

Improving health outcomes of people with diabetes

Global Health and Population Project on Access to Care for Cardiometabolic Diseases

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Improving Health Outcomes of People with Diabetes Mellitus: Global Target Setting for the WHO Diabetes Compact

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ABSTRACT

The Global Diabetes Compact is a World Health Organization-driven initiative uniting stakeholders around goals of reducing diabetes risk and ensuring that those with diabetes have equitable access to comprehensive, affordable care and prevention. In this report we describe the development and scientific basis for key health metrics and coverage and treatment target levels accompanying the *Compact*. We considered metrics across four domains (structural, system- or policy-level factors; processes of care; biomarkers and behaviours; and health events and outcomes) and three risk tiers (diagnosed diabetes, high risk, or whole population) and reviewed and prioritized them according to their health importance, modifiability, data availability and global inequality. We reviewed global distributions of levels for each metric to set target levels for future attainment. This process led to 5 country-level core metrics and target levels for UN member states: 1) at least 80% of the persons with diabetes are diagnosed; 2) 80% of those with diagnosed diabetes having HbA1c levels below 8.0%; 3) 80% with diagnosed diabetes having blood pressure levels below 140/90 mmHg; 4) 60% with persons aged ≥ 40 with diagnosed diabetes using statins, and, 5) 100% of persons with type 1 diabetes having continuous access to insulin, blood glucose meters and test strips. We also propose several complementary metrics that currently have limited global coverage but warrant scale-up in population-based surveillance systems, including collection of data and estimation of cause-specific mortality, and incidence of end-stage kidney disease, lower-extremity amputations, and incidence of diabetes. Primary prevention of diabetes and integrated care to prevent long-term complications remain important areas to develop and validate new metrics. These metrics and targets are intended to drive multi-sectoral action applied to individuals, health systems, policies, and country-level health care access to achieve the goals of the *Global Diabetes Compact*. Although ambitious, their achievement can result in broad health benefits for the growing global population with diabetes.

Introduction

Diabetes mellitus is one of the world's most challenging public health problems due to its high and growing prevalence and the extensive morbidity it causes, impacting individuals, health systems, and national economies (1, 2). Recent global estimates indicate that 537 million adults have the condition, of whom 80% live in low- and middle-income countries (LMICs) (1, 3). Further, the global impact and costs of diabetes are expected to grow considerably, disproportionately affecting LMICs and the most disadvantaged people of high-income countries (HICs) (4-6).

Despite the relentless growth of diabetes, the pathways to its adverse outcomes are highly modifiable across a broad continuum of its pathogenesis, and many of interventions are cost-effective and feasible to implement. For people with diagnosed diabetes, delivery of essential medications, management of glycaemia and cardiometabolic risk factors, alongside early screening for complications via well-organized care reduce acute and chronic complications and extend life (2, 7-10). Further, type 2 diabetes can be delayed or prevented through intensive lifestyle interventions and medications directed at high-risk individuals alongside population-wide changes to dietary quality, physical activity levels, and levels of obesity (11-15).

Unfortunately, population-based studies have shown that the delivery of evidence-based care for people with diabetes is sub-optimal even in well-resourced health systems. Many countries have high proportions of their populations with diabetes undiagnosed and without timely care for extended periods (16-19). In HICs, the achievement of recommended targets of risk factors or biomarkers for complications such as HbA1c and blood pressure control ranges from 50-70% and only about 20% meet all recommended targets (20-22). Levels are worse in LMICs, where only about half have good glycaemic control and about one in four have good blood pressure control (6, 18, 23). Multicomponent quality-improvement initiatives have shown sustained benefits in achievement of diabetes care goals and reducing vascular complications, even in low resource settings, but have had limited global reach (24). Similarly, the implementation of primary prevention programmes has been variable and non-systematic at best (2, 25).

In the context of a large and growing burden of diabetes-related morbidity and missed opportunities to employ evidence-based care and prevention, the World Health Organization (WHO) recently announced the *Global Diabetes Compact* (26). The *Compact* is intended to stimulate implementation of the Global Action Plan for the Prevention and Control of Non-communicable Diseases (NCDs) 2013-2020 endorsed by World Health Assembly Resolution 74.4 (27). The Global Action Plan calls for formulation of specific coverage and treatment targets to drive action, and assess progress at global and national levels, with attainment by 2030. To do this, it aims to unite diverse stakeholders to achieve targets which reflect common goals of reducing the risk of diabetes and ensuring that all people who are diagnosed with diabetes have equitable access to comprehensive, affordable and quality treatment and care (26). This is inspired by prior successes in HIV and the premise that measurement drives action, including prioritisation of interventions and resources for diabetes at the national, regional, and global levels (28). It also build on recommendations of a recent Lancet Commission that highlighted better measurement at multiple levels as a crucial component of health policy to drive action and reduce the global burden of diabetes (2).

To prioritize metrics and target levels for the *Compact*, WHO assembled a group of experts (the authors) and followed a systematic process (details in the appendix) to organize potential metrics across four domains (policy and system-level factors, processes of care, biomarkers and behaviours, and long-term health outcomes) and three risk tiers (diagnosed diabetes, high risk for diabetes, whole population) and then prioritized metrics according to their health importance, modifiability, data availability, and the degree to which they represent areas of global inequality (29). In this report we propose core and complementary metrics, their definitions, and target levels for the *Global Diabetes Compact* to stimulate global action and describe the scientific basis and justification.

Types and Range of Options for Health Metrics

Target-setting for public health efforts is credited with influencing major successes in public health, ranging from vaccine delivery to the reductions in HIV and CVD-related mortality and has used diverse criteria to establish health metrics and their targets (28, 30). Metrics, or standardized health measurements, can be applied to individuals (e.g. clinical health conditions, biomarkers, or behaviours), or to health care providers and health systems (e.g. indicators of the delivery of interventions, or the

presence of policies, or processes) (31). Metrics may also represent actions or policies taken by broader institutions or governments. For the *Compact*, we organized metrics into four domains: *structural, system- or policy-level factors; processes of care; biomarkers and behaviours; and health events and outcomes* (Table 1).

In this framework, structural, system- or policy-level factors address multiple aspects of health services delivery or can target the entire population. For example, multi-disciplinary teams for care management and decision-support via patient registries improves risk factors and management that should improve health outcomes (32-35). Processes of care are essential procedures, such as testing for HbA1c, eye examinations, or foot examinations, conducted by health care providers or individuals on the pathway to affecting biomarkers, behaviours, and long-term health outcomes (36). Intermediate biomarkers and behaviours such as HbA1c, blood pressure, and lipids are prioritised if they are independently associated with long-term diabetes-related health outcomes like microvascular and macrovascular complications, ideally established through randomized controlled trials (2, 7, 8, 37, 38). Finally, diabetes-related health events and outcomes indicators such as incidence of diabetes or its complications (e.g., lower extremity amputations (LEAs), end stage kidney disease (ESKD) represent the key essence of diabetes morbidity that affect quality and length of life that clinical and public health efforts aim to affect (39).

Metrics can also be organized according to a risk tier, defined by the stage of disease that they primarily affect, including persons with diagnosed diabetes, persons at high risk (such as intermediate hyperglycaemia), or the whole population (Table 1). For example, managing blood glucose is particularly important in persons with diagnosed diabetes while improving overall dietary quality and physical activity, and applying taxation or incentivisation policies to promote healthy behaviours is important for the general population (40).

Criteria for Prioritizing Metrics for Diabetes

The selection of any given metric has advantages and disadvantages. For example, reducing health events and outcomes comes closest to the ultimate goals of clinical and public health practices, but can be difficult to measure, difficult to modify in the short term, and is uninformative about what factors are driving change (41). Processes of care may be immediately measurable and responsive to interventions but may not predict health changes well (42, 43). Biomarkers and behaviours are both modifiable and predictive of long-term outcomes and have generally standardized measurement approaches with reasonable global reach (38); however, they often lack consensus on the appropriate target thresholds, and obtaining reliable and comparable measures across different settings is difficult. System and policy-level metrics have wide variation in adoption, can be difficult to implement in the short-term, have modest effect sizes, or inconsistently predict health outcomes at the individual level when achieved (10, 42, 43). However, they have the potential to efficiently affect multiple risk factors and large segments of the population.

