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Comparing Approaches for Deriving Diabetes Care Cascades to Inform Policy: A Cross-sectional Analysis Using National Data From 88 Countries

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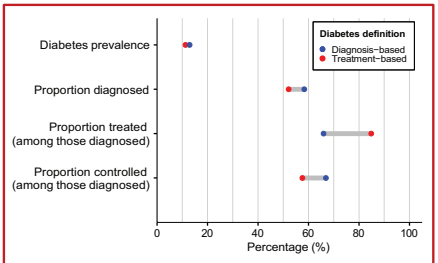
1 Background

Care cascade indicators are widely used to monitor and guide national diabetes control efforts. However, diabetes definitions used to derive care cascades currently vary.

2 Methods

- We analyzed nationally representative data of 800,348 individuals aged ≥25 years from 88 countries in 2008–2021
- We compared two diabetes definitions: biomarkers and self-reported diagnosis versus biomarkers and self-reported treatment
- For each definition, we calculated the proportion of individuals who were diagnosed, received treatment, and attained glycemic control

3 Results



- Using the diagnosis-based rather than treatment-based diabetes definition increased percentages of individuals who attain diagnosis and control stages by 11% and 16%, respectively, but decreased percentages receiving treatment by 22%
- Depending on diabetes definition, 22% versus 6% of countries met the WHO 80%-control target

4 Conclusions

Care cascade estimates diverged substantially and consistently across diabetes definitions, skewing policy implications in predictable ways. Harmonizing indicators may improve decision-making.

WHO, World Health Organization.

ARTICLE HIGHLIGHTS

- **Why did we undertake this study?**
  Care cascade indicators are widely used to monitor and guide national diabetes control efforts. However, diabetes definitions used to derive care cascades currently vary, which could impact policy decisions.
- **What are the specific questions we wanted to answer?**
  We examined how care cascade estimates differ across two commonly used diabetes definitions.
- **What did we find?**
  Across diabetes definitions, care cascade estimates consistently diverged in the same direction, on average by ~10–20%. The choice of diabetes definition predictably skewed policy implications toward either expanded screening or treatment.
- **What are the implications of our findings?**
  Harmonizing diabetes performance metrics may improve decision-making and facilitate cross-country comparisons.

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ORIGINAL ARTICLE

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OBJECTIVE

Care cascade indicators are widely used to monitor national diabetes control efforts. However, diabetes definitions used to derive care cascades vary across studies, which may markedly affect results and subsequent policy decisions. Here, we examine the magnitude of resultant differences between approaches.

RESEARCH DESIGN AND METHODS

We analyzed nationally representative, cross-sectional data of 800,348 individuals aged ≥25 years from 88 countries in 2008–2021. We used two different diabetes definitions: elevated biomarkers (glycated hemoglobin [HbA_{1c}] ≥6.5%; fasting plasma glucose ≥7.0 mmol/L; or random plasma glucose ≥11.1 mmol/L) or self-reported diagnosis ("diagnosis-based definition") versus elevated biomarkers or self-reported treatment ("treatment-based definition"). Care cascade estimates included *1*) proportions of individuals with diabetes who were diagnosed, and proportions of individuals with diagnosed diabetes who *2*) received treatment and *3*) attained glycemic control. We benchmarked results against World Health Organization (WHO) diabetes targets.

RESULTS

Diabetes prevalence was 12.9% (95% CI 12.1–13.8) applying the diagnosis-based definition and 11.3% (95% CI 10.5–12.1) with the treatment-based definition. Using the diagnosis-based rather than treatment-based diabetes definition to derive care cascades consistently increased the percentages of those who attain diagnosis and control stages but decreased percentages of those receiving treatment. Across countries, median differences between approaches were 11.3% (interquartile range [IQR] 5.1–24.7) for diabetes diagnosis, 21.6% (IQR 14.5–37.8) for treatment, and 16.4% (IQR 7.8–26.8) for control. The WHO 80% glycemic control target was met by 22% versus 6% of countries when using the diagnosis-based versus treatment-based definition, respectively.

