



Global challenges in diabetes research and care: which way forward? An appraisal from the EASD Global Council

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Abstract

This review article, developed by the EASD Global Council, addresses the growing global challenges in diabetes research and care, highlighting the rising prevalence of diabetes, the increasing complexity of its management and the need for a coordinated international response. With regard to research, disparities in funding and infrastructure between high-income countries and low- and middle-income countries (LMICs) are discussed. The under-representation of LMIC populations in clinical trials, challenges in conducting large-scale research projects, and the ethical and legal complexities of artificial intelligence integration are also considered as specific issues. The development of global research networks and strategies for improved training, standardisation of data and enhanced accessibility to big data analytics to drive innovation and personalised medicine are recommended. With regard to diabetes care, inequalities in access to essential medications, particularly insulin and novel therapies, and disparities in healthcare infrastructure are discussed. Proposed initiatives include international support programmes, improved healthcare provider training and the inclusion of newer diabetes medications in essential drug lists. The importance of global screening programmes, a universal diabetes education curriculum and standardised healthcare checklists is also emphasised. Regarding healthcare organisation, the development of national diabetes registers, benchmarking performance across regions and strengthening international collaborations are highly advised. The role of diabetes specialists as care coordinators and the need for structured assessments to improve early intervention and long-term outcomes are also discussed. Ultimately, the EASD Global Council urges action for a unified, global approach to diabetes research and care to bridge the gap between scientific innovation and clinical practice, ensuring equitable healthcare worldwide.

Keywords Artificial intelligence · Big data · Clinical trials · Diabetes · Diabetes registers · Digital health · Education and training · Equity, diversity and inclusion · Health systems · Low- and middle-income countries · Personalised medicine · Review

Abbreviations

AI	Artificial intelligence
CGM	Continuous glucose monitoring
CKD	Chronic kidney disease
CRO	Contract research organisation
DSMES	Diabetes self-management education and support
EHR	Electronic health record
GLP-1	Glucagon-like peptide-1
HICs	High-income countries
LDL-C	LDL-cholesterol
LMICs	Low- and middle-income countries

NHS	National Health Service
SGLT2	Sodium–glucose cotransporter 2

Introduction

Diabetes mellitus is one of the most pressing global health challenges of our time, demanding a coordinated, multidisciplinary and multisectoral response through research, prevention and care. The number of people living with diabetes has been rising over recent decades. At the same time, the methods used to understand diabetes pathophysiology and advance management are rapidly evolving, encompassing novel technologies and new medications [1]. This dynamic calls for a global approach to align all efforts to maximise

synergism and impacts. All prior predictions have significantly underestimated the rate at which the number of people living with diabetes has grown [2, 3]. In this global crisis, the increase in diabetes incidence is observed in all age groups, from infants to the elderly. This diversity in population attributes and settings calls for a proactive, context-relevant and sustainable strategy targeting society, community and individuals [4].

A particular challenge is the considerable heterogeneity in pathophysiological and clinical presentations of diabetes. Traditionally, diabetes has been classified as type 1 or type 2, with type 1 characterised by autoimmune destruction of pancreatic beta cells and type 2 marked by progressive beta cell dysfunction, frequently combined with insulin resistance [5]. However, emerging research has revealed additional subtypes and clinical/pathophysiological phenotypes resulting from genetic, environmental and lifestyle factors, further influenced by social determinants of health and access to care, posing challenges in developing standardised treatment protocols and necessitating personalised therapeutic approaches to address the varied manifestations effectively [6, 7].

These clinical challenges are compounded by the inequitable distribution of resources dedicated to diabetes research and care on a global scale. High-income countries (HICs) often benefit from robust healthcare systems, advanced research infrastructure and substantial investments in comprehensive diabetes management programmes. In contrast, low- and middle-income countries (LMICs) frequently face significant obstacles, such as insufficient funding for research programmes, limited access to essential medications and shortages of trained researchers and healthcare and research personnel [3, 8].

The EASD has long had an impact beyond European borders, embracing scientific and educational activities in various regions worldwide. This has recently inspired the establishment of a Global Council (<https://www.easd.org/about-easd/global-council/>) consisting of 12 representatives from five continents, ensuring global representation, and chaired by the EASD Senior Vice-President. The ambition is to combine, format, stimulate, streamline and eventually strengthen individual and global efforts to combat diabetes and its epidemic across the globe, bridging gaps between scientific innovation and clinical practice.

The aim of this review is to identify the most urgent challenges and needs in diabetes research and care in terms of basic and clinical research, clinical care and care organisation, and to recommend specific actions that consider local and international diabetes communities. This review was developed by the EASD Global Council following identification of global challenges in diabetes research, care and organisation during a face-to-face meeting on 8 September 2024 at the EASD Annual Meeting in Madrid, Spain. The

discussion was developed over the course of three online meetings, culminating in agreement on a final document. Specific challenges and proposed ‘ways forward’ were identified by three dedicated working groups (focused, respectively, on diabetes research, care and organisation), each composed of members of the EASD Global Council selected based on their predominant scientific expertise (e.g. basic vs clinical). The resulting proposals were subsequently reviewed and approved during a joint consensus phase.

Global challenges in diabetes research

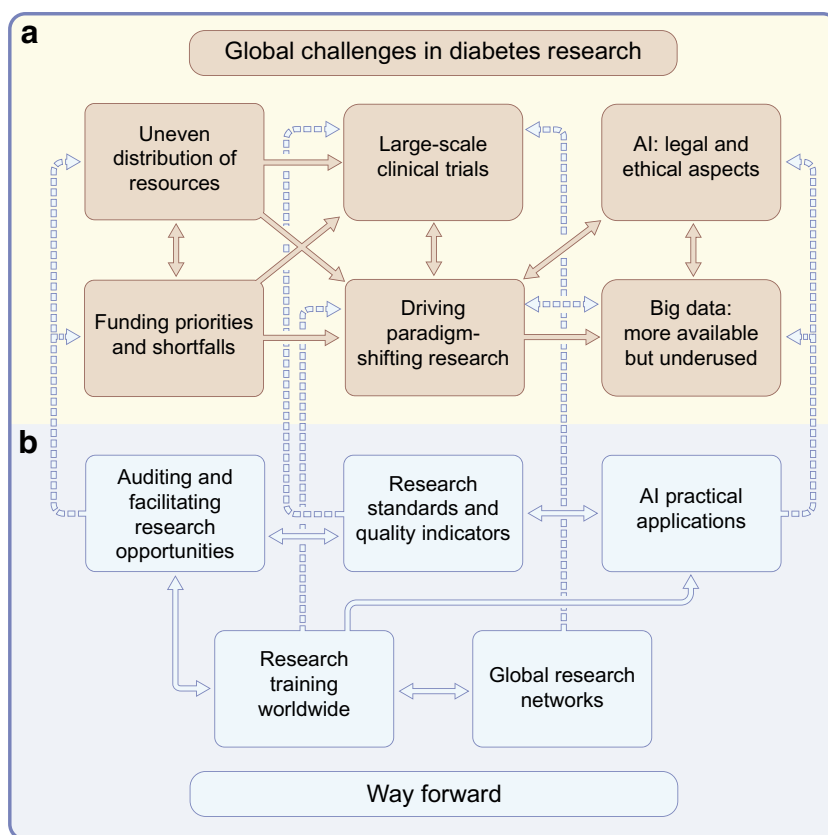
Uneven distribution of resources Infrastructure and funding disparities exist between HICs and LMICs [8]. Currently, 75% of people with diabetes live in LMICs, from South and South-East Asia to the Middle East and North Africa, Latin America and the Caribbean, and these countries are projected to have the highest increases in diabetes burden up to 2050 [3, 9]. Yet, research, and the capacity to conduct it, are concentrated in HICs, where access to infrastructure and regionally accessible pharmaceutical and biotech industry partners is most concentrated. Indeed, an analysis of clinical trial data for 2006–2012 from ClinicalTrials.gov found that 83% of trials were conducted in HICs while only 5% were conducted in LMICs [10].