The selection of different population risk tiers also has trade-offs. Focusing on people with established disease or high risk may meet immediate health system demands and have more evidence for short-term effectiveness but not achieve the long-term goal of preventing the condition itself. Interventions aimed at the whole population depend upon policy-level interventions that can be difficult to measure and have unclear magnitudes of effect but may have important benefits over longer time horizons (43). Focusing on prevention among at-risk adults with individualized prevention approaches has established effectiveness, but few examples of successful population-wide scale-up exist.

Metrics for *the Compact* have been considered against four main criteria (Appendix page 2). First, priority metrics should be of *intrinsic health importance* or else be a factor or intervention that strongly predicts major health events or outcomes. Second, a good metric should be *modifiable via scalable interventions across diverse settings*. Third, priority metrics should have good *global data availability and acceptable measurement properties*, be reasonably consistent across settings and be measurable through practical surveillance approaches. Fourth, priority metrics should ideally represent a *gap and area of global inequality* that is modifiable. We also classified metrics into “core” metrics for prioritisation by national, regional, or facility-level monitoring systems that can currently be assessed in many countries using health surveys or registries and additional promising “complementary” metrics that require more surveillance infrastructure, scale-up, or international consensus on operational definitions.

Prioritisation and Justification for Metrics

Using the domains of metrics and criteria described above, we propose five core and ten complementary metrics that have the best chance of driving improved care and prevention due to their combination of health importance, modifiability, global data availability, and equity (Figure 1). These metrics can also be organized along a continuum, from the metrics of primary prevention, processes of care, to intermediate and long-term health outcomes. The proposed core metrics and their basic definitions include the following:

- 1: *The proportion of cases that are diagnosed out of the total number with diabetes*, with total cases defined by either self-report, taking medications, or having glycemic levels diagnostic of diabetes (FPG >7 mmol/l (126 mg/dl), random plasma glucose ≥ 11.1 mmol/l (200 mg/dl), or glycosylated haemoglobin (HbA1c) $\geq 6.5\%$. (44).
- 2: *The proportion of adults with diagnosed diabetes with controlled HbA1c, defined as less than 8% (63.9 mmol/mol).*
- 3: *The proportion of adults with diagnosed diabetes who have controlled blood pressure, defined as less than 140/90 mmHg.*
- 4: *The proportion of adults with diagnosed diabetes aged ≥ 40 years taking a statin.*
- 5: *The proportion of the population with type 1 diabetes having continuous access to insulin, blood glucose meters, and test strips.*

The proportion of cases that are diagnosed out of the total number with diabetes (metric #1) is an essential step linking those affected with treatments and preventive screenings for diabetes complications. Although the effectiveness of community-based testing and population-wide screening remains unclear and not established by randomized controlled trials (RCTs) (45, 46), opportunistic testing in clinical practice is recommended if the health care system has capacity to handle increasing case-loads. It has also been shown to be cost-effective in some HICs if paired with identification of high-risk individuals for lifestyle change (9, 47, 48). Further, the levels of diagnosis have been shown to be starkly low in many LMICs (18). The proportion meeting HbA1c levels $<8\%$ (metric #2), blood pressure $< 140/90$ (metric #3), and taking a statin (metric #4) are based on their established importance in reducing risk of acute, microvascular, and macrovascular outcomes (2, 7, 8). Improving blood pressure levels and taking statins reduce risk for CVD events in persons with diagnosed diabetes (2, 49). Ensuring access to insulin and essential monitoring equipment (metric #5) is warranted by the recognized lack of availability and affordability in some settings, with the result of deaths and high complication rates, often among children and young adults (50, 51). Three of the metrics (glycaemic control, blood pressure, and statin use) are highly modifiable using affordable medications available in primary care, particularly if supported by team-based care. Diabetes diagnosis and insulin availability can each be improved through concerted health system or policy-level interventions.

Several additional complementary metrics warrant scale-up in population monitoring settings. *All-cause mortality, end-stage kidney disease, and lower-extremity amputations (LEAs)* among the population with diagnosed diabetes (Figure 1) are intrinsically important health outcomes, highly modifiable via established evidence-based practices, and lend themselves to standardized, objective, population-based monitoring. They also represent good sentinel indicators of secondary prevention because they are affected by multiple aspects of recommended care. *Incidence of diagnosed diabetes* is more sensitive to the changes of the diabetes epidemic and is less affected by mortality than is prevalence. However, its assessment requires either very large panel surveys or health system-based registries that are available only in a few countries (52, 53). The percent of cases of type 1 diabetes who have diabetic ketoacidosis (DKA) at diagnosis, is a recognized proxy for timely diagnosis of type 1 diabetes (54). In addition to DKA being a cause of morbidity, subsequent DKA, and mortality, timely diagnosis of type 1 diabetes is considered to be modifiable through improved community awareness about signs and symptoms (54).

Some metrics could conceivably drive important improvements in care and prevention but lack consensus in how to define, quantify, and measure success. For example, improving the delivery and effectiveness of both primary prevention and integrated care are essential to reduce incidence of diabetes, and its complications, respectively. The WHO has recommended goals of reducing by 10% the prevalence of insufficient physical activity and halting the rise in diabetes and obesity, along with

recommending numerous policy and health promotion approaches to improve healthy diet to reduce diabetes risk (27). In addition, the WHO Package of Essential Non-communicable (PEN) disease interventions includes recommendations for healthy lifestyle counselling for diabetes prevention, as well as for organization of care to improve risk factor management (51). In some settings, the proportion of high-risk adults with access to diabetes prevention interventions may be considered for monitoring (14, 55, 56). Similarly, the proportion of patients receiving team-based care with registry-driven decision support are important to facilitate attainment of core targets (2). However, to operationalize both of these metrics, there would need to be investments in adequate data systems and agreement about the standardized definitions and measurement approaches (2, 57).

As diabetes is affected by multiple aetiologies and evidence-based options across stages of disease, there are many other potential metrics. For example, gestational diabetes is an important contributor to the diabetes burden and a potential target for prevention of morbidity, but there remains inadequate global consensus on definition and diagnostic criteria, and there is uncertainty over benefits of screening and long-term benefits of treatment (58). Treatment with guideline-directed medical therapy, such as taking blood pressure- and glucose-lowering medications, are often assessed in cascades of care, and available data suggests that the primary gap in treatment is due to people who have not been diagnosed. Further, the accuracy of treatment status using self-report is unclear and is complicated by the increasing number of medications and drug classes available. In addition, some individuals may be appropriate for management using lifestyle interventions only, which is generally not captured in questions on treatment. Processes of care, including receipt of HbA1c tests, foot, and eye exams are considered essential elements of high-quality diabetes care but are not consistently associated with later health outcomes (10, 36, 43, 59). Additional policy or system-level factors such as policies to increase physical activity remain difficult to measure and there is a lack of agreement about intervention effectiveness (43).

Current Global Status of Metrics: Variation, Levels, and Coverage:

Within metrics, selecting target levels for the *Compact* can be informed by several sources. We synthesized three types of evidence: 1) Recent and current population-based national estimates to provide realistic baselines; 2) Estimates of trends in rates of metrics over time from various settings to identify a plausible and realistic magnitude of change over time; 3) Estimates of projected health benefit and costs associated with meeting versus not meeting targets.

We assembled data from systematic reviews, published sources, and a subset of studies from 65 LMICs from the Global Health and Population Project on Access to Care for Cardiometabolic diseases (HPACC) collaborators using methods described in the Appendix (18, 25, 60). For the complementary metrics, we also assembled data from previously published reviews of diabetes incidence, all-cause and CVD mortality, and incidence of diabetes-related complications (52, 61, 62).

