USA includes creation of the [HRSA Office for the Advancement of Telehealth](#) and the [Department of Health and Human Services Telehealth](#) website that provides information for patients, physicians and clinics. A meta-analysis of systematic reviews of interventions using telemedicine to deliver diabetes mellitus care in LMICs noted a mean HbA_{1c} reduction of 0.38%, with the highest yield noted in interventions that used telephone and short message services⁸¹. Telemedicine has been successfully integrated into national health systems to support diabetes mellitus care in countries such as Australia and Canada. Studies from these regions demonstrate that virtual platforms and remote monitoring tools can improve access, support self-management and maintain glycaemic control among patients with diabetes mellitus, particularly during periods of healthcare disruption^{82,83}.

Artificial intelligence

Artificial intelligence has already begun to revolutionize the business and education industries and will drastically change the practice of medicine in the coming years. In 2025, artificial intelligence tools can support clinicians with diagnostics, clinical decision-making, personalized and precision medicine, drug discovery and development, remote monitoring and telehealth, operational efficiency, patient engagement and health literacy, and public health and epidemiology. As deeper integration occurs, artificial intelligence systems that not only assist clinicians but also co-design treatment strategies in partnership with clinicians and patients have the potential for advancing clinical care in all areas of medicine, including diabetes mellitus. Artificial intelligence applications in development or early adoption include prediction models for glycaemic management that can be applied to insulin-dose and insulin pump decision support for individuals in the outpatient setting⁸⁴ or by clinicians in the hospital setting⁸⁵; prediction and detection of diabetes mellitus comorbidities, including retinopathy⁸⁶ and diabetic foot ulcers⁸⁷; self-management of diabetes mellitus⁸⁸; development of diabetes mellitus medications⁸⁹; and even prediction of future diabetes mellitus burden in a population⁹⁰.

Artificial intelligence has the potential to advance equity in diabetes mellitus by expanding access to high-quality care, which is currently limited by workforce capacity, geographic location and human bias. For example, as artificial intelligence tools for glycaemic management are adopted, insulin dosing adjustment and insulin pump use might become available for people who do not have access to endocrinology specialists. Similarly, artificial intelligence tools to diagnose retinopathy and diabetic foot ulcers that use smartphone cameras will increase access to early diagnosis and treatment. As the use of wearable monitoring devices expands, including continuous glucose monitors, artificial intelligence tools will be able to provide individualized support for the self-management of diabetes mellitus, which could be developed to consider SDOH and to reflect specific population preferences and needs. Artificial intelligence tools

could also be tailored to connect individuals to local resources and to address social needs.

Although artificial intelligence holds great promise in advancing diabetes mellitus care, there is also a notable risk that artificial intelligence applications could perpetuate disparities in diabetes mellitus and other areas of medicine. In a secondary analysis of articles included in a review of artificial intelligence tools for diabetes mellitus management and decision support, only 10 of 141 articles (most from the USA, with one from the Netherlands) reported the ethnic or racial backgrounds of participants, and only two articles reported inclusion of Native American participants⁹¹. Ongoing efforts will need to focus on ensuring that artificial intelligence models are trained using high-quality data that is unbiased and representative of communities at the highest risk of poor health outcomes. Community members need to be included in the development of artificial intelligence tools to ensure that they serve their intended purpose and do not increase inequities.

Care quality standards

Equitable clinical care standards and clinical practice guidelines (CPGs) are essential to ensuring that all populations receive high-quality healthcare services. These guidelines, particularly those endorsed by large medical professional groups, such as the Endocrine Society, ADA, the International Society for Pediatric Endocrinology, the WHO and IDF, inform clinical decision-making and set standards of practice for providers caring for individuals. These CPGs are typically written by subject experts and can decrease health disparities by facilitating standardized care. Conversely, CPGs can perpetuate health disparities when they endorse race-biased practices or do not sufficiently consider equity in the guideline development and implementation phases⁹². Inclusion of patient representatives and/or health equity experts in CPG writing teams could facilitate the development of CPGs that improve diabetes mellitus care for all populations.