Global disparities in research also lead to an underrepresentation of data from LMICs, which limits insights into disease diversity and the global applicability of solutions [11, 12] (Fig. 1). Regional disparities also undermine research priorities and restrain the capabilities of individual researchers, especially in LMICs [13, 14]. As a result, HICs may benefit more from research outcomes than regions with the highest diabetes burdens. Globally, there is a need to recognise the diversity among countries and strengthen efforts to promote access to research, knowledge and care in areas that need them most. That said, efforts over recent decades have had an impact on global barriers, for example mandates on open access have made science more accessible to underserved regions [15]. Such initiatives may help to level the research playing field.

Challenges in conducting large-scale clinical trials Conducting large-scale international clinical trials is a complex task with operational and regulatory challenges [16]. However, expanding the geographical footprint of clinical trials is necessary to capture diverse populations and increase the generalisability of research, particularly when recruitment presents challenges, for example in trials of rare conditions [16].

Regulatory heterogeneity, infrastructural inadequacies, public illiteracy and mistrust of science, and cultural differences are common challenges when clinical trials go global (Fig. 1). Global contract research organisations (CROs) can

Fig. 1 Global challenges in diabetes research and the proposed way forward. From basic science to population health, diabetes research faces global challenges (a). These include resource disparities, funding shortfalls, regulatory hurdles and others. Proposed strategies for the way forward include adoption of research standards, quality indicators and artificial intelligence (AI) practical applications and implementation of research training worldwide and global research networks (b). Dotted and solid lines represent potential and existing connections among different items, respectively. This figure is available as part of a [downloadable slideset](#)



address regulatory challenges and monitor standardisation and maintenance of data integrity [17, 18]. However, global CROs cannot address all cultural or societal factors, such as negative public perceptions of clinical research, making recruiting and retaining participants more challenging. A systematic review showed that clinical trials conducted in under-resourced settings face several barriers that affect participant retention rates compared with well-established centres [19].

The Organisation for Economic Co-operation and Development (OECD) Global Science Forum (GSF) initiative (<https://www.oecd.org/en/networks/global-science-forum.html>) supports countries to improve science policies and share the benefits of international collaboration. Related to the GSF, the Clinical Research Initiative for Global Health (CRIGH) is a partnership of research institutions and organisations that works to establish a framework for international cooperation in non-commercial trials and to promote evidence-based medicine [18, 20]. Advances such as telemedicine and remote site monitoring have also decentralised the day-to-day running of trials, making them more accessible to under-resourced regions. The ABILITY trial (NCT04236609) is one successful example of a global diabetes trial, with 100 investigational centres distributed over 20 countries in Europe, Asia, Australia and Latin America. In this trial, the global CRO's role spanned set-up activities, monitoring, project

management, safety and clinical reporting, among others [21].

Barriers to driving a paradigm shift in research The evolution of omics technologies, and their increased adoption, has transformed our understanding of diabetes. The market size of omics-based trials is increasing and is estimated to rise to US\$70.9 billion by 2034 [22]. Oncology is leading the way in using omics approaches, with the identification of cancer hallmark mutations and incorporation of transcriptomes, proteomes and metabolomes data into pharmacological research [23]. However, success stories in diabetes have also emerged, with multi-omics leading to the discovery of early non-invasive biomarkers of kidney disease [24, 25] and helping to predict type 2 diabetes development [26] and the need for insulin therapy [27]. Omics continue to evolve with the addition of single-cell and spatial modalities that provide higher resolution than ever before. These efforts have generated large repositories and atlases with a wealth of accessible data [28–30]. These studies exemplify the scientific advances driven by multi-omics research but also highlight the persistent challenges in translating such findings into clinical practice, including regulatory, infrastructural and economic barriers.

While biotech and diagnostics industries are committed to the development of high-value diagnostic tools, new

therapeutic targets and personalised medicine approaches based on omics technologies are yet to deliver benefits to patients [31, 32]. Despite precision medicine resulting in the reclassification of diabetes endotypes, in an attempt to better represent disease heterogeneity and complications risk [6, 33, 34], discovery and validation alone of these tools will not guarantee uptake. To realise a paradigm shift that fully exploits the available technology, an adapted scientific, regulatory and funding structure is needed [32].

Balanced structures prioritising discovery-based science followed by industry-driven development may be ideal, depicting a space where innovation is driven by non-profit research. Implementation science could also be prioritised to establish research capacity and deliver improved healthcare in LMICs, addressing cost and infrastructure limitations, lack of trained personnel and bioinformatics support, and absence of tailored frameworks to integrate discoveries into public health interventions. Industry partners are increasingly recognising the value of this approach by pursuing cross-sector collaborations, including scientific partnerships with academic and government organisations [35, 36].

Big data: more available but underused Adoption of digital health technologies provides more layers of data per patient, ranging from electronic health records (EHRs) to data captured by wearables, although equity and access remain challenging (Fig. 1). This parallels the boom in omics and multiparametric research technologies [37, 38], with genomics alone estimated to surpass exabase scale in annual capacity by 2020 [39]. In many countries, EHRs aim to achieve national coverage, including data from devices such as continuous glucose monitors [40, 41]. Additional applications include crowdsourcing and citizen science data. Despite the sheer volume of data that can be accessed, a sizable portion remains underused by the global diabetes research community, with only a fraction of the collected digital health data effectively integrated into research protocols [42]. There is also underuse of data owing to a lack of standardisation and interoperability of physical or cloud infrastructures, further compounded by differences in regulatory and legal frameworks [43] and lack of incentives.

Big data analytics requires resources and expertise, which are often concentrated in HICs [44]. Resource-limited settings may not have the necessary infrastructure for big data analytics. Cloud computing services offer a solution if prerequisite internet access and competencies are available, as well as financial investment in platform subscriptions [45]. Legal and regulatory requirements must also be addressed so that data are accessible but individual privacy is maintained. Other considerations include standardisation and training initiatives [38]. A future where big data and digital health technologies are accessible and operable is within reach, particularly with the increasing availability of cloud

computing and artificial intelligence (AI) large language models, albeit with ongoing challenges of poor data quality and inadequate regulatory frameworks. Continuous glucose monitor data have been successfully used to refine the prediction of type 1 diabetes staging and develop data-driven glycaemic phenotypes associated with complication risk [34, 46] and sentiment analysis of crowdsourced data has been used to identify the socioeconomic concerns of people with diabetes [47]. However, although some diabetes applications synchronise with wearables to track physical activity, data are often siloed.