CONCLUSIONS

Care cascade estimates diverged substantially and consistently across diabetes definitions, skewing policy implications in predictable ways. Harmonizing diabetes performance metrics may improve decision-making and facilitate cross-country comparisons.

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The global burdens of diabetes and other noncommunicable diseases (NCDs) continue growing (1). To guide effective health system responses, robust surveillance and monitoring efforts are essential. Empirical assessments of health system performance for NCDs commonly entail national estimates of care cascades (also called care continua) (2). Care cascades describe the proportion of individuals with a disease who are diagnosed, and among those diagnosed, the proportions who are treated and who attain disease control. Originally conceived for hypertension (3) and later used to benchmark the global HIV response (4), the care cascade has been a cornerstone of NCD surveillance for at least three decades (5). Recently, this set of indicators gained further relevance as part of the first-ever global diabetes targets, which World Health Organization (WHO) member states endorsed after a systematic expert-led target-setting process through the Global Diabetes Compact (GDC) initiative (6). However, consensus on the derivation of care cascades is lacking in the extant literature.

Diabetes care cascades are typically estimated using cross-sectional, nationally or regionally representative health surveys with data on diabetes biomarkers and self-reported diagnosis and treatment status (7,8). Such survey data are needed because diabetes prevalence cannot be reliably estimated from medical records, particularly in settings without electronic health record systems. However, definitions of diabetes used in the derivation of care cascades currently vary across countries and studies, with the potential to markedly affect results and lead to different policy decisions. While some studies identify individuals with diabetes based on elevated biomarkers or self-reported diagnosis (9–14), other studies identify individuals with diabetes based on elevated biomarkers or self-reported treatment (2,7,15–19). Beyond diabetes prevalence estimates, this difference in diabetes definitions can propagate across subsequent care cascade steps. The resulting variability likely impedes evidence-based decision-making, for example, when policymakers must prioritize between investing in screening campaigns, expanding access to treatments, or pursuing other disease-control strategies (20). Similarly, inflated estimates of health system performance can lead stakeholders to scale back efforts toward achieving targets, such as the WHO 80% targets for diabetes diagnosis and glycemic control (6). To date, no study has quantified how findings from those two different approaches for deriving diabetes care cascades diverge.

Using nationally representative data from 88 low-, middle-, and high-income countries, we examined theoretical and empirical differences between two commonly used approaches for deriving diabetes care cascades. Our findings can inform future efforts aimed at improving the monitoring and control of diabetes and other NCDs globally.

RESEARCH DESIGN AND METHODS

Study Design

In this cross-sectional study, we pooled and harmonized individual-level data from 89 nationally representative surveys in 88 low-, middle-, and high-income countries (Zanzibar and mainland Tanzania conducted separate surveys, although both are part of Tanzania). The systematic data search process is summarized in the Supplementary Fig. 1 and further detailed elsewhere (21). Surveys were considered eligible for this study if they *1*) contained individual-level data; *2*) were nationally representative; *3*) were done during or after 2009; and *4*) included a diabetes biomarker (blood glucose or glycated hemoglobin [HbA_{1c}]). Detailed sampling strategies of each survey are listed in Supplementary Table 1.

The Emory University Institutional Review Board (Atlanta, Georgia) classified this study as not human subjects research on 14 June 2024, so no further ethical approval was required. Participants provided informed consent prior to data collection.

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Participants

Our sample included all nonpregnant individuals aged ≥25 years old with complete data on diabetes biomarkers (measured blood glucose or HbA_{1c}), self-reported diabetes diagnosis, and glucose-lowering medication use (Supplementary Fig. 2). Since various surveys had a minimum age limit of 25 years, we restricted the entire sample to this age threshold to harmonize our sample across countries.