Race-based diabetes mellitus screening and T1DM diagnosis tools can increase disparities in timely diagnosis and early management. In the USA, people from minoritized populations are more likely to present with DKA³⁹ at T1DM onset than NHW people. Misdiagnosis of T1DM as T2DM and initiation of non-insulin therapies are also more likely among minoritized populations^{93,94}. Although these disparities are probably multifactorial, resulting from implicit bias of providers, disease heterogeneity, phenotypic overlap with T2DM and/or an inadequately binary classification system of diabetes mellitus type⁹⁵, they are also perpetuated by current diabetes mellitus screening practices guided by CPGs. For instance, the current ADA recommendations for diabetes mellitus screening and for investigation of suspected T1DM in newly diagnosed adults include 'non-white race and ethnicity' as a risk factor for T2DM and as a possible exclusion factor for diagnosis of T1DM⁹⁶. This practice of using race and/or ethnicity as a risk factor for T2DM and exclusion factor for T1DM fails to inform our understanding of the complex interplay of structural conditions that increase the risk of T2DM, and perpetuates the erroneous use of race and/or ethnicity as a biological, rather than sociological, construct. Furthermore, by minimizing the need to screen for social factors, race-based screening threatens to limit progress towards rectifying addressable risk factors, including inadequate access to quality healthcare, food insecurity, poor mental health, language barriers, disparities in education level, and physical inactivity due to lack of access to safe, walkable neighbourhoods and parks, which are conditions tied to structural racism⁹⁷.

A major limitation of CPGs used for the identification of T1DM risk factors and for T1DM diagnosis is a dearth of data for minoritized

populations. The natural history of T1DM progression has been characterized through international decades-long prospective cohort studies of people born with a specific genetic marker (high-risk HLA haplotype)^{98–101} or in those with a first-degree or second-degree relative with T1DM^{102–104}. These foundational studies of T1DM risk and progression have been conducted nearly exclusively with participants of European ancestry residing in well-resourced countries but now inform recommendations for islet auto-antibody screening and monitoring in all individuals with early-stage T1DM¹⁰⁵. Screening and monitoring of early T1DM considerably reduces the prevalence of DKA at T1DM onset^{60,106,107} and identifies individuals eligible for teplizumab (the first disease-modifying therapy approved to delay progression to T1DM)¹⁰⁸ and those who might be eligible to participate in active clinical trials to delay or prevent T1DM¹⁰⁵. In the USA, minoritized populations have lower overall participation in T1DM screening trials and were more likely to be lost to follow-up for monitoring of disease progression than NHW people¹⁰⁹, which means that minoritized populations remain at higher risk of DKA at diagnosis and do not receive the potential benefits of teplizumab and clinical research participation.

Access to clinical care and advanced technologies

Despite advances in the tools and medications available for the management of both T1DM and T2DM, access to these advances has been inequitable, with particularly low uptake among individuals from minoritized groups. Advanced diabetes mellitus technologies, including continuous glucose monitors and insulin pump delivery systems, have been proven to improve glycaemic control and reduce disease burden¹¹⁰. However, large disparities exist in access to and use of these tools that adversely affect patients from minoritized groups¹¹¹. In the USA, NHW people are nearly four times more likely than Black people and two times more likely than Hispanic people to be using an insulin pump for T1DM management, and this disparity persists when controlling for socioeconomic status¹¹².

Beyond race and ethnicity, individuals with other less protective SDOH factors, such as lack of insurance, inadequate public insurance, low educational attainment and low household income, also have reduced use of advanced technologies and medications, which is associated with worse glycaemic control^{113–115}. Among providers, implicit bias in recommending advanced technologies promotes disparities in diabetes mellitus technology use^{116,117}. When studied, there has been high patient acceptance and perceived benefit from continuous glucose monitoring technology across races and ethnicities^{118,119}, which suggests the presence of extrinsic barriers to access. Despite an exponential increase in the use of mobile phones in sub-Saharan regions, internet use is still low, which leads to low uptake of technologies such as continuous glucose monitors and automated insulin pumps, or even telehealth¹⁹. Along with aid from individual countries, the World Bank, WHO, United Nations and philanthropic organizations are working on economic development and funding diabetes mellitus care by facilitating international collaboration and improvements in health infrastructure^{5,120–123}.