Legal and ethical aspects of AI integration AI has transformative potential in managing big data, predictive analytics and personalised care [41, 48]. However, such integration entails legal and ethical considerations (Fig. 1). According to European Commission guidelines, only a fraction of AI applications in healthcare currently meet criteria for transparency, accountability and fairness [49]. Key issues include data privacy, algorithmic bias and establishing clear lines of accountability for AI-driven decisions. In many jurisdictions, the legal infrastructure governing AI is nascent or non-existent [50], leading to uncertainty about the limits of its applicability, as the lack of infrastructure poses ethical, safety and public trust concerns.

Funding priorities and shortfalls Despite the escalating burden of diabetes, investment in diabetes research remains disproportionately low compared with investment in research into other chronic diseases [51]. For example, using data for 2022, the ADA reported that, while the economic impact of diabetes in the USA exceeds US\$400 billion annually [52], research funding has not kept pace. Similarly, data from the National Institutes of Health (2024) indicate that funding increases for diabetes research have averaged 2% annually, far outstripped by the approximate 10% annual increase in diabetes prevalence [51]. For comparison, while cancer has a similar prevalence to that of diabetes, the 2024 funds dedicated to diabetes research were sixfold lower than the funds allocated to cancer research [51].

Inadequate funding or funding models limit the scale and scope of studies at a global level [53] (Fig. 1). Some instruments from governmental agencies do exist to specifically support international collaborations, albeit with a very competitive entry point and geographical limitations based on bidirectional agreements [54, 55]. Currently, scientific societies and non-governmental funders are key in sustaining the global diabetes research ecosystem. A more agile funding model would address some of the challenges experienced. Less siloed funding would more readily allow international collaboration and drive capacity building in LMICs [56]. Building consortia from LMICs with revenue generation embedded from the planning phases and including training

for the next generations of scientists would ensure continuity [57, 58].

Moreover, serious concerns have recently been raised regarding actions taken by the US government, including withdrawal from international health agreements, censorship of essential scientific terminology, deletion of critical health datasets (termed ‘digital genocide’) and suppression of research involving vulnerable populations [59]. These actions risk undermining evidence-informed decision-making and disproportionately harming marginalised groups, warranting significant attention and heightened awareness.

Potential solutions to global challenges in diabetes research are summarised in the text box (‘Way forward for diabetes research’).

Way forward for diabetes research

- **Audit and facilitate research opportunities:** Audits should be carried out by governmental agencies in cooperation with non-governmental organisations and scientific societies to identify opportunities to improve infrastructure and training, resulting in allocation of resources to where they are most needed.
- **Define research standards and quality indicators:** Globally weighted standards and quality indicators should be developed to guide funding decisions and scientists, with the aim of being regionally sensitive and weighing rigour, reliability, gender balance and resources.
- **Develop global research networks:** Formal frameworks to exchange expertise, technology and data should be developed to facilitate collaborative studies and support training for the next generations of scientists, spanning income and development spectrums.
- **Improve research training worldwide:** Standalone or network-integrated training programmes should be developed to disseminate knowledge worldwide and address universal priorities in diabetes research, including technical aspects of omics, digital health, big data analytics and AI.
- **Enhance AI practical applications:** Data scientists, clinicians, policy makers and researchers should work collaboratively to make AI tools more robust, ethical, professional and regionally responsive, decentralising processing and lightening administrative and regulatory workloads.

Global challenges in diabetes care

Heterogeneous care settings There is significant heterogeneity in diabetes care across different national health systems. While highly developed healthcare infrastructures are common in HICs, with healthcare systems in these countries providing patients with insulin pumps, continuous glucose monitoring (CGM) devices and multidisciplinary care teams, LMICs are often under-resourced [60, 61]. Lack of trained personnel, irregular drug supplies and high treatment costs can all work against optimal and durable diabetes management in resource-stressed settings [62, 63]. In addition, individuals with diabetes are particularly vulnerable to environmental stressors, which are being exacerbated by climate change, including extreme heat, air pollution, natural disasters and disruptions to food systems, which can negatively impact glycaemic management, medication access and continuity of care, especially in low-resource settings. For instance, higher ambient temperatures have been associated with an increase in emergency visits for hyperglycaemia and heat-related complications in people with diabetes [64]. Air pollution has also been linked to an increased incidence of type 2 diabetes [65]. Moreover, as the incidence of natural and human-induced disasters rises globally, significant new risks emerge, particularly for people with diabetes who are dependent on insulin. Recent global crises such as the COVID-19 pandemic in India, the ongoing war in Ukraine and the conflict-related blockade in Ethiopia’s Tigray region have exposed critical vulnerabilities in healthcare systems’ capacity to sustain essential diabetes supplies during emergencies [66]. To overcome these barriers, a coordinated, multidisciplinary approach enhanced through international collaboration, technology and targeted policy interventions is needed. Potential solutions include global financing mechanisms, learning from the best, scaling access to technology, infrastructure development, and monitoring and evaluation of clinical indicators and outcomes [3, 67, 68]. For natural and human-induced disasters, effective strategies may involve stockpiling medical supplies, establishing supply chains that are resilient to disruptions and training healthcare workers to manage diabetes care under emergency conditions [66].

Inequities in access to insulin and novel medications Inequalities in insulin availability and access to treatment technologies pose significant challenges to treatment quality and quality of life. In non-European countries, humanitarian partnerships such as Life for a Child (<https://lifeforachild.org/>) have improved paediatric access to insulin, but adult care remains underfunded. In India, there are stark regional contrasts, with urban centres offering advanced care while rural areas face critical shortages of basic medications [3].

Significant problems persist in accessing insulin and newer therapies in LMICs, with high costs and limited

distribution networks. Opportunities for health workers to receive training on advanced therapies are also limited [69]. International efforts to alleviate costs and improve access remain fragmented. Recommendations include developing global subsidy programmes, reinventing the supply chain, improving healthcare provider training, including inclusion on the WHO Model List of Essential Medicines, fostering collaborations between governments, pharmaceutical companies and NGOs, and implementing targeted community programmes [70–74]. The addition of newer type 2 diabetes medicines on the WHO Model List of Essential Medicines will improve global access to these medications and, in turn, help to address unmet needs in diabetes care. A proposed list of essential medications in type 2 diabetes classified according to therapeutic class and key benefits is provided in Table 1.

Discrepancies in type 1 diabetes care Type 1 diabetes is a clinical scenario with multiple challenging interacting factors. In Europe, several countries provide coverage for advanced technology in insulin pumps, such as hybrid closed loop systems, while non-European countries often face limited access to modern diabetes care tools, with less than 10% of patients on insulin pumps owing to their high costs and limited distribution networks [75, 76].