PROCEDURES

Data were collected by trained research teams visiting participants' households. Biomarkers to ascertain diabetes status included HbA_{1c}, laboratory-based assessment of fasting plasma glucose, and point-of-care capillary glucose (Supplementary Table 2) (21). Based on extant evidence-based recommendations (22), capillary glucose measurements were multiplied by a factor of 1.11 to calculate plasma equivalents. All surveys, except the Indian National Family and Health Survey 2019–21, required ≥8 h of fasting prior to blood glucose testing.

Outcomes

We used two different but commonly used definitions to identify individuals with diabetes for inclusion in care cascades: *1*) elevated biomarkers or a self-reported diabetes diagnosis (diagnosis-based definition); and *2*) elevated biomarkers or self-reported use of glucose-lowering medicines (treatment-based definition) (Table 1). We defined elevated diabetes biomarkers based on the following WHO diagnostic thresholds: HbA_{1c} ≥6.5%; fasting plasma glucose (FPG) ≥7.0 mmol/L (126 mg/dL); or random plasma glucose (RPG) ≥11.1 mmol/L (200 mg/dL) (23). FPG was prioritized over HbA_{1c} among individuals for whom both measures were available, given comparatively higher sensitivity and specificity of FPG for identifying individuals with diabetes (24). Prior diabetes diagnosis by a health care worker and current use of prescribed medications for diabetes (insulin or other glucose-lowering medicines) were based on self-report. Survey items on diabetes diagnosis and medication use are nested, so all participants using medication were also diagnosed. Using a combination of diagnosis and medication use to define diabetes would therefore not yield an independent third definition.

We used each of the two diabetes definitions to calculate diabetes care cascades; that is, the proportion of all individuals with diabetes who were diagnosed, received pharmacological treatment (among those diagnosed), and attained glycemic control (among those diagnosed), consistent with the WHO GDC (6). Glycemic control was defined as HbA_{1c} <8%, FPG <9.3 mmol/L (167 mg/dL), or RPG <10.0 mmol/L (180 mg/dL) (6,25,26). In line with clinical guidelines on diabetes management (25), we used HbA_{1c} to define glycemic control for individuals with more than one biomarker. In sensitivity analyses, we *1*) exclusively used FPG to identify individuals with diabetes, and *2*) stratified care cascades by biomarker in a subsample of 14 countries with data on both HbA_{1c} and FPG. The main outcomes of this study were the absolute and relative differences in estimates of diabetes prevalence, diagnosis, treatment, and control between the two alternative diabetes definitions.

Statistical Analysis

Our analysis was conducted in six steps. First, we categorized individuals with diabetes into mutually exclusive subgroups based on the four binary variables defining the care cascade: elevated biomarkers, diagnosis, treatment, and glycemic control. Second, we used these subgroups to algebraically illustrate the numerator and denominator of each cascade step and to highlight differences between diagnosis-based and treatment-based definitions of diabetes. Third, using nationally representative data from 88 countries, we empirically quantified absolute and relative differences in diabetes prevalence, diagnosis, treatment, and control between diabetes definitions. Fourth, we disaggregated care cascades by country and calculated the median, minimum, maximum, and interquartile range (IQR) of country-level care cascade differences across the two approaches. Fifth, we descriptively examined sociodemographic, clinical, and health behavioral characteristics among different subgroups of individuals with diabetes. We also disaggregated diabetes care cascades by World Bank country income classification (low-, lower-middle-, upper-middle-, and high-income country). Sixth, we mapped country-level estimates against diagnosis and control targets from the WHO GDC (6), which recommend 80% of individuals with diabetes are diagnosed, and 80% of individuals with diagnosed diabetes attain glycemic control, respectively.

All analyses were restricted to participants with complete data on diabetes biomarkers, diagnosis, and treatment. We accounted for clustered and stratified data sampling and calculated descriptive statistics using sampling weights that adjust for nonresponse and selection probabilities. We rescaled sampling weights inversely to the sample size of the respective survey to ensure equal contribution from each country in the analysis. Statistical analyses were computed using Stata 15.1 and R 4.2.2 software.