Similar racial disparities are observed in prescription rates for the new classes of diabetes mellitus medications such as sodium–glucose cotransporter 2 inhibitors and glucagon-like peptide 1 receptor agonists¹²⁴. These medications have revolutionized T2DM management, demonstrating high glucose-lowering effects and weight loss, renal protection, and cardioprotective effects¹²⁵. These classes of medications are now recommended as first-line treatments for some people with T2DM; however, use rates among minoritized populations have remained low^{124,126}.

Expanded access to health insurance coverage improves diabetes mellitus outcomes in individuals from low-income areas. In the USA, the Affordable Care Act (enacted in 2010) enabled individual states to expand Medicaid access. After Medicaid expansions in Texas and Arkansas, there was a decrease in the incidence of hospitalizations for DKA, especially among patients from low-income areas¹²⁷. Other interventions, such as lowering the cost of co-payments for drugs, can also have a positive effect on medication adherence. For instance, in Wisconsin, a change in Medicaid coverage to reduce drug co-payments and place caps on out-of-pocket spending improved adherence to oral diabetes mellitus medications in adults¹²⁸.

Community health worker teams can partner with healthcare organizations and clinics to help patients navigate complex health systems and identify community resources; sustained efforts will require institutional support and reimbursement from insurers. Systemic-level improvements in reducing barriers to prescribing and providing federal-based and state-based insurance coverage, along with local-level targeted quality improvement projects involving modalities such as tailored quality improvement, electronic health record monitoring, clinical education and community engagement, and which consider stakeholder-defined barriers, can result in improved equitable access to diabetes mellitus technologies and medications¹²⁹.

Research

Systemic approaches to tailor interventions for minoritized populations must include a critical look at current research practices, which often exclude patients facing health disparities. Published in 2024, a review of high-impact T2DM pharmacotherapy clinical trials from around the world over the past 20 years found that only 24% of all participants were from racial and/or ethnic minority groups despite the disproportionately high burden of T2DM in those groups¹³⁰. Globally, transformative advanced clinical trials of diabetes mellitus technology in T1DM have similarly enrolled non-representative and homogeneous populations, with nearly 85% of those enrolled being NHW, and only 6% identifying as Hispanic and 2.2% identifying as Black¹³¹. Furthermore, most participants in diabetes mellitus technology trials had private insurance and high educational levels¹³². Similarly, disease-modifying therapeutic clinical trials in people with T1DM have overwhelmingly included NHW people living in high-resourced countries^{133–137}. Although no immunotherapy has shown sustained efficacy in T1DM, subset analyses suggest that baseline factors, such as age, islet auto-antibody profile and HLA haplotype, might distinguish people who are likely to respond well from those who are less likely to respond, which indicates that distinct disease endotypes might be present¹³⁸. These endotypes probably reflect heterogeneous immunobiological mechanisms underlying T1DM and might inform precision medicine approaches; however, validation in diverse cohorts is needed to ensure generalizability. Few clinical trials have involved youth with T2DM, and those that are available have eligibility criteria that limit enrolment¹³⁹.

Many studies require the participant to speak the majority language for a given country and only provide study materials in that language. SDOH interact negatively with study exclusionary criteria, which leads to underrepresentation of the most in-need individuals and contributes to inherent systems bias¹⁴⁰. People excluded from trials often have a specific set of health-related social vulnerabilities that are not captured in current research studies, which means that ‘gold-standard’ interventions are likely to fail when applied to all patients. The Feel4Diabetes study, performed in six European countries, noted that sociodemographic factors were important in determining which participants

completed the school-based programme interventions for youth at risk of T2DM¹⁴¹. The Diabetes in Children, Adolescents and Young Adults (DiCAYA) Network, composed of eight diabetes mellitus centres across the USA, uses electronic health records to identify the prevalence of T1DM and T2DM in youth and develop further understanding of phenotypes¹⁴². Databases of electronic health records can help identify cohorts of patients within specific communities who might benefit from targeted interventions. Expanding this approach to include SDOH data could inform community-based strategies and guide policy development at local, state and federal levels.