The main roadblock in type 1 diabetes care is cost, which makes it virtually impossible for people in LMICs to access expensive technological items such as CGM systems and insulin pumps. Furthermore, modern healthcare services are sparse in rural or smaller communities. The lack of

skilled health workers and professional human relationships with respect to these technologies are other critical barriers. Potential solutions to ensure that life-empowering technologies are accessible to all individuals with type 1 diabetes include international partnerships, regional training in centres of excellence, government subsidies, targeted outreach programmes, and research into low-cost technologies [76–78].

Underdiagnosis and misdiagnosis In several regions, such as Africa, the Western Pacific and South-East Asia, early detection of diabetes is a challenge, leaving more than 50% of affected people undiagnosed. Moreover, differing diagnostic procedures across nations may amplify this issue. Rural areas are particularly disadvantaged regarding access to specific diagnostic tools such as standardised HbA_{1c} assays and healthcare staff to perform OGTTs. Public knowledge of diabetes symptoms and risk factors is still suboptimal, resulting in delayed diagnosis and intervention [75–77]. Lack of screening programmes and evidence-based but context-relevant guidelines, and inadequate healthcare infrastructures represent additional critical barriers to diagnosis [79].

Developing national screening programmes and implementing globally recognised diagnostic protocols and public awareness campaigns may improve diabetes identification and proper diagnosis. Governments should adopt diabetes screening as part of their national health agendas, while international bodies should provide technical support as and when needed. Community-driven approaches, such as grassroots educational programmes and mobile health units, can help

Table 1 A proposed list of essential medications in type 2 diabetes

Therapeutic class	Drug examples	Key benefits
SGLT2 inhibitors	Empagliflozin, dapagliflozin and canagliflozin with or without metformin	Improve glycaemic management with low risk of hypoglycaemia, promote weight loss and reduce risk of cardiovascular and renal complications
GLP-1 receptor agonists	Liraglutide, semaglutide and dulaglutide	Improve glycaemic management with low risk of hypoglycaemia, promote weight loss and reduce risk of cardiovascular and renal complications
Dual GLP-1/GIP receptor agonist	Tirzepatide	Improves glycaemic management and promotes weight loss
DPP-4 inhibitors	Sitagliptin, linagliptin and vildagliptin with or without metformin	Improve glycaemic management with low risk of hypoglycaemia. Suitable alternative for patients who are intolerant to other therapies. Widely used in some East Asian countries (e.g. Japan)
Basal insulin analogues	Insulin glargine U300, insulin degludec	Long-acting with a lower risk of nocturnal hypoglycaemia and improved convenience for patients
Prandial insulin analogues	Insulin lispro, insulin aspart, insulin glulisine	Provide rapid-acting control for postprandial glucose spikes, improving overall glycaemic management
Fixed-ratio combinations	Insulin glargine + lixisenatide, insulin degludec + liraglutide	Combine insulin with a GLP-1 receptor agonist for enhanced glycaemic management and simplified regimens with reduced risk of hypoglycaemia

DPP-4, dipeptidyl peptidase-4; GIP, glucose-dependent insulintropic polypeptide; GLP-1, glucagon-like peptide-1; SGLT2, sodium–glucose cotransporter 2

address systemic inequities and improve diabetes recognition [80, 81].

A global diabetes screening programme may reduce the burden of undiagnosed diabetes and impaired glucose regulation, particularly in high-risk and underserved populations. However, to be effective and sustainable, such a programme must be highly scalable and adaptable to a wide range of healthcare systems and resource levels without diverting attention or capacity from those already diagnosed and in need of care. The core objectives would include early diagnosis, risk assessment, prevention of complications, data collection and technology integration. Target populations may include high-risk individuals and vulnerable groups identified through community-level engagement and local health data [82, 83]. A phased approach, starting with pilot implementation in representative regions, would allow for the evaluation of feasibility, resource needs and health system integration. Based on lessons learned, these pilot programmes could be scaled up through a broader global roll-out, with continuous monitoring and evaluation to ensure effectiveness and equity. Ultimately, successful models could be integrated into national health strategies, with technical and strategic support from global organisations such as the WHO and IDF [82]. Real-world examples illustrate both the promise and the challenges of such initiatives. For instance, India's National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) implemented wide-scale community screening but faced bottlenecks in follow-up care and system capacity, highlighting the risks of overextending under-resourced systems [84]. In contrast, the UK National Health Service (NHS) Diabetes Prevention Programme uses routine primary care data to stratify risk and engage individuals selectively, providing a more efficient and targeted approach [85]. Likewise, International Federation of Gynecology and Obstetrics (FIGO) guidelines on gestational diabetes mellitus [86] recommend context-sensitive adaptations, recognising that universal screening may not be feasible in low-resource settings. Grounding global screening efforts in implementation science and lessons learned from these prior initiatives will be critical to achieving an equitable, scalable and sustainable impact [82, 83].

Similarly to underdiagnosis of diabetes, delays in diagnosis of the early stages of retinopathy, chronic kidney disease (CKD), foot disease and subclinical CVD, as well as misdiagnosis of conditions such as monogenic diabetes or diabetic neuropathies, represent opportunities lost for implementation of prevention programmes and introduction of early and appropriate treatments. Although detecting complications is more complex than diagnosing diabetes, global diabetes screening policies should be aligned to unify procedures for diagnosing eye, kidney, foot and cardiovascular complications. In LMICs, AI could be effective in retinopathy screening, although integration with screening for modifiable risk factors is important to drive actions.

Sustaining a high profile in health policies Unlike other pressing health concerns (e.g. CVD, cancer, HIV/infectious diseases), diabetes is often perceived as less urgent and receives relatively scant attention in health programmes and funding priorities [87]. In the UK, diabetes prevention has been successfully synergised with broader non-communicable disease management strategies through the NHS [85, 88, 89]. Conversely, in some African countries, resource allocation is heavily weighted towards the fight against infectious diseases such as HIV/AIDS and tuberculosis, leaving diabetes neglected and underfunded [90]. To maintain a high profile of diabetes healthcare policy, it is crucial that governments recognise diabetes within a national health agenda. Local empowerment through community mobilisation and local partnerships can articulate groundwork issues and empower patients. Technological innovations, such as telemedicine and mobile health unit services, can bridge gaps and maintain diabetes care even during challenging conditions as experienced during the recent COVID-19 pandemic [83]. However, geopolitical tensions involving China and the USA may pose unexpected challenges related to availability, logistics and costs, etc. at the expense of global and local healthcare needs [91].

Use of multidisciplinary professional teams in diabetes management Diabetes is a chronic condition that requires timely and effective multidisciplinary care provided by endocrinologists, primary care providers, dietitians, diabetes educators, podiatrists, ophthalmologists, psychologists and pharmacists, with the care process coordinated by qualified professionals [92]. Attention should also be paid to gender balance among healthcare professionals, as disparities in representation remain evident in certain areas. In Germany, federal health insurance ensures access to certain services [93], while, in Sweden, well-coordinated collaboration between endocrinologists, dietitians and diabetes educators has reduced the incidence of complications [94, 95]. However, in many LMICs, multidisciplinary care is underdeveloped, with patients having limited access and there being poor communication among care providers, clinical inertia and lack of resources and professional training [96].