RESULTS

Our final study sample included 800,348 individuals aged ≥25 years old with complete data on diabetes biomarkers, self-reported diagnosis, and medication use (Supplementary Fig. 2). Data were collected between 2008 and 2021 in 15 low-, 59 middle-, and 14 high-income countries. The median response rate across surveys was 88.0% (Supplementary Table 3).

Using the diagnosis-based definition, we identified 55,458 individuals with diabetes compared with 45,543 individuals when using the treatment-based definition. These numbers correspond to a weighted diabetes prevalence of 12.9% (95% CI 12.1–13.8) and 11.3% (95% CI 10.5–12.1), respectively (Fig. 1). Differences between the diagnosis-based and treatment-based definition of diabetes were exclusively driven by individuals in group E (Table 1) that had the following characteristics: *1*) glycemic levels below diagnostic threshold for diabetes, *2*) reporting a diabetes diagnosis, and *3*) reporting no use of glucose-lowering medication. Individuals in group E were designated as having diabetes when using the diagnosis-based diabetes definition, but not in the treatment-based diabetes definition. In our aggregated data set of 88 countries, group E comprised 9,915 participants.

Variation across the two disease definitions propagated when calculating care cascades (Table 2). Using the diagnosis-based rather than treatment-based diabetes definition to identify individuals with diabetes increased the proportion who were diagnosed from 52.1% (95% CI

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Table 1—Subgroups of individuals with diabetes

Group label	Elevated biomarkers*	Diagnosed	Treated	Glycemic control†	Diagnosis-based diabetes definition	Treatment-based diabetes definition	No.
A	Yes	Yes	Yes	Yes (A1) or No (A2)	Included	Included	4,040 (A1); 9,050 (A2)
B	Yes	Yes	No	Yes (B1) or No (B2)	Included	Included	1,042 (B1); 1,716 (B2)
C	Yes	No	No	n.a.‡	Included	Included	20,056
D	No	Yes	Yes	Yes	Included	Included	9,639
E	No	Yes	No	Yes	Included	*Excluded*	9,915

Five subgroups of people with diabetes based on mutually exclusive combinations of four binary variables used to define care cascades. While the diagnosis-based diabetes definition considers individuals in group E as having diabetes, the treatment-based diabetes definition assumes that individuals in group E do not have diabetes. The composition of diabetes care cascade steps based on these five subgroups is shown in Table 2. Only individuals who reported a diabetes diagnosis were asked whether they currently use any prescribed glucose-lowering medicines. n.a., not applicable. *HbA_{1c} ≥6.5% or FPG ≥7 mmol/L or RPG ≥11.1 mmol/L. †HbA_{1c} <8% or FPG <9.3 mmol/L or RPG <10.0 mmol/L. ‡Group C is not part of the denominator for diabetes control.

50.3–54.0) to 58.3% (95% CI 56.6–60.1%) and the proportion controlled among those diagnosed from to 57.6% (95% CI 55.2–59.9) to 66.9% (95% CI 64.8–69.0), whereas the proportion receiving treatment among those diagnosed decreased from 84.8% (95% CI 81.6–87.6) to 66.0% (95% CI 63.2–68.6) (Fig. 1 and Supplementary Table 4).

When disaggregating our results by country, we found large variation in the impact of competing disease definitions on diabetes care cascades (Fig. 2). Care cascade estimates differed between definitions by a median of 5.1 percentage points (ppt) for diagnosis (IQR 3.1–8.3), 17.7 ppt for treatment (IQR 12.3–29.8), and 8.9 ppt for control (IQR 4.8–13.9); that is, 11.3% (IQR 5.1–24.7), 21.6% (IQR 14.5–37.8), and 16.4% (IQR 7.8–26.8) in relative terms, respectively (Supplementary Table 5). In some countries, such as Nepal, Libya, and China, care cascade estimates differed by <5 ppt between the two approaches. The largest absolute difference in diabetes prevalence was seen in Kazakhstan (12.6% vs. 19.9%). The difference between definitions in the proportion of diagnosed individuals was largest in the Solomon Islands (12.2% vs. 40.5%). Similarly, the proportion of individuals with diagnosed diabetes who received treatment was 86.5% vs. 39.0% in Kenya, and the proportion achieving glycemic control was 52.0% vs. 90.2% in the Solomon Islands.