Tables 2 and appendix pages 4-8 present regional and country-specific estimates for core metrics. Levels of each of the core metrics varied considerably around the world. Among all countries, the median percent diagnosed was 61%. Of diagnosed individuals, the median percent with HbA1c <8%, blood pressure <140/90mmHg, and using statins were 68%, 56%, and 12% respectively. Regional median levels of attainment vary considerably, particularly for blood pressure and statin use. Few studies exist on trends in the attainment of these targets over time. As most countries of the world lack any published estimates for these metrics, these medians could underestimate the true global coverage of these targets. Where they exist, they tend to find large increases during the 1990s and 2000s but generally flat or marginally increasing trends since 2010. In the U.S., for example, the proportion meeting targets increased 12-13 percentage points (PPTs) from 1999-2009 but have been relatively stagnant since (20, 22, 63-65).

Published data for LEAs, CVD, and all-cause mortality among persons with diabetes, and incidence of diagnosed diabetes is mostly limited to high-income countries (53, 61, 62, 66) (Table 3). For example, rates of LEAs across most countries range from 4 to 35 per 10,000 per year with an average of about 16-18 per 10,000 per year. Annual rates of all-cause mortality vary from 10 to 60 per 1000, with an average of about 23. Estimates for diabetes related ESKD use the overall population as the denominator; thus, the increase in ESKD incidence observed across most countries is affected by the increasing prevalence of diabetes. The annual incidence of diagnosed diabetes tends to range from 1 to 10 per 1000, with an average of roughly 7 per 1000. Although these metrics lend themselves to

international standardization, existing published estimates are difficult to compare because of variations in sampling methods and denominators, outcome definitions, and population standardization approaches (67). For these reasons, as well as the lack of availability in current surveillance systems, the *Compact* did not set global targets for the complementary metrics.

Few studies have examined the health effects that could be achieved by changing target levels. Each of the core metrics has established cost-effectiveness or is cost saving with the exception of screening for undiagnosed diabetes, wherein some degree of targeting by age and risk is required to make it cost-effective (47, 60). Quality improvement programs have achieved reductions in HbA1c, blood pressure, and lipid levels that would be expected to reduce CVD incidence and all-cause mortality by 40% (68). Similarly, model-based estimates from a recent Lancet Commission also suggest that the application of integrated care to improve diabetes care and prevention targets could reduce cardiovascular (CVD) complications of diabetes by half and for those with poor control, increase life expectancy by 5 years from age 40 (2). A recent study using STEPwise approach to NCD risk factor surveillance data from 67 LMICs and microsimulation modelling found that enhancing diagnosis and glycaemic control leads to 8 to 18% reduction in microvascular outcomes (neuropathy, ESKD, retinopathy) while meeting blood pressure and statin targets has similar effects on macrovascular outcomes (60). Achieving 60% on diagnosis, treatment, and all three control metrics (glycaemia, blood pressure, and statin use) reduces CVD deaths by >40%, consistent with findings from a recent Lancet Commission (2).

Recommending Target Levels for Metrics

Selection of target levels ultimately requires a difficult balance between being ambitious yet attainable. Table 4 presents proposed target levels for the core metrics. Our review suggests that target levels of 80% for the proportion of persons with diabetes who are diagnosed, and among those with diagnosed diabetes, 80%, 80%, and 60% meeting targets for HbA1c (<8%), blood pressure (<140/90mmHg), and statin use, respectively are achievable and would have large health benefits in many countries of the world. The gaps between current levels of attainment and the proposed targets vary considerably by region and country of the world. These target levels are generally consistent with the top 85 to the 100th percentile of countries of the world that currently have data.

Based on current estimates, meeting the target of 80% of persons with diabetes being diagnosed will require an average 19 percentage point (PPT) increase, ranging from 6 to 25 PPT across regions. Current levels of attainment of 80% of patients with diagnosed diabetes having glycemic control < 8% will require a 12% PPT increase, ranging from 3 to 25 PPTs across regions; achieving the goal of blood pressure <140/80mmHg are highly variable and will require a 24 PPT increase globally and require an increase of 2 to 35 PPTs across regions. Current levels of attainment of the statin target are considerably below 60%, ranging from 10% to 25% across all regions outside of North America, where it is 57%. Thus, meeting the statin target will likely require substantial country-level policy actions, and country-specific target setting may again be appropriate. For the insulin availability metric, we propose an ambitious target of 100% because of insulin's essential role in survival of persons with type 1 diabetes.

Setting targets for the complementary targets of incidence of diagnosed diabetes, and among persons with diagnosed diabetes, LEAs, ESKD, and mortality rates is difficult because of the high degree of baseline variability and the further needs in standardization of metrics. However, preliminary data suggests that country-level relative reductions of 50% over 10 years may be appropriate.

Monitoring and Achieving Global Targets

Long-term success of the *Global Diabetes Compact* will also depend upon consistent and accurate monitoring of the targets accompanied by continued support and strengthening of comprehensive NCD surveillance systems. The assessment of core targets of percent diagnosed and percent with HbA1c and blood pressure control and statin use can be conducted via population-based surveys such as STEPs with inclusion of HbA1c and blood pressure measurement for people with previously diagnosed diabetes. However, many STEPS surveys lack adequate sample sizes to monitor trends within countries, with precision, over time. Additionally, frequency and country-coverage of STEPs surveys is limited. Although population monitoring of insulin availability remains a challenge, it can be improved via other surveillance systems such as the WHO biennial Country Capacity survey and the WHO MedMon surveys for monitoring health service availability and prices of medicines (50, 69)

(70-73). However, to be effective for monitoring, many of these surveys require increased geographical reach and frequency of data collection. Thus, for optimal monitoring of core, complementary, and future metrics should be complemented by other national surveys, data pooling studies, health systems-based registries, and new WHO efforts supporting facility-based monitoring of quality of care. Such expansion will also require further consensus-based development of standardized definitions, methods, and target levels. Unfortunately, there is great variation and disparities in the availability of population-based data; LMICs often lack population data apart from in those who conduct STEPs surveys, making the complementary metrics especially lacking. This underscores the need for concentrated efforts to develop new efficient ways of measuring levels of risk, care, and disease in populations.

The *Compact* focuses most on metrics which reflect diagnosis and reduction of reducing complications through risk factor control and access to essential medications for persons with diabetes. However, they should be viewed in the context of broader approaches to prevent and control NCDs by ensuring health care access and strengthening health systems around primary care to reduce modifiable risk factors and address underlying social determinants of health (27). The Compact supports the implementation of the six work streams and complements NCD targets of the WHO Global action plan for the prevention and control of NCDs. It is also supported by recent Lancet Commissions addressing the global challenges of using data to transform diabetes care globally and in Sub-Saharan Africa (2, 6, 27, 74). Priorities of the Global Action Plan range from scaling up diagnosis and medication availability to improving skills and competencies, and to building clinical decision supports and population monitoring systems (Table 5). They are also an extension of the targets on treatment coverage of people at risk of heart attacks and strokes; reduction in the prevalence of raised blood pressure and availability and affordability of essential medicines and basic technologies to treat major noncommunicable diseases. The breadth of the diabetes challenge also calls for efforts to reduce diabetes incidence through a combination of individual-targeted and population-wide approaches. Thus, the metrics should not be viewed as covering the comprehensive set of objectives necessary to impact the full breadth of the current diabetes problem. However, achieving them can be expected to make an important impact on the global burden caused by diabetes.