To mitigate these challenges, expenditure should be directed toward the construction of healthcare infrastructure, training programmes and technological solutions in telemedicine for underserved populations [97]. Providing training opportunities to take part in global initiatives may help disseminate knowledge and accelerate the adoption of virtuous solutions on a larger scale.

Standards for a diabetes education curriculum Building a common diabetes education curriculum for global adoption may foster early case identification and effective management with

improved health outcomes. This would involve defining core learning objectives and using a modular design with multilevel education followed by implementation, including the use of e-learning platforms, and assessment and certification processes. The curriculum should cover compulsory topics (e.g. pathophysiology, diagnostic criteria, diabetes management tools, mechanisms of complications, psychosocial aspects) along with elective modules that address regional challenges, allowing flexibility for adaptation in different contexts and countries (Table 2) [82, 83].

Diabetes checklist for outpatient visits A global diabetes outpatient visit checklist is proposed to ensure comprehensive and consistent diabetes care. The proposed checklist includes information on treatment goals, glycaemic management and management of other cardiometabolic risk factors, screening for complications, assessment of lifestyle and psychosocial barriers, self-care practices and adherence to medications, patient education, vaccinations and use of organ-protective drugs, follow-up visits and engagement with other care team members [7] (Table 3).

A summary of the way forward for diabetes care is shown in the text box.

Way forward for diabetes care

- **Implement a global screening programme:** A global screening programme may appear to be ambitious, but a framework for such a programme could be implemented with the aim of improving diabetes identification and proper diagnosis.
- **Set standards for a universal/global diabetes education curriculum:** Defining a curriculum to be adopted globally might help fill the gap in quality of care between less and more advanced communities.
- **Prepare a diabetes checklist for outpatient visits:** Key components should include glycaemic, cardiovascular and renal risk management, medication optimisation, complications screening, lifestyle support, patient education, preventive care, technology integration and coordinated follow-up. Such a checklist could potentially be adopted globally to ensure comprehensive and consistent diabetes care.
- **Add new drugs to the essential medications list:** New drugs should be added to the essential medications list, coupled with the introduction and implementation of diabetes management guidelines.

Global organisational challenges

Epidemiological context In the global diabetes epidemic, most people with diabetes live in LMICs, where there is a paucity of data to inform the true magnitude, trends and impacts of this challenge and its solutions [9]. In 2017, the Lancet Commission on Diabetes in Sub-Saharan Africa highlighted the need to strengthen health systems, identify high-risk groups for prevention and gather data to inform decision-making [98]. In 2020, experts in global health, clinical care, research and education and health economics published the Lancet Commission report after 4 years of extensive critique of the evidence and concluded that (1) control of blood glucose, blood pressure, LDL-cholesterol (LDL-C) and body weight reduced cardiovascular and renal events and death in type 2 diabetes; (2) use of metformin, statins, renin–angiotensin system inhibitors, sodium–glucose cotransporter 2 (SGLT2) inhibitors and glucagon-like peptide-1 (GLP-1) receptor agonists conferred independent organ-protective effects in type 2 diabetes; (3) reduction of 15% body weight in people with type 2 diabetes diagnosed for less than 6 years and obesity was associated with remission of diabetes for at least 2 years; and (4) intensive lifestyle intervention and use of metformin prevented onset of type 2 diabetes in people with impaired glucose tolerance [99]. However, there was an enormous variation across the globe in the achievement of HbA_{1c} goals because of differences in medication costs, professional knowledge and access to and quality of care [99]. This was echoed by a recent nationwide survey from India, where only 7.7% of people with type 2 diabetes attained all treatment goals [100].

Self-management, multifactorial intervention and early use of organ-protective drugs are pivotal in changing disease trajectory, preventing organ damage and improving quality of life [101]. A meta-analysis has confirmed the benefits of quality improvement strategies targeting health systems, people with diabetes and providers for achieving HbA_{1c} and other targets, with team change, facilitated patient relay (for improving doctor–patient communication), patient education and self-management having the largest effects [102] (Fig. 2). However, to date, delivery of diabetes care remains fragmented because of lack of alignment among people with diabetes, providers and payors [103].

Access to quality care and use of registers The basic human right to healthcare is underpinned by international human rights laws, including the right to life, the right to health and the right to information, and is based on dignity and the universality of obligation and non-discrimination [69]. The burden of diabetes and untreated diabetes is increasingly borne by LMICs. The WHO Global Diabetes Compact has established ambitious global targets for 2030, including

Table 2 A proposed diabetes curriculum for worldwide adoption to promote the knowledge, skills, attitudes and behaviours expected from diabetes healthcare providers

Structure	Step 1: design	Step 2: key components	Step 3: implementation
Modular structure	Design a flexible, modular curriculum with content that can be adopted by different regions and countries based on their specific needs and resources	Core modules should cover compulsory universal topics, while elective modules can focus on regional challenges (e.g. addressing foot ulcers in low-resource settings)	Recommend the core modules for all health practitioners followed by implementation as needed
Multilevel education	Develop tiered content for different professionals, including general practitioners, nurses, dietitians and community health workers	Components on patient education should be aimed at empowering individuals to manage their condition effectively	Recommend the core modules for all health practitioners
Standardised certification	Develop a globally recognised certification programme for diabetes care professionals, ensuring uniformity in the quality of care across regions	Collaborate with international organisations (e.g. WHO, IDF) for endorsement of certification	Create programmes where the basic knowledge in the universal curriculum can be certified. Depending on the level of training and evaluation undertaken, different certificates could be issued for different categories of healthcare professionals and specialists
E-learning platforms	Embrace e-learning technology to deliver expedient, cost-effective training to under-resourced communities	Provide video tutorials to improve the learning experience, including the use of interactive case studies and virtual simulations	An e-learning platform based in Europe or other HICs may help with implementation of the diabetes curriculum

Curriculum adapted from [83, 128]. This proposed curriculum aligns with and builds on existing educational frameworks developed by global and national organisations, such as the International Curriculum for Diabetes Health Professional Education from the IDF [129], the DESMOND initiative in the UK [130] and the Diabetes Self-Management Education and Support (DSMES) framework from the ADA and the Association of Diabetes Care & Education Specialists (ADCES) [131]

Table 3 A proposed checklist for comprehensive outpatient diabetes assessment [7, 82, 128, 132]