When the diagnosis-based diabetes definition was used, 11 of the 88 countries (13%) met the WHO GDC 80% diagnosis target compared with 7 (8%) when the treatment-based diabetes definition was used (Fig. 2). The 80% glycemic control target was met by 19 countries (22%) when the diagnosis-based diabetes definition was used compared with 5 countries (6%) when the treatment-based diabetes definition was used, representing a 3.8-fold difference.

Next, we characterized the 9,915 participants in group E (Supplementary Table 6), who underlie differences across disease definitions and care cascade estimates. Compared with all other individuals with diabetes (groups A–D), these individuals on average were younger (47.6 [95% CI 46.8–48.5] years vs. 50.9 [95% CI 50.4–51.5] years), more often female (60.6% [95% CI 57.8–63.2] vs. 53.6% [95% CI 52.5–54.7]), and more educated. BMI did not differ between groups, but mean waist circumference (97.0

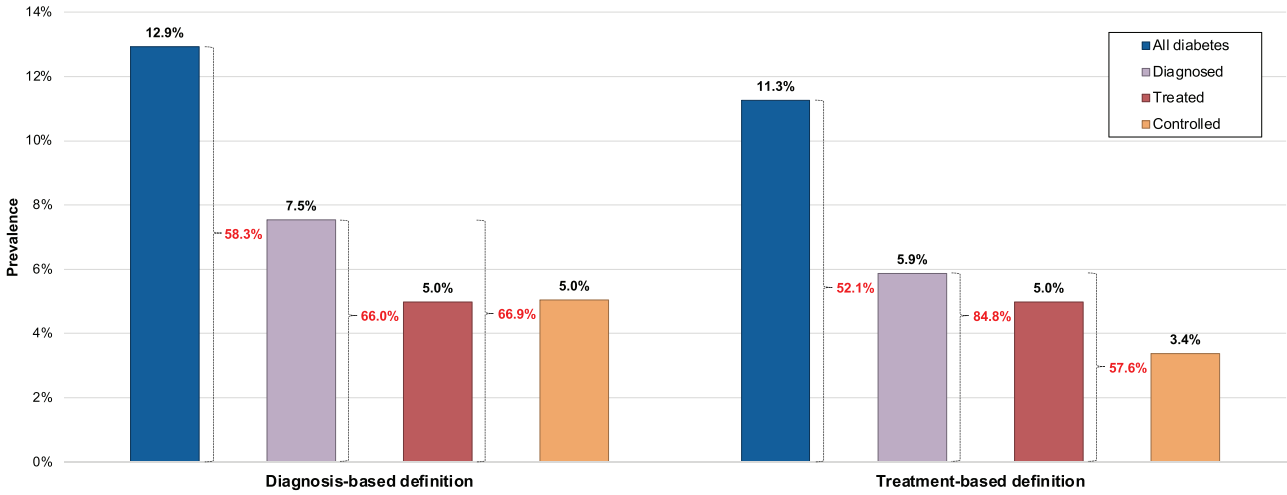


Figure 1—Diabetes care cascade estimates based on different diabetes definitions across 88 countries. Prevalence of diabetes, diagnosed diabetes, treated diabetes, and controlled diabetes based on the diagnosis-based (left panel) versus treatment-based (right panel) diabetes definition. Percentages in bright red indicate the proportions diagnosed among individuals with diabetes, treated among those diagnosed, and controlled among those diagnosed. Diabetes diagnosis and medication use (i.e., treatment) were self-reported. Controlled diabetes was defined as HbA_{1c} <8%, FPG <9.3 mmol/L, or RPG <10.0 mmol/L.