Summary: The WHO Global Diabetes Compact aims to unite key international stakeholders around ambitious but achievable goals that will lead to a reduction in the diabetes burden. This report prioritises the core and complementary metrics to serve as catalysts for action and a framework for monitoring progress toward the core metrics of improving diagnosis, HbA1c, blood pressure, statin use, and for T1DM, ensuring insulin and supplies. The targets represent key conduits to long-term health for people with diabetes, achieving them can be expected to lead to substantial population-level reductions of diverse macrovascular, microvascular, acute complications for both T1DM and T2DM. In addition, developing improved data systems that can measure complementary metrics will be of great value in LMICs as such data are currently lacking. Most important, the development and innovation in health financing, access to care, improving health systems and promotion can pay off in health outcomes for the metrics being promoted. Achieving the overarching goals of the *Global Diabetes Compact* will require multi-sectoral efforts applied to individuals, health systems, policies, and country-level actions.

FIGURE AND TABLE LEGENDS

Figure 1. Proposed core, complementary, and base metrics for the *Global Diabetes Compact*.

Legend: Recommended core metrics shown in black, complementary metrics in blue, and base metrics in green. The core metrics are intended for priority implementation by UN member states and monitoring by the *Global Diabetes Compact*. The complementary metrics currently lack adequate global data availability or consensus-based definitions but should be considered for scale-up in population health data and surveillance systems.

Table 1. Range of potential metrics for the *Global Diabetes Compact*, stratified by domain and risk tiers.

Table 2. Median levels of percent of the population attaining target levels for core metrics for all regions of the world, and according to world region.

Legend: Estimates assembled from four primary types of sources: IDF Diabetes Atlas, Global Health and Population Project on Access to Care for Cardiometabolic diseases (HPACC) collaborators, literature reviews, and web-sites containing estimates from national diabetes surveillance systems. References listed in Appendix.

Table 3. Published estimates for complementary metrics among people with diabetes in WHO member states.

Legend: DM: diabetes mellitus; IR: Incidence rate; ESRD: End stage renal disease; DKA: diabetes keto-acidosis.(39, 54, 75-107) (108)

Table 4. Summary of global medians, 90th percentiles, and proposed targets for core metrics of the *Global Diabetes Compact*.

Legend: Estimates assembled from four primary types of sources: IDF Diabetes Atlas, Global Health and Population Project on Access to Care for Cardiometabolic diseases (HPACC) collaborators, literature reviews, and web-sites containing estimates from national diabetes surveillance systems. References listed in Appendix.

Box 1. Diabetes-relevant priorities of the Global Action Plan for the Prevention of Non-Communicable Diseases.

Legend: Based on World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013-2020. World Health Organization. 2013.

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EG designed and wrote most of the manuscript and coordinated data collection. JB, BG, and RM collected data and conducted literature reviews. MA, JD, LL, JMG, NS, GR, SS, and JPS served on consensus-based work group prioritising metrics, reviewed data, and contributed to writing and reviewing the manuscript. JM, DF, and JD assimilated data for HPACC and DF analysed data and coordinated contributions of the HPAAC team.

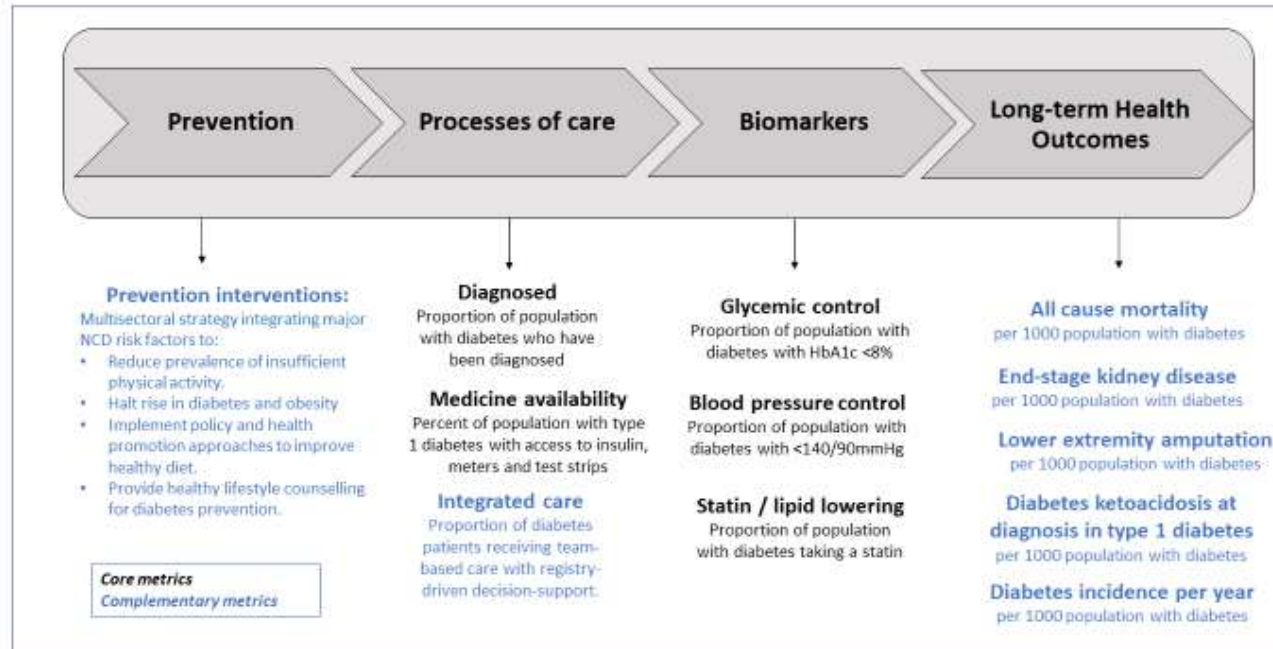
The Global Health and Population Project on Access to Care for Cardiometabolic diseases (HPACC) collaborators contributed important data from population surveys that contributed to the recommendation of target levels and review by the Diabetes Targets Expert Consultation Group. All HPACC authors reviewed the manuscript and provided critical feedback.

Table 1: Potential metrics for the *Global Diabetes Compact*, stratified by domain and risk tiers.

Population Segment	Structural, system, or policy factors	Processes of care	Biomarkers and Behaviours	Health events and outcomes
Diagnosed diabetes	National or regional DM registry Guidelines and dissemination efforts Presence of Decision support tools Facilities with essential medicines Policies for low cost medication availability	Diagnosis of diabetes Receiving treatment among diagnosed Availability of essential medicines Team-based care Statin use Diabetes education Vaccinations Foot exam Eye exam Renal testing	Glycaemic control Controlled blood pressure Controlled lipids Microalbuminuria	Diabetes prevalence Diabetes incidence Hyperglycaemic emergencies DM-related death DM-related hospitalisation CKD prevalence Incidence of LEA Retinopathy prevalence Incidence of ESKD Incidence of CVD events Incidence of CVD death
High risk	Support for nutritional counselling Support for structured LSI Guidelines for testing and referral	Structured lifestyle programme Counselling for diet/exercise Testing for diabetes Metformin prescriptions Glycaemic assessments for GDM	Intermediate hyperglycaemia Controlled blood pressure Controlled Lipids Body mass index	Diabetes prevalence Diabetes incidence
Whole population	Facilities with essential medicines Promotion of healthy diet Policy to increase physical activity Incentives for healthy diet programmes Food policy taxation (SSBs) Policies for smoking prevention	Smoking cessation services Proportion of population with healthcare coverage for DM and CVD risk factors	Physical activity levels Body mass index Fruit and vegetable consumption	Diabetes prevalence Diabetes incidence

GDM: gestational diabetes mellitus; LEA: lower extremity amputation; CKD: chronic kidney disease; ESKD: end stage kidney disease; SSB: sugar-sweetened beverages; LSI lifestyle intervention; DM: diabetes mellitus

Figure 1. Proposed core, complementary, and base metrics for the *Global Diabetes Compact*.



Recommended core metrics shown in black and complementary metrics in blue. The core metrics are intended for priority implementation by UN member states and monitoring by the *Global Diabetes Compact*. The complementary metrics currently lack adequate global data availability or consensus-based definitions but should be considered for scale-up in population health data and surveillance systems.