Category	Tools/assessments	Purpose
Glycaemic management	HbA _{1c} testing, blood glucose logs, CGM data	Monitor glycaemic levels, identify trends and assess treatment efficacy
Management of cardiovascular, kidney and metabolic risk factors	Blood pressure, lipids (fasting triglycerides, total cholesterol, LDL-cholesterol and HDL-cholesterol), BMI, waist circumference, eGFR and UACR	Management of major modifiable risk factors and surrogates of complications (notably eGFR and UACR) to reduce the risk of cardiovascular and renal complications
Drug use including organ-protective drugs	Review current list of medications and need for organ-protective drugs including metformin, renin–angiotensin system inhibitors, statins, SGLT2 inhibitors and GLP-1 receptor agonists	Ensure appropriate use of organ-protective drugs, which can modify disease progression independently of management of cardiometabolic risk factors
Complications screening (eyes, feet and heart)	Visual acuity, fundoscopic eye examination, monofilament and tuning fork testing, Doppler scan for foot pulses, ECG, echocardiogram	Detect microvascular and macrovascular complications
Lifestyle and behaviour	Dietary recall tools, physical activity questionnaires, use of alcohol and smoking cessation counselling tools, assessment of sleep and emotions (e.g. stress and depression)	Assess psychological needs and encourage adherence to lifestyle changes that improve diabetes management
Patient education	Medication adherence checklists, glucose monitoring training kits, ‘sick day’ management guides	Empower patients to manage their condition and respond to emergencies effectively
Preventive care	Vaccination schedules, cancer screening protocols	Prevent comorbidities and ensure holistic health maintenance
Technology integration	Telemedicine platforms, mobile health applications for glucose monitoring	Enhance access to care, use biometrics to provide feedback and motivate behavioural change, improve communication between patients and healthcare providers
Follow-up and monitoring	EHRs, shared care plans	Promote health literacy, improve coordinated, quality- and value-based care focusing on empowerment, early intervention and prevention

GLP-1, glucagon-like peptide-1; SGLT2, sodium–glucose cotransporter 2; UACR, urinary albumin/creatinine ratio

	N	I ²	M.D. (95%-C.I.)
Case management	52	84.6	-0.24 (-0.31 to -0.17)
Team change	53	97.1	-0.36 (-0.48 to -0.24)
Electronic patient registry	8	0.1	-0.09 (-0.14 to -0.03)
Facilitated patient relay	48	96.4	-0.28 (-0.37 to -0.19)
Electronic health	35	86.4	-0.16 (-0.23 to -0.10)
Continuous QI	18	46.8	-0.19 (-0.30 to -0.08)
Audit and feedback	16	92.8	-0.19 (-0.30 to -0.08)
Clinician education	15	98.0	-0.25 (-0.36 to -0.14)
Clinician reminder	45	94.9	-0.20 (-0.28 to -0.12)
Patient education	38	92.5	-0.30 (-0.38 to -0.21)
Self-management	65	96.5	-0.30 (-0.39 to -0.22)
Patient reminder	57	97.4	-0.24 (-0.32 to -0.16)

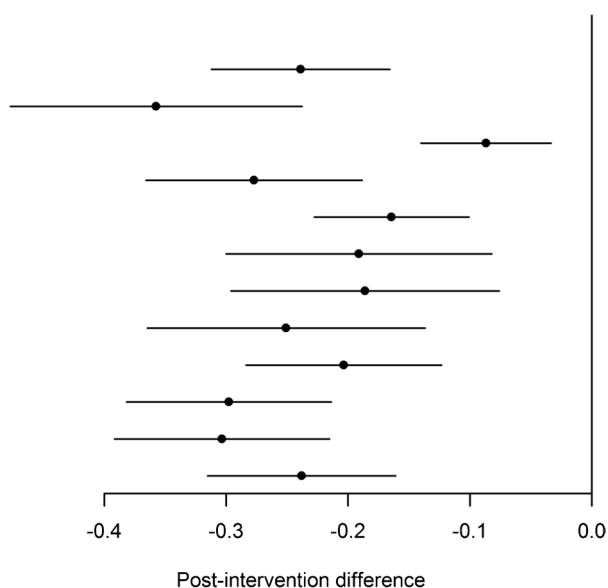


Fig. 2 Systematic analysis including 181 clinical trials ($n=135,112$) showing the effects of different quality improvement strategies targeting people with diabetes (self-management, patient education, patient reminders), providers (audit/feedback, clinician education, clinician reminders) and systems (case management, team change, electronic patient registry, facilitated patient relay, electronic health, continuous quality improvement) on HbA_{1c} levels vs usual care. Team change,

facilitated patient relay (for improving doctor–patient communication), patient education and self-management have the largest effect sizes. Similar patterns of improvement also apply to blood pressure and LDL-C. M.D., mean difference; QI, quality improvement. Reproduced from Lim et al [102] with permission. © 2018 by the American Diabetes Association. This figure is available as part of a [downloadable slideset](#)

diagnosing 80% of people with diabetes, achieving HbA_{1c} targets in 80% of those diagnosed and ensuring that 80% of them have controlled blood pressure and 60% of those aged 40 years and above receive statin therapy, and guaranteeing 100% access to affordable insulin and blood glucose monitoring for people with type 1 diabetes [83]. In 1993, the IDF St Vincent Declaration proposed the establishment of diabetes centres and the use of diabetes registers to improve the quality of diabetes care [104]. The purpose of diabetes registers is to collate information from defined groups over time, which can then be used in the provision of aftercare, to monitor changing patterns of disease and medical care, and in the evaluation and planning of services [105].

Silent cardiovascular, kidney and metabolic risk factors, such as HbA_{1c}, blood pressure, LDL-C levels and body weight, plus albuminuria (urinary albumin/creatinine ratio) and eGFR [106], should be measured at least annually within the same setting and interpreted along with other determinants [107]. The latter include age, sex, age at diagnosis, disease duration, prior cardiovascular events, socioeconomic factors, use of medications and patient-reported experiences and outcomes (e.g. use of tobacco and alcohol, sleep, diet, exercise, psychosocial stress, self-management practices and treatment adherence). Interactions between these factors will define prognosis and inform decision-making [101]. In addition, organ-protective drugs should be regularly reviewed,

with dose adjustment depending on clinical stage, responses and side effects, taking into consideration adherence, preference and affordability [106]. Care processes proposed for establishing a diabetes register to inform decision-making are provided in Table 4 [101, 108].

Benchmarking performances and motivation for self-management Unlike hypertension and hyperlipidaemia, where good adherence to medications is likely to result in the achievement of treatment goals, self-management holds the key to success in achieving body weight and blood glucose targets [109, 110]. Many people with diabetes may need multiple medications, including injections, notably of insulin, which require courage, effort and commitment. All professional practice guidelines highlight the importance of a structured diabetes self-management education and support (DSMES) programme, including self-monitoring of blood glucose with appropriate actions [101]. Trained providers should deliver education on CGM devices to help users interpret actionable metrics [111]. On average, a person with diabetes needs at least 4–6 h of education, if not more, with periodic reinforcement to initiate and sustain positive behaviours [110].