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Table 2—Theoretical and empirical differences in care cascade estimates based on different diabetes definitions

Cascade step	Definition X (biomarker or diagnosis)			Definition Y (biomarker or treatment)			Difference (definition X − definition Y)		
	Theoretical	Empirical		Theoretical	Empirical		Theoretical	Empirical (weighted)	
		Unweighted	Weighted, %		Unweighted	Weighted, %		ppt	Relative, %
Diabetes prevalence	$\frac{A + B + C + D + E}{N}$	$\frac{55{,}458}{800{,}348}$	12.9	$\frac{A + B + C + D}{N}$	$\frac{45{,}543}{800{,}348}$	11.3	X > Y	+1.7	+14.9
Proportion diagnosed (among all individuals)	$\frac{A + B + D + E}{A + B + C + D + E}$	$\frac{35{,}402}{55{,}458}$	58.3	$\frac{A + B + D}{A + B + C + D}$	$\frac{25{,}487}{45{,}543}$	52.1	X > Y	+6.2	+11.9
Proportion treated (among diagnosed individuals)	$\frac{A + D}{A + B + D + E}$	$\frac{22{,}729}{35{,}402}$	66.0	$\frac{A + D}{A + B + D}$	$\frac{22{,}729}{25{,}487}$	84.8	X < Y	−18.9	−22.2
Proportion controlled (among diagnosed individuals)	$\frac{A1 + B1 + D + E}{A + B + D + E}$	$\frac{23{,}645}{35{,}402}$	66.9	$\frac{A1 + B1 + D}{A + B + D}$	$\frac{13{,}886}{25{,}487}$	57.6	X > Y	+9.4	+16.3

Theoretical and empirical composition of each step of the diabetes care cascade, including differences between the two competing approaches. Subgroups A–E are defined in Table 1. Theoretical differences in care steps between diabetes definitions result from individuals in group E being added to numerator, denominator, or both. When the same positive number is added to both numerator and denominator of a fraction, the resulting fraction is always larger than the original fraction. Empirical results are based on aggregated data of 89 nationally representative surveys. Sampling weights were rescaled so that each country contributes equally to weighted estimates.

[95% CI 96.0–97.9] cm vs. 99.3 [95% CI 98.7–100.0] cm and systolic blood pressure (130.8 [95% CI 129.7–131.9] mmHg vs. 136.4 [95% CI 135.6–137.2] mmHg) were lower in group E than in groups A–D. Individuals in group E more frequently reported receiving lifestyle advice from clinicians (67.7% [95% CI 64.7–70.5] vs. 41.9% [95% CI 40.2–43.6]) and engaging in moderate physical activity (27.1% [95% CI 23.9–30.5] vs. 20.8% [95% CI 18.9–22.9]) than groups A–D.

Differences in care cascade estimates across diagnosis-based and treatment-based disease definitions did not vary by World Bank country-income group (Supplementary Fig. 3) or across glycemic markers (Supplementary Table 7). Our findings were similar when exclusively using FPG to identify individuals with diabetes (Supplementary Table 8). Estimates of controlled diabetes did not differ across the two disease definitions when the treatment stage was used as the denominator (Supplementary Fig. 4).

CONCLUSIONS

Using nationally representative data from 88 countries, we found that between two competing definitions of diabetes status, estimates of diabetes diagnosis, treatment, and control on average diverged by 11%, 22%, and 16%, respectively. In a few countries, estimates of the proportion treated diverged by >40 ppt. Heterogeneity across countries is likely driven by differences in clinical practice, survey methodology, and population characteristics, such as health literacy levels. When using the diagnosis-based diabetes definition, the number of countries meeting the WHO GDC glycemic control target was nearly fourfold higher compared with the treatment-based diabetes definition.