Table 2. Median levels of percent of the population attaining target levels for core metrics for all regions of the world, and according to world region.

		Diagnosed / total diabetes population	Glycaemic control (HbA1c <8%) / diagnosed diabetes (%)	Blood pressure control (<140/90mmHg) / diagnosed diabetes	Statin / diagnosed diabetes population
All regions	Mean	61.1	66.8	54.0	22.8
All regions	Median	61.4	67.6	55.6	12.3
All regions	IQR	22.2	15.3	20.9	25.8
East Asia & Pacific		54.9	58.9	54.7	12.3
Europe & Central Asia		74.0	77.1	50.0	12.1
Latin America & Caribbean		71.8	68.2	65.4	10.0
Middle East & North Africa		58.9	67.6	50.8	25.1
North America		69.7	75.5	78.3	56.8
South Asia		56.3	67.3	52.8	13.4
Sub-Saharan Africa		57.6	54.7	44.8	23

Table 3. Summary of developmental metrics among people with diabetes in WHO member states.

Country	Income	DM IR†	All-cause mortality rate §		ESRD IR†	LEA IR†	DKA Prevalence
			Male	Female			
East Asia & Pacific							
Australia	HIC	30.0	3070	2630	-	35.0	24.9
Japan	HIC	88	-	-	-	-	-
New Zealand	HIC	-	-	-	-	-	26.3
Singapore	HIC	70.2	-	-	-	-	-
South Korea	HIC	54.9	940*	-	-	-	-
Data unavailable for 24 countries							
Europe & Central Asia							
Austria	HIC	-	-	-	-	-	38.0
Czechia	HIC	-	-	-	-	-	28.8
Denmark	HIC	31.6	4560	4460	-	-	20.7
Finland	HIC	35	4260*	-	-	4.8	-
France	HIC	79.5	-	-	-	15.8	-
Germany	HIC	87	-	-	16.7	4.8	26.8
Hungary	HIC	40.2	4380	4000	-	-	-
Ireland	HIC	-	-	-	-	17.6	-
Italy	HIC	40	3450*	-	10.4	15.3	41.2
Latvia	HIC	31.6	5470	4380	-	-	-
Lithuania	HIC	25.5	5000	4350	-	-	-
Luxembourg	HIC	-	-	-	-	-	43.8
Netherlands	HIC	37.3	970	880	-	25.1	-
Norway	HIC	39.8	3470	3620	-	-	22.1
Portugal	HIC	97.2	-	-	-	-	-
Slovenia	HIC	-	-	-	-	-	40.3
Spain	HIC	47.1	3460	3550	5.9	34.4	-
Sweden	HIC	-	3380*	-	-	-	19.5
UK	HIC	36.9	2100	2240	15.5	4.2	25.0
Ukraine	LMIC	11.1	-	-	-	-	-
Russia	UMIC	-	2320	-	-	-	-
Data unavailable for 28 countries							
Latin America & Caribbean							
Brazil	UMIC	200	-	-	-	-	-
Colombia	UMIC	-	-	-	-	-	-
Mexico	UMIC	144	-	-	-	-	-
Peru	UMIC	195	-	-	-	-	-
Data unavailable for 27 countries							
Middle East & North Africa							
Israel	HIC	108	1070*	-	-	-	-
Data unavailable for 18 countries							
North America							
Canada	HIC	62.1	1220*	-	13.3	-	-
USA	HIC	71	6400*	-	20	28.4	36.9
South Asia: Data unavailable							
Sub-Saharan Africa: Data unavailable							

†Incidence Rates per 10,000 person-years; § Mortality rate per 100,000 people; *Total for both sexes

Table 4: Summary of global medians, 90th percentiles, and proposed targets for core metrics of the *Global Diabetes Compact*.

Core Metric	Definition	Global median (%)	Global 90th percentile (%)	Proposed Global Target (%)
Percent diagnosed	Number diagnosed divided by number with clinical diabetes	64	76	80
Glycaemic control	Number controlled (HbA1c < 8%) divided by total diagnosed diabetes	68	84	80
Blood pressure control	Number controlled (BP < 140/90) divided by total diagnosed diabetes	53	70	80
Statin treated	Number treated with statin divided by total with diagnosed diabetes	12	47	60
Medicine availability	Availability of insulin, meters, and glucose test-strips for persons with type 1 diabetes	N/A	N/A	100

Box 1. Diabetes-relevant priorities of the Global Action Plan for the Prevention of Non-Communicable Diseases.

- Scaling up diagnosis of diabetes to initiate cost-effective medical and behavioral risk factor management.
- Improving availability, affordability, and equitable access to essential medicines, including life-saving insulin, and technologies.
- Enhancing skills and capacity of health care providers to provide team-based comprehensive care for diabetes management.
- Establishing continuous quality improvement systems for disease management and prevention with an emphasis on evidence-based guidelines, treatment protocols, and decision tools.
- Improving information management and sharing across settings to optimize the ability of local data registries and electronic medical records to support clinical and health services decisions.
- Development of facility- or health-system level diabetes registries where feasible to assist in both patient care and population monitoring.

REFERENCES

1. International Diabetes Federation. Diabetes Atlas Brussels, Belgium 2021 [Ninth: [Available from: www.diabetesatlas.org.
2. Chan JCN, Lim LL, Wareham NJ, Shaw JE, Orchard TJ, Zhang P, et al. The Lancet Commission on diabetes: using data to transform diabetes care and patient lives. *Lancet*. 2021;396(10267):2019-82.
3. Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. *Lancet*. 2016;387(10027):1513-30.
4. Williams R, Karuranga S, Malanda B, Saeedi P, Basit A, Besançon S, et al. Global and regional estimates and projections of diabetes-related health expenditure: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. *Diabetes Res Clin Pract*. 2020;162:108072.
5. Bommer C, Heesemann E, Sagalova V, Manne-Goehler J, Atun R, Barnighausen T, et al. The global economic burden of diabetes in adults aged 20-79 years: a cost-of-illness study. *Lancet Diabetes Endocrinol*. 2017;5(6):423-30.
6. Atun R, Davies JI, Gale EAM, Barnighausen T, Beran D, Kengne AP, et al. Diabetes in sub-Saharan Africa: from clinical care to health policy. *Lancet Diabetes Endocrinol*. 2017;5(8):622-67.
7. Tight blood pressure control and risk of macrovascular and microvascular complications in type 2 diabetes: UKPDS 38. UK Prospective Diabetes Study Group. *BMJ*. 1998;317(7160):703-13.
8. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. *Lancet*. 1998;352(9131):837-53.
9. Jonas DE, Crotty, K., Yun J.D.Y. et al. Screening for prediabetes and type 2 diabetes: Updated evidence report and systematic review for the US Preventive Services Task Force. *JAMA*. 2021.
10. Holman N, Knighton P, O'Keefe J, Wild SH, Brewster S, Price H, et al. Completion of annual diabetes care processes and mortality: A cohort study using the National Diabetes Audit for England and Wales. *Diabetes Obes Metab*. 2021;23(12):2728-40.
11. US Guide for Community Preventive Services. Diabetes prevention and control: combined diet and physical activity promotion programs to prevent type 2 diabetes among people at increased risk (abbreviated) 2014 [Available from: www.thecommunityguide.org/diabetes/combineddietandpa.html.
12. Ali MK, Echouffo-Tcheugui J, Williamson DF. How effective were lifestyle interventions in real-world settings that were modeled on the Diabetes Prevention Program? *Health Aff (Millwood)*. 2012;31(1):67-75.
13. Gillies CL, Abrams KR, Lambert PC, Cooper NJ, Sutton AJ, Hsu RT, et al. Pharmacological and lifestyle interventions to prevent or delay type 2 diabetes in people with impaired glucose tolerance: systematic review and meta-analysis. *British Medical Journal*. 2007;334(7588):299-302B.
14. Haw JS, Galaviz KI, Straus AN, Kowalski AJ, Magee MJ, Weber MB, et al. Long-term Sustainability of Diabetes Prevention Approaches: A Systematic Review and Meta-analysis of Randomized Clinical Trials. *JAMA Intern Med*. 2017;177(12):1808-17.
15. Galaviz KI, Weber MB, Straus A, Haw JS, Narayan KMV, Ali MK. Global Diabetes Prevention Interventions: A Systematic Review and Network Meta-analysis of the Real-World Impact on Incidence, Weight, and Glucose. *Diabetes Care*. 2018;41(7):1526-34.
16. Ali M, Siegel, K., Chandrasekar, E., Tandon, N., Montoya, P., et al., editor. *Diabetes: An Update on the Pandemic and Potential Solutions*: Washington, DC: World Bank; 2021.
17. Beagley J, Guariguata L, Weil C, Motala AA. Global estimates of undiagnosed diabetes in adults for 2013 for the IDF Diabetes Atlas. *Diabetes Res Clin Pract*. 2013.
18. Manne-Goehler J, Geldsetzer P, Agoudavi K, Andall-Brereton G, Aryal KK, Bicaba BW, et al. Health system performance for people with diabetes in 28 low- and middle-income countries: A cross-sectional study of nationally representative surveys. *PLoS Med*. 2019;16(3):e1002751.
19. Chan JC, Gagliardino JJ, Baik SH, Chantelot JM, Ferreira SR, Hancu N, et al. Multifaceted determinants for achieving glycemic control: the International Diabetes Management Practice Study (IDMPS). *Diabetes Care*. 2009;32(2):227-33.
20. Fang M, Wang D, Coresh J, Selvin E. Trends in Diabetes Treatment and Control in U.S. Adults, 1999-2018. *N Engl J Med*. 2021;384(23):2219-28.
21. Ali MK, Bullard KM, Gregg EW, Del Rio C. A cascade of care for diabetes in the United States: visualizing the gaps. *Ann Intern Med*. 2014;161(10):681-9.