Given the complexity of diabetes management, multi-component strategies are needed to close the know-do gaps (from knowing to doing) [112, 113]. Establishing registers

Table 4 Suggested care processes for establishing a diabetes register using structured risk assessment at least every 2 years to drive actions and improve outcomes

Objectives	Care components	Setting, people and processes of assessments	Essential variables in register	Self-reported outcomes with biennial assessment or retrieval from EMR systems (if available)
<ul style="list-style-type: none"> • Prevent complications • Improve quality of life 	<ul style="list-style-type: none"> • Effective practice and care organisation • Complications surveillance and screening • Monitoring and ongoing review • Consider underlying physiology • Avoid therapeutic inertia • Diabetes structured education and support • Reducing risk of hypoglycaemia • Shared decision-making • Psychosocial factors • Health behaviour modification • Social determinants of health • Language matters • Consider local healthcare setting and resources 	<ul style="list-style-type: none"> • Small room away from busy clinics • Trained doctors to design context-relevant protocols with follow-up actions; train non-medical staff and monitor fidelity of implementation • Nurses to perform assessments (blood, urine, eyes, feet) • Clerical staff or healthcare assistants to assist doctor–nurse teams to gather data and manage databases • Simple tools such as Snellen charts, monofilaments and tuning forks • Retinal photography or direct ophthalmoscopy by trained doctors • Laboratory tests 	<ul style="list-style-type: none"> • Age • Sex • Age at diagnosis • Disease duration • Family history • Prior significant events or complications • Blood pressure • BMI • Waist circumference • Eyes: visual acuity, retinopathy • Feet: skin, deformities, sensation and pulses • Biomarkers (fasting plasma glucose, HbA_{1c}, LDL-C, lipids, UACR, eGFR) • Patient-reported experiences and outcomes (e.g. SMBG, depression) 	<ul style="list-style-type: none"> • Hospitalisations • Major events (coronary artery disease, stroke, cancer, kidney failure) • Death

Based on the recommendations of the ADA/EASD Consensus report [101] and an example of a data-driven care model introduced through the establishment of the Hong Kong Diabetes Register [108]

EMR, electronic medical record; SMBG, self-monitoring of blood glucose; UACR, urinary albumin/creatinine ratio

serves multiple purposes: (1) implementation of structured assessments provides on-the-job training, while personalised data collected during structured assessments can be relayed to people with diabetes, empowering self-management, and to care providers, facilitating early intervention; (2) aggregate register data increase the transparency of care standards and improve communication among people with diabetes, providers and payors; (3) when linked to hospitalisation and death data, which are often available in electronic medical records, using unique identifiers, an ongoing diabetes register will reveal changes in disease trajectories, identify unmet needs and promote knowledge-sharing to drive actions at all levels [99].

As well as making diabetes education widely accessible through multiple channels, including social media, people and processes need to be put in place to implement multifactorial interventions [114, 115]. The expansion of primary healthcare and health insurance, including reimbursement of medications at early detection of diabetes for effective management, should be accompanied by diabetes care programmes delivered by adequately trained staff and resources. Cost-effective programmes supporting lifestyle changes, including those aiming at major weight loss during the initial phases of type 2 diabetes to minimise the need for multiple medications, will have long-term benefits. The addition of new pharmacological agents such as SGLT2 inhibitors and GLP-1 receptor agonists to lists of essential medicines and the implementation of cost-effective population-based interventions to confront the obesity epidemic are highly relevant in this context [99].

DSMES may be delivered face-to-face or online. In a systematic review, online DSMES was comparable to face-to-face interventions in reducing HbA_{1c} in type 1 diabetes and was more effective in type 2 diabetes [114]. Similarly, online DSMES was more cost-effective than face-to-face consultations in improving quality of life, supporting the use of online interventions to complement clinical practice [116]. Online DSMES can be augmented by a minimal digital care model that enables monitoring of selected outcome indicators, such as the percentages of people in different HbA_{1c} categories and incidence of hyperglycaemic crises and chronic complications [95].

Diabetes specialists as care coordinators With increasing recognition of the heterogeneity of diabetes [117] and the expanding number of drugs, devices, diagnostic tools and digital solutions, there is a strong case for using diabetes specialists to coordinate care and provide quality assurance to avoid gaps and overlaps [118, 119] (Fig. 3). The extremely low event rates in clinical trial settings owing to the use of protocols, care coordinators and data monitors provides a framework for improving quality of care [120].

By improving practice environments and workflows, diabetes specialists can train nurses or care assistants to perform regular structured assessments (eye, feet, blood, urine) to identify care gaps, triage care, review treatment and reinforce self-management. This systematic data collection could form the basis of registers, which will enable recall of those who do not follow protocols to prevent silent deterioration and the development of complications [108]. Importantly, through these assessments, diabetes specialists can identify people with atypical presentations, such as those with slowly progressive autoimmune type 1 diabetes masked as type 2 diabetes, monogenic diabetes and endocrinopathies that warrant additional investigations and specialist care, as well as specific metabolic diseases or disorders such as lipodystrophy and sarcopenia [121]. Whenever the setting allows, linking registers to hospitalisation and death data will enable the building of outcome models to predict multiple events, identify subgroups who would benefit most from specific interventions and inform the design of clinical trials to maximise cost-effectiveness. Diabetes specialist teams could also perform regular screening of relatives of people with diabetes and other high-risk groups to detect impaired glucose regulation for early intervention [122].

Value and implementation of registers Registers can thus provide an important data resource for integration with upstream determinants and downstream outcomes for surveillance purposes [83, 99]. In the Lancet Commission report on diabetes, experts used epidemiological and clinical trial data to compute mathematical models, demonstrating the life- and money-saving effects of using this multipronged strategy to prevent and manage type 2 diabetes, early and effectively [99]. However, establishing a diabetes register requires commitment to reorganise care and train non-medical staff to systematically gather routine measurements, with data digitalisation and the use of computer programmes for regular review. In many LMICs, EHR systems are either non-existent or only just being developed, and the lack of standardised, linkable EHRs and fragmented health information systems pose significant barriers to implementing such registers. Stepwise development of minimal datasets, mobile health tools for manual data entry or hybrid models that combine sentinel site data with population surveillance data could represent potential solutions in such contexts. The Swedish National Diabetes Register [95] and Hong Kong Diabetes Registry [123] were established in the mid-1990s, when EHR systems were rare, and have contributed to the transformation of local care practices and global knowledge.