Difficulties engaging diverse research participants are not unique to diabetes mellitus research; in the USA, the **NIH Inclusion Policy** adheres to federally mandated requirements for the inclusion of diverse participants in NIH-funded research, requiring proposals to describe the planned composition of the targeted study population by sex, race, and ethnicity and to describe planned outreach strategies to recruit and retain that population. Industry-sponsored studies and agencies in many other countries do not have similar policies in place, which might contribute to the lower levels of diversity in industry-sponsored diabetes mellitus trials versus those funded by the NIH¹³⁰. Industry could be held to similar standards as NIH-funded trials, in which proportional representation of participants affected by diabetes mellitus by race and/or ethnicity is mandated or strongly recommended, driving more intentional study design and site selection, hiring of more diverse study staff, and promoting community engagement. Regulatory agencies, such as the US Food and Drug Administration or the European Medicines Agency, might hold considerable sway in driving such industry mandates.

Strategies to optimize recruitment and retention of under-represented groups into studies require a deep examination of current research practices and acknowledgement of the historical and justified mistrust many minoritized groups hold for the medical and research community. Efforts must be made to reduce barriers and facilitate participation. Research materials should be provided in non-majority languages, and study teams should be linguistically and culturally congruent with the targeted populations. Whenever possible, research locations should be expanded beyond large academic centres and into trusted community clinics to enable easier access, reduce transportation burden and promote a sense of local investment with community partners. To reduce logistical barriers for participants, study designs should include flexibility in data collection, consideration for digital and remote options, and flexibility in study visits to minimize conflicts with rigid work schedules. Currently, many of these strategies remain untested or require further study, but early initiatives have shown success in recruiting and retaining more diverse paediatric participants with diabetes mellitus^{143,144} by using culturally and linguistically congruent research staff, maintaining flexibility in recruitment practices and approaching eligible participants in a clinic setting^{144,145}.

Community partners in care delivery and research also matter. Not-for-profit organizations have considerable experience working with both professional and lay communities and can influence their networks. Industry should embed its own research and post-marketing surveillance with SDOH variables and partner with healthcare professional organizations and the public health sector to examine this information with the goal of improving care. Insurance companies can explore partnerships with community organizations, receiving feedback regarding coverage and development of programmes. Collaborative learning professional organizations, such as the T1D Exchange and the T2D Exchange, can continue to leverage not only professional

knowledge and deep commitment to improving outcomes of care but also a more representative sample of research participants and testing of quality outcomes for varied populations.

Intermediate factors and approaches

Food insecurity

Food insecurity affects nearly 20% of the population of the USA^{146,147}, with racial and/or ethnic minority groups experiencing even higher rates. Individuals facing food insecurity might rely on inexpensive carbohydrate-rich processed foods and might also lack financial resources for consistent access to insulin and diabetes mellitus supplies. Levels of food insecurity might be even higher in LMICs, especially in areas experiencing political or climate-related turmoil. Food insecurity is associated with decreased adherence to self-care and medications, depression, diabetes mellitus distress and worse glycaemic outcomes^{148–150}. In a study of youth and young adults in the USA, 17.7% of those with T1DM and 30.7% of those with T2DM reported household food insecurity, with a higher proportion being Black or Hispanic compared with the overall survey group¹⁵¹. Among participants with T1DM, high food insecurity was associated with higher levels of HbA_{1c}, more episodes of DKA and more occurrences of severe hypoglycaemia compared with those who reported food security¹⁵². Additionally, the participants experiencing food insecurity were less likely to use diabetes mellitus-related technologies¹⁵³.