22. Ali MK, Bullard KM, Saaddine JB, Cowie CC, Imperatore G, Gregg EW. Achievement of goals in U.S. diabetes care, 1999-2010. *N Engl J Med*. 2013;368(17):1613-24.
23. Manne-Goehler J, Atun R, Stokes A, Goehler A, Houinato D, Houehanou C, et al. Diabetes diagnosis and care in sub-Saharan Africa: pooled analysis of individual data from 12 countries. *Lancet Diabetes Endocrinol*. 2016;4(11):903-12.
24. Ali MK, Singh K, Kondal D, Devarajan R, Patel SA, Shivashankar R, et al. Effectiveness of a Multicomponent Quality Improvement Strategy to Improve Achievement of Diabetes Care Goals: A Randomized, Controlled Trial. *Ann Intern Med*. 2016;165(6):399-408.
25. Flood D, Hane J, Dunn M, Brown SJ, Wagenaar BH, Rogers EA, et al. Health system interventions for adults with type 2 diabetes in low- and middle-income countries: A systematic review and meta-analysis. *PLoS Med*. 2020;17(11):e1003434.
26. Hunt D, Hemmingsen B, Matzke A, Varghese C, Hammerich A, Luciani S, et al. The WHO Global Diabetes Compact: a new initiative to support people living with diabetes. *Lancet Diabetes Endocrinol*. 2021;9(6):325-7.
27. Organization WH. Global action plan for the prevention and control of noncommunicable diseases 2013-2020. World Health Organization. . 2013.
28. Medlock J, Pandey A, Parpia AS, Tang A, Skrip LA, Galvani AP. Effectiveness of UNAIDS targets and HIV vaccination across 127 countries. *Proc Natl Acad Sci U S A*. 2017;114(15):4017-22.
29. Ayanian JZ, Markel H. Donabedian's Lasting Framework for Health Care Quality. *N Engl J Med*. 2016;375(3):205-7.
30. van Herten LM, Gunning-Schepers LJ. Targets as a tool in health policy. Part I: Lessons learned. *Health policy (Amsterdam, Netherlands)*. 2000;53(1):1-11.
31. Hubbard K, Talih M, Klein RJ, Huang TD. Target-setting methods in healthy people 2030. *Healthy People Statistical Notes*. 2020;28.
32. Lim LL, Lau ESH, Kong APS, Davies MJ, Levitt NS, Eliasson B, et al. Aspects of Multicomponent Integrated Care Promote Sustained Improvement in Surrogate Clinical Outcomes: A Systematic Review and Meta-analysis. *DIABETES CARE*. 2018;41(6):1312-20.
33. Alharbi NS, Alsubki N, Jones S, Khunti K, Munro N, de Lusignan S. Impact of Information Technology-Based Interventions for Type 2 Diabetes Mellitus on Glycemic Control: A Systematic Review and Meta-Analysis. *J Med Internet Res*. 2016;18(11):e310.
34. Levensgood TW, Peng Y, Xiong KZ, Song Z, Elder R, Ali MK, et al. Team-Based Care to Improve Diabetes Management: A Community Guide Meta-analysis. *Am J Prev Med*. 2019;57(1):e17-e26.
35. Tricco AC, Ivers NM, Grimshaw JM, Moher D, Turner L, Galipeau J, et al. Effectiveness of quality improvement strategies on the management of diabetes: a systematic review and meta-analysis. *Lancet*. 2012;379(9833):2252-61.
36. The TRIAD Study Group. Health systems, patients factors, and quality of care for diabetes: a synthesis of findings from the TRIAD study. *Diabetes Care*. 2010;33(4):940-7.
37. Rawshani A, Rawshani A, Franzén S, Sattar N, Eliasson B, Svensson AM, et al. Risk Factors, Mortality, and Cardiovascular Outcomes in Patients with Type 2 Diabetes. *N Engl J Med*. 2018;379(7):633-44.
38. Kontopantelis E, Springate DA, Reeves D, Ashcroft DM, Rutter MK, Buchan I, et al. Glucose, blood pressure and cholesterol levels and their relationships to clinical outcomes in type 2 diabetes: a retrospective cohort study. *Diabetologia*. 2015;58(3):505-18.
39. Gregg EW, Li Y, Wang J, Burrows NR, Ali MK, Rolka D, et al. Changes in diabetes-related complications in the United States, 1990-2010. *N Engl J Med*. 2014;370(16):1514-23.
40. Essman M, Taillie LS, Frank T, Ng SW, Popkin BM, Swart EC. Taxed and untaxed beverage intake by South African young adults after a national sugar-sweetened beverage tax: A before-and-after study. *PLoS Med*. 2021;18(5):e1003574.
41. Ali MK, Siegel KR, Laxy M, Gregg EW. Advancing Measurement of Diabetes at the Population Level. *Curr Diab Rep*. 2018;18(11):108.
42. Selby JV, Swain BE, Gerzoff RB, Karter AJ, Waitzfelder BE, Brown AF, et al. Understanding the gap between good processes of diabetes care and poor intermediate outcomes: Translating Research into Action for Diabetes (TRIAD). *MedCare*. 2007;45(12):1144-53.
43. Davies JI, Reddiar SK, Hirschhorn LR, Ebert C, Marcus ME, Seigle JA, et al. Association between country preparedness indicators and quality clinical care for cardiovascular disease risk factors in 44 lower- and middle-income countries: A multicountry analysis of survey data. *PLoS Med*. 2020;17(11):e1003268.