International collaborations and sharing best practices LMICs have the least resources to cope with complications from undiagnosed, untreated or uncontrolled diabetes,

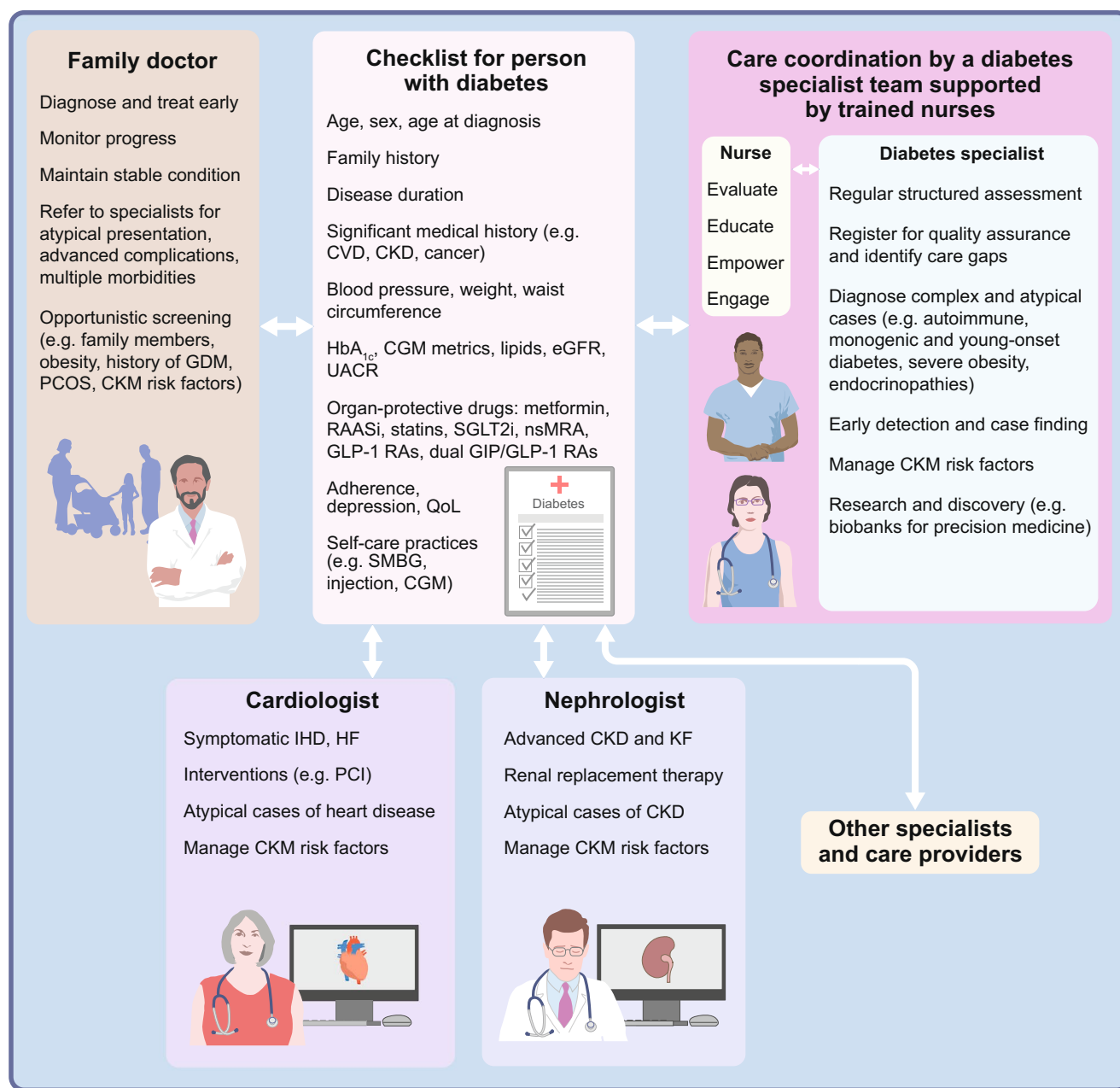


Fig. 3 Schematic diagram illustrating the multiple providers encountered by a person living with diabetes. While each specialty has its own expertise in managing different stages of diabetes, diabetes specialists equipped with the latest knowledge about the fundamentals of energy metabolism and the diagnosis, prevention and management of diabetes are in a unique position to provide quality assurance, identify care gaps and promote value-based care. The establishment of diabetes registers by diabetes specialist teams with feedback of personalised information to individuals with diabetes will empower self-management and benchmark performance with objective evidence of the achievement of key performance indexes. In academic settings, the establishment of biobanks accompanying these high-quality registers and related cohorts will aid in the discovery of biomarkers to improve

the precision of diagnosis, prevention, classification and treatment of diabetes [124]. Other specialists and care providers include neurologists and vascular surgeons. CKM, cardiovascular, kidney and metabolic; GDM, gestational diabetes mellitus; GIP, glucose-dependent insulinotropic peptide; HF, heart failure; IHD, ischaemic heart disease; KF, kidney failure; nsMRA, non-steroidal mineralocorticoid receptor antagonists; PCI, percutaneous coronary intervention; PCOS, polycystic ovary syndrome; QoL, quality of life; RA receptor agonist; RAASi, renin-angiotensin-aldosterone system inhibitors; SGLT2i, SGLT2 inhibitors; SMBG, self-monitoring of blood glucose; UACR, urinary albumin/creatinine ratio. This figure is available as part of a [downloadable slideset](#)

as well as limited capacity to detect, prevent and treat diabetes early. The lack of understanding of risk and causes (including genotypes), trajectories and outcomes of diabetes in people living outside North America and Western Europe further impedes our pursuit of using precision medicine to maximise benefits and minimise harm [124]. On the other hand, as advocated by experts from Africa, by adapting the best practices and policies from HICs and LMICs, it is possible to expedite implementation to fill care gaps [125].

According to the European Diabetes Forum (EUDF), early screening and detection and use of integrated care, self-care technology and digitalisation, data and registers, and disease-changing medications are key strategies to combat diabetes and obesity [126]. The challenges of diabetes transcend all sectors, domains and populations. However, there is increasing recognition of this scenario from global agencies, including philanthropic organisations, which are in a position to support large-scale diabetes prevention, management and education programmes to bridge the gap between practice and policies [99]. Meanwhile, by training young doctors to design context-relevant, multi-purpose diabetes registers, and other healthcare professionals, such as nurses and healthcare assistants, to provide structured assessments, education (including peer support) and liaison [127], the medical community will be one step closer to standardising care practices [99].

A summary of the way forward for global organisational challenges is shown in the text box.

Way forward for diabetes care organisation

- **Develop and implement diabetes registers:** The development of registers will help in benchmarking performance in different countries/regions to reduce variations in care standards, promote best practices and gather personalised data to motivate self-management and deliver precision medicine. Implementing diabetes registries in LMICs will require a targeted strategy, likely integrating digital health interventions with manual data collection methods and leveraging available technologies.
- **Develop a central role for diabetes specialists:** Development of this central role will support early and appropriate intervention actions, coordinate care and identify care gaps.
- **Set up international collaborations and share best practices:** International collaborations and sharing best practices will enable a more homogeneous level of care to be delivered in settings worldwide.

Conclusions

Uneven availability of resources and finances in diabetes research and care, as well as large discrepancies in access to medications, facilities and properly trained healthcare practitioners, are unwanted but real elements of the diabetes world at the close of the 21st century's first quarter. Specific challenges include increasing difficulties in conducting large-scale clinical trials, the underuse of big data, and the legal and ethical complexities of AI integration. Coordinated, international efforts that extend beyond traditional models may facilitate the establishment of global research and care networks, enhancing research and medical training and defining shared standards in diabetes research and care. Implementation of specific tools, such as training curricula and registers, can be key to accomplishing ambitious goals, such as creating a more inclusive and effective research ecosystem and attenuating persistent disparities in diabetes care worldwide.

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