Globally, food insecurity is assessed using the Food Insecurity Experience Scale, which was created by the Food and Agriculture Organization and focuses on availability, access, utilization, stability, sustainability and agency. Using this measure, it is estimated that 2.33 billion people worldwide were affected with moderate to severe food insecurity in 2023 (ref. 154). In the USA, food insecurity can be assessed with a validated two-item screening tool called Hunger vital-sign, which is available in English and Spanish¹⁵⁵, and enables referral to community resources, providing important insight into challenges faced by the patient and family. Universal screening for food insecurity in diabetes mellitus clinics, coupled with system-wide investment in national and community-based nutrition support programmes, might help mitigate its effect on diabetes mellitus outcomes. The Academy of Nutrition and Dietetics lists several approaches, including connecting individuals with high food insecurity to available benefits, incentive programmes to encourage purchasing of nutritious foods, increased access to fresh produce in lower-income communities, farm-to-school or higher-education institution programmes, redistribution of recovered food, and continued advocacy for funding of safety-net programmes¹⁵⁶. Addressing food deserts at the community level and developing food prescription programmes are promising interventions in reducing food insecurity¹⁵⁷.

Geographic and economic displacement: migrant and refugee persons

In a host country, fluctuations in the numbers of immigrant and refugee persons might alter the populations accessing healthcare services and could require rapid adoption of a health system to address the needs of culturally and linguistically distinct individuals. Using the USA as an example, there were 46.2 million foreign-born people in the USA in 2022, an increase from 40 million in 2010 (according to the United States Census Bureau Report¹⁵⁸). Those entering the USA without proper documentation might have access to a patchwork system of safety-net providers, including public and not-for-profit hospitals, federally qualified community health centres, and migrant health

centres, where care for chronic conditions such as diabetes mellitus might be challenging¹⁵⁹. Laws such as those in Florida and Texas that require a person to declare their immigration status upon engaging with health institutions can be deterrents to accessing healthcare as discussed in a 2024 KFF Issue Brief¹⁶⁰. From 2011 to 2018, the National Health and Nutrition Examination Survey reported that foreign-born persons in the USA have higher rates of undiagnosed diabetes mellitus than those who were born in the USA, and almost all minoritized populations had a higher prevalence of diagnosed and undiagnosed diabetes mellitus than NHW people¹⁶¹.

Humanitarian crises in LMICs, driven by climate change and armed conflict, present considerable challenges to delivering adequate diabetes mellitus care for forcibly displaced populations. These challenges include limited access to insulin and essential medications, food insecurity, insufficient healthcare provider training, restricted access to healthcare owing to security concerns, and poor integration into existing healthcare systems. Addressing these concerns requires a comprehensive and integrated model, including data collection, food assistance policies, stockpiling of medications, community-level programming and implementation of operational guidelines^{162,163}. Migrant populations moving from areas of low to high T1DM prevalence acquire and/or exceed the T1DM risk of their new community within a generation, placing considerable demand on individuals with unfavourable SDOH factors in navigating complex healthcare needs^{164,165}.

Migrant and refugee youth from resource-limited countries often face socioeconomic hardship and health challenges in resettlement, including language barriers, low parental education, trauma, and cultural or religious factors, such as dietary practices and health beliefs, that might influence patient-provider trust and adherence to medical care. Given these barriers, migrant and refugee persons have less favourable glycaemic control, lower levels of physical activity, less use of advanced diabetes mellitus technology and increased diabetes-related hospitalization rates compared with the rest of the population^{166,167}. Although CPGs recommend culturally sensitive and patient-centred T1DM education^{168,169}, little has been published on how to deliver such care. However, several small pilot studies have been published to help inform further efforts^{170,171}. Culturally congruent patient navigators or community health workers, who are often trusted members of migrant communities, can successfully provide language-concordant support that is mindful of cultural differences that might affect diabetes mellitus management¹⁶⁸. For example, the [Migrant Clinicians Network's Project ECHO](#) is an innovative learning and knowledge-sharing platform that helps build specialty care capacity in the primary care model through a series of free web-based conferences for providers.