44. World Health Organization. WHO Guidelines Approved by the Guidelines Review Committee. Use of Glycated Haemoglobin (HbA1c) in the Diagnosis of Diabetes Mellitus: Abbreviated Report of a WHO Consultation. Geneva: World Health Organization 2011.
45. Simmons RK, Echouffo-Tcheugui JB, Sharp SJ, Sargeant LA, Williams KM, Prevost AT, et al. Screening for type 2 diabetes and population mortality over 10 years (ADDITION-Cambridge): a cluster-randomised controlled trial. *Lancet*. 2012;380(9855):1741-8.
46. Griffin SJ, Rutten G, Khunti K, Witte DR, Lauritzen T, Sharp SJ, et al. Long-term effects of intensive multifactorial therapy in individuals with screen-detected type 2 diabetes in primary care: 10-year follow-up of the ADDITION-Europe cluster-randomised trial. *Lancet Diabetes Endocrinol*. 2019;7(12):925-37.
47. Siegel KR, Ali MK, Zhou X, Ng BP, Jawanda S, Proia K, et al. Cost-effectiveness of Interventions to Manage Diabetes: Has the Evidence Changed Since 2008? *Diabetes Care*. 2020;43(7):1557-92.
48. Zhou X, Siegel KR, Ng BP, Jawanda S, Proia KK, Zhang X, et al. Cost-effectiveness of Diabetes Prevention Interventions Targeting High-risk Individuals and Whole Populations: A Systematic Review. *Diabetes Care*. 2020;43(7):1593-616.
49. Holman RR, Paul SK, Bethel MA, Neil HA, Matthews DR. Long-term follow-up after tight control of blood pressure in type 2 diabetes. *N Engl J Med*. 2008;359(15):1565-76.
50. Beran D, Lazo-Porras M, Mba CM, Mbanya JC. A global perspective on the issue of access to insulin. *Diabetologia*. 2021;64(5):954-62.
51. World Health Organization. WHO Model list of essential medicines for children - 8th list, 2021 2021 [Available from: <https://www.who.int/publications/i/item/WHO-MHP-HPS-EML-2021.03>].
52. Magliano DJ, Chen L, Islam RM, Carstensen B, Gregg EW, Pavkov ME, et al. Trends in the incidence of diagnosed diabetes: a multicountry analysis of aggregate data from 22 million diagnoses in high-income and middle-income settings. *Lancet Diabetes Endocrinol*. 2021;9(4):203-11.
53. Magliano DJ, Islam RM, Barr ELM, Gregg EW, Pavkov ME, Harding JL, et al. Trends in incidence of total or type 2 diabetes: systematic review. *Bmj*. 2019;366:15003.
54. Cherubini V, Grimsman JM, Åkesson K, Birkebæk NH, Cinek O, Dovč K, et al. Temporal trends in diabetic ketoacidosis at diagnosis of paediatric type 1 diabetes between 2006 and 2016: results from 13 countries in three continents. *Diabetologia*. 2020;63(8):1530-41.
55. Haw JS, Tantry S, Vellanki P, Pasquel FJ. National Strategies to Decrease the Burden of Diabetes and Its Complications. *Current Diabetes Reports*. 2015;15(9):65.
56. Ali MK, McKeever Bullard K, Imperatore G, Benoit SR, Rolka DB, Albright AL, et al. Reach and Use of Diabetes Prevention Services in the United States, 2016-2017. *JAMA Netw Open*. 2019;2(5):e193160.
57. Lim LL, Lau ES, Kong AP, Davies MJ, Levitt NS, Eliasson B, et al. Aspects of multicomponent integrated care promote sustained improvement in surrogate clinical outcomes: a systematic review and meta-analysis. *Diabetes Care*. 2018;41(6):1312-20.
58. Kapur A, McIntyre HD, Divakar H, Di Renzo GC, Kihara AB, McAuliffe F, et al. Towards a global consensus on GDM diagnosis: Light at the end of the tunnel? *Int J Gynaecol Obstet*. 2020;149(3):257-61.
59. The TRIAD Study Group. Health systems, patients factors, and quality of care for diabetes: a synthesis of findings from the TRIAD study. *diabetes care*. 2010;33(4):940-7.
60. Basu S, Flood D, Geldsetzer P, Theilmann M, Marcus ME, Ebert C, et al. Estimated effect of increased diagnosis, treatment, and control of diabetes and its associated cardiovascular risk factors among low-income and middle-income countries: a microsimulation model. *Lancet Glob Health*. 2021;9(11):e1539-e52.
61. Harding JL, Pavkov ME, Magliano DJ, Shaw JE, Gregg EW. Global trends in diabetes complications: a review of current evidence. *Diabetologia*. 2019;62(1):3-16.
62. Chen L, Islam RM, Wang J, Hird TR, Pavkov ME, Gregg EW, et al. A systematic review of trends in all-cause mortality among people with diabetes. *Diabetologia*. 2020;63(9):1718-35.
63. Imperatore G, Cadwell BL, Geiss L, Saadinne JB, Williams DE, Ford ES, et al. Thirty-year trends in cardiovascular risk factor levels among US adults with diabetes: National Health and Nutrition Examination Surveys, 1971-2000. *Am J Epidemiol*. 2004;160(6):531-9.
64. Centers for Disease Control and Prevention. National Diabetes Surveillance System 2016 [Available from: Available from <http://www.cdc.gov/diabetes/statistics/index.htm>].

65. Wang L, Li X, Wang Z, Bancks MP, Carnethon MR, Greenland P, et al. Trends in Prevalence of Diabetes and Control of Risk Factors in Diabetes Among US Adults, 1999-2018. *Jama*. 2021.
66. Harding JL, Pavkov ME, Gregg EW, Burrows NR. Trends of Nontraumatic Lower Extremity Amputation in End-Stage Renal Disease and Diabetes, United States, 2000-2015. *Diabetes Care*. 2019.
67. Ali MK, Pearson-Stuttard J, Selvin E, Gregg EW. Interpreting global trends in type 2 diabetes complications and mortality. *Diabetologia*. 2022;65(1):3-13.
68. Shao H, Shi L, Fonseca VA. Using the BRAVO Risk Engine to Predict Cardiovascular Outcomes in Clinical Trials With Sodium-Glucose Transporter 2 Inhibitors. *Diabetes Care*. 2020;43(7):1530-6.
69. Robertson J, Macé C, Forte G, de Joncheere K, Beran D. Medicines availability for non-communicable diseases: the case for standardized monitoring. *Globalization and health*. 2015;11:18.
70. Wang W, Winter R, Mallick L, Florey L, Burgert-Brucker C, Carter E. The relationship between the health service environment and service utilization: linking population data to health facilities data in Haiti and Malawi. Rockville, Maryland, USA: ICF International; 2015.
71. Burgert CR, Prosnitz D. Linking DHS household and SPA facility surveys: Data considerations and geospatial methods. Rockville, Maryland, USA: ICF International; 2014.
72. Assaf S, Kothari MT, Pullum T. An assessment of the quality of DHS anthropometric data, 2005-2014. Rockville, Maryland, USA: ICF International; 2015.
73. World Health Organization. MedMon - WHO Essential Medicines and Health Products Price and Availability Monitoring Mobile Application 2018 [cited 2022. Available from: <https://www.who.int/news/item/18-02-2018-medmon-mobile-application>.
74. World Health Organization. Reducing the burden of noncommunicable diseases through strengthening prevention and control of diabetes. 2021.
75. Lind M, Garcia-Rodriguez LA, Booth GL, Ceasoriano L, Shah BR, Ekeroth G, et al. Mortality trends in patients with and without diabetes in Ontario, Canada and the UK from 1996 to 2009: a population-based study. *Diabetologia*. 2013;56(12):2601-8.
76. Abouzeid M, Wikstrom K, Peltonen M, Lindstrom J, Borodulin K, Rahkonen O, et al. Secular trends and educational differences in the incidence of type 2 diabetes in Finland, 1972-2007. *European Journal of Epidemiology*. 2015;30(8):649-59.
77. Ikonen TS, Sund R, Venermo M, Winell K. Fewer major amputations among individuals with diabetes in Finland in 1997-2007: a population-based study. *diabetes care*. 2010;33(12):2598-603.
78. Boehme MW, Buechele G, Frankenhauser-Mannuss J, Mueller J, Lump D, Boehm BO, et al. Prevalence, incidence and concomitant comorbidities of type 2 diabetes mellitus in South Western Germany - a retrospective cohort and case control study in claims data of a large statutory health insurance. *BMC Public Health*. 2015;15:855.
79. Karpati T, Cohen-Stavi CJ, Leibowitz M, Hoshen M, Feldman BS, Balicer RD. Towards a subsiding diabetes epidemic: trends from a large population-based study in Israel. *Popul Health Metr*. 2014;12(1):32.
80. Lombardo FL, Maggini M, De Bellis A, Seghieri G, Anichini R. Lower extremity amputations in persons with and without diabetes in Italy: 2001-2010. *PLoS One*. 2014;9(1):e86405.
81. Almaraz MC, Gonzalez-Romero S, Bravo M, Caballero FF, Palomo MJ, Vallejo R, et al. Incidence of lower limb amputations in individuals with and without diabetes mellitus in Andalusia (Spain) from 1998 to 2006. *Diabetes Res Clin Pract*. 2012;95(3):399-405.
82. Zghebi SS, Steinke DT, Carr MJ, Rutter MK, Emsley RA, Ashcroft DM. Examining trends in type 2 diabetes incidence, prevalence and mortality in the UK between 2004 and 2014. *Diabetes, Obesity & Metabolism*. 19(11):1537-45.
83. Harding JL, Shaw JE, Peeters A, Davidson S, Magliano DJ. Age-Specific Trends From 2000-2011 in All-Cause and Cause-Specific Mortality in Type 1 and Type 2 Diabetes: A Cohort Study of More Than One Million People. *Diabetes Care*. 2016;39(6):1018-26.
84. Schmidt MI, Bracco PA, Yudkin JS, Bensenor IM, Griep RH, Barreto SM, et al. Intermediate hyperglycaemia to predict progression to type 2 diabetes (ELSA-Brasil): an occupational cohort study in Brazil. *Lancet Diabetes Endocrinol*. 2019;7(4):267-77.
85. Lok CE, Oliver MJ, Rothwell DM, Hux JE. The growing volume of diabetes-related dialysis: a population based study. *Nephrol Dial Transplant*. 2004;19(12):3098-103.
86. Guerrero-Núñez S, Valenzuela-Suazo S, Cid-Henríquez P. Effective Universal Coverage of

- Diabetes Mellitus Type 2 in Chile. *Rev Lat Am Enfermagem*. 2017;25:e2871.
87. Monesi L, Baviera M, Marzona I, Avanzini F, Monesi G, Nobili A, et al. Prevalence, incidence and mortality of diagnosed diabetes: evidence from an Italian population-based study. *Diabet Med*. 2012;29(3):385-92.
88. Forssas E, Keskimäki I, Reunanen A, Koskinen S. Widening socioeconomic mortality disparity among diabetic people in Finland. *Eur J Public Health*. 2003;13(1):38-43.
89. Fuentes S, Mandereau-Bruno L, Regnault N, Bernillon P, Bonaldi C, Cosson E, et al. Is the type 2 diabetes epidemic plateauing in France? A nationwide population-based study. *Diabetes Metab*. 2020;46(6):472-9.
90. Fosse S, Hartemann-Heurtier A, Jacqueminet S, Ha Van G, Grimaldi A, Fagot-Campagna A. Incidence and characteristics of lower limb amputations in people with diabetes. *Diabet Med*. 2009;26(4):391-6.
91. Bruno G, Biggeri A, Merletti F, Bargerò G, Ferrero S, Pagano G, et al. Low incidence of end-stage renal disease and chronic renal failure in type 2 diabetes: a 10-year prospective study. *Diabetes Care*. 2003;26(8):2353-8.
92. Goto A, Goto M, Noda M, Tsugane S. Incidence of type 2 diabetes in Japan: a systematic review and meta-analysis. *PLoS One*. 2013;8(9):e74699.
93. Pildava S, Strēle I, Briģis G. The mortality of patients with diabetes mellitus in Latvia 2000-2012. *Medicina (Kaunas)*. 2014;50(2):130-6.
94. González-Villalpando C, Dávila-Cervantes CA, Zamora-Macorra M, Trejo-Valdivia B, González-Villalpando ME. Incidence of type 2 diabetes in Mexico: results of the Mexico City Diabetes Study after 18 years of follow-up. *Salud Publica Mex*. 2014;56(1):11-7.
95. Dale AC, Vatten LJ, Nilsen TI, Midthjell K, Wiseth R. Secular decline in mortality from coronary heart disease in adults with diabetes mellitus: cohort study. *BMJ*. 2008;337:a236.
96. Carrillo-Larco RM, Bernabé-Ortiz A. [Type 2 diabetes mellitus in peru: a systematic review of prevalence and incidence in the general population]. *Rev Peru Med Exp Salud Publica*. 2019;36(1):26-36.
97. Comas J, Arcos E, Castell C, Cases A, Martínez-Castelao A, Doñate T, et al. Evolution of the incidence of chronic kidney disease Stage 5 requiring renal replacement therapy in the diabetic population of Catalonia. *Nephrol Dial Transplant*. 2013;28(5):1191-8.
98. Rawshani A, Rawshani A, Gudbjörnsdóttir S. Mortality and Cardiovascular Disease in Type 1 and Type 2 Diabetes. *N Engl J Med*. 2017;377(3):300-1.
99. Heintjes EM, Houben E, Beekman-Hendriks WL, Lighaam E, Cremers SM, Penning-van Beest FJA, et al. Trends in mortality, cardiovascular complications, and risk factors in type 2 diabetes. *Neth J Med*. 2019;77(9):317-29.
100. van Houtum WH, Lavery LA. Regional variation in the incidence of diabetes-related amputations in The Netherlands. *Diabetes Res Clin Pract*. 1996;31(1-3):125-32.
101. Zghebi SS, Steinke DT, Carr MJ, Rutter MK, Emsley RA, Ashcroft DM. Examining trends in type 2 diabetes incidence, prevalence and mortality in the UK between 2004 and 2014. *Diabetes Obes Metab*. 2017;19(11):1537-45.
102. Canavan RJ, Unwin NC, Kelly WF, Connolly VM. Diabetes- and nondiabetes-related lower extremity amputation incidence before and after the introduction of better organized diabetes foot care: continuous longitudinal monitoring using a standard method. *Diabetes Care*. 2008;31(3):459-63.
103. Yashkin AP, Picone G, Sloan F. Causes of the change in the rates of mortality and severe complications of diabetes mellitus: 1992-2012. *Med Care*. 2015;53(3):268-75.
104. Weng W, Liang Y, Kimball ES, Hobbs T, Kong SX, Sakurada B, et al. Decreasing incidence of type 2 diabetes mellitus in the United States, 2007-2012: Epidemiologic findings from a large US claims database. *Diabetes Res Clin Pract*. 2016;117:111-8.
105. Icks A, Haastert B, Genz J, Giani G, Hoffmann F, Trapp R, et al. Incidence of renal replacement therapy (RRT) in the diabetic compared with the non-diabetic population in a German region, 2002-08. *Nephrol Dial Transplant*. 2011;26(1):264-9.
106. de Sousa-Uva M, Antunes L, Nunes B, Rodrigues AP, Simões JA, Ribeiro RT, et al. Trends in diabetes incidence from 1992 to 2015 and projections for 2024: A Portuguese General Practitioner's Network study. *Prim Care Diabetes*. 2016;10(5):329-33.
107. Buckley CM, O'Farrell A, Canavan RJ, Lynch AD, De La Harpe DV, Bradley CP, et al. Trends in the incidence of lower extremity amputations in people with and without diabetes over a five-year period in the Republic of Ireland. *PLoS One*. 2012;7(7):e41492.