In Minnesota, USA, which is home to a large Somali immigrant population, paediatric diabetes mellitus providers sought to improve health outcomes among Somali immigrants by hosting focus groups at a Somali community centre with the goal of uncovering factors specific or unique to the Somali population and creating effective and culturally sensitive diabetes mellitus educational materials¹⁷¹. This effort improved diabetes mellitus care, and can be used as a template for tailoring education in specific immigrant or minority populations.

Community networks

Community and connectiveness promote health in those with T1DM; conversely, a lack of social support is associated with worse health outcomes⁴. Community partners, such as community health workers,

peer supporters and community leaders, can be effective in delivering diabetes mellitus self-management and education services and improving social cohesion, especially in underserved communities¹⁷². Informed community engagement and culturally sensitive care delivery can be strengthened through bidirectional partnerships with healthcare providers.

Traditionally, residential diabetes mellitus camps have acted as a key social support for youth with T1DM in the USA and elsewhere¹⁷³. Attending a diabetes mellitus camp increases diabetes mellitus-related knowledge, glycaemic control and psychological functioning^{174,175}. Minoritized youth with T1DM are grossly under-represented in these camps¹⁷⁶. Identifying and targeting barriers to minority youth participation at residential and day camps would improve access to these services. On the basis of a survey of children and caregivers regarding barriers to attending diabetes mellitus camps, the authors suggested that actions of promoting awareness (using social media and other tactics), assisting with transportation and funding scholarships would help diversify camp participation¹⁷⁷. However, more work is needed to build bidirectional trust and engagement.

Support from community health workers in combination with the use of evidence-based lifestyle and chronic disease interventions is a powerful approach for decreasing diabetes mellitus disparities that affect minoritized adult populations. Interventions such as the National Diabetes Prevention Program and the Diabetes Self-Management Education and Support have been adapted for community-based delivery by community health workers. Community-based programmes enable culturally and linguistically appropriate service delivery, addressing common social barriers, including lack of transportation to clinical settings, limited English proficiency and low trust in the healthcare system, and make it possible to tailor interventions to the cultural practices of participants. A systematic review of the literature that was published in 2017 reported that diabetes mellitus prevention programmes are moderately effective in reducing diabetes mellitus risk among Hispanic adults in the USA¹⁷⁸; however, more studies are needed that use a randomized controlled design, include men and assess the effectiveness of specific cultural adaptations. Less is known about the effectiveness of diabetes mellitus prevention programmes culturally tailored for African American adults, but the limited literature suggests suboptimal effectiveness of the National Diabetes Prevention Program adaptations for this population, and few studies include African American men^{178,179}.

Conclusions

Current interventions to address T1DM and T2DM in both adult and paediatric populations often fail to engage minoritized populations, including certain racial and/or ethnic groups, migrant populations, and rural communities. Consistently using tools to identify SDOH factors in our patient populations is the first step in identifying strategies to mitigate their negative effects on diabetes mellitus care. Focusing on distal (system-level) and intermediate (community-level) interventions can enable wide-ranging effects of even small changes and innovations. Methods of screening and diagnostic testing need to be able to identify persons with diabetes mellitus, regardless of race and/or ethnicity. Initial and ongoing medical care, interventions and education should reflect the specific needs of the population being addressed. Furthermore, members of the community to be engaged should have a key role in the development and implementation of these interventions. In addition, the development of continuous improvement feedback loops should involve the community itself.

Finally, we must not understate the importance of involvement by local, regional and national governments in decreasing the barriers to equitable care. Incentivizing hospitals and other care partners and prioritizing fair reimbursement for care provided by healthcare professionals to people with chronic conditions such as diabetes mellitus could address the shortage of physicians and other healthcare professionals available to care for all people with diabetes mellitus globally (Fig. 2).

To achieve accessible, cost-effective and quality healthcare for minoritized people with diabetes mellitus, we need to cross-train the community, industry and professional sectors in methods of understanding policy and engaging with local, regional and national lawmakers to provide accurate and timely information about the care needs of people with diabetes mellitus and the specific and varied interventions that can be considered. Working through these channels simultaneously should move us closer to the goal of equitable care for all.

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Competing interests

The authors declare no competing interests.

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