Importantly, the two approaches for deriving diabetes care cascades consistently resulted in estimates diverging in predictable ways, each yielding different policy implications. The diagnosis-based diabetes definition led to higher estimates of the proportion of people with diabetes who are diagnosed, lower estimates of those who are treated, and higher estimates of those whose diabetes is controlled. This combination of findings could encourage policymakers to prioritize expanding access to diabetes treatments, including medicines (27), rather than investing in efforts for improving diagnosis. Conversely, the

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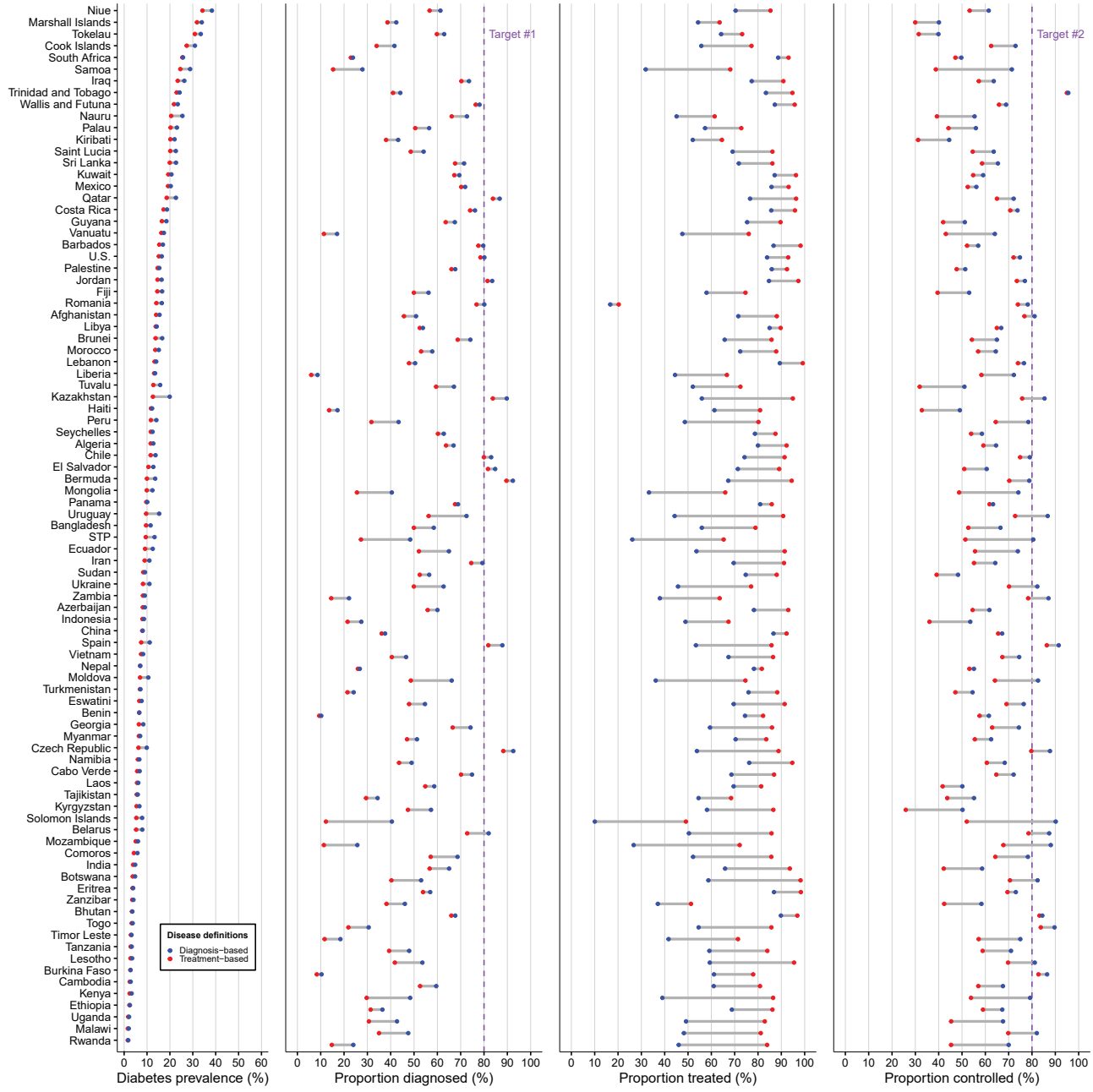


Figure 2—Differences in care cascade estimates within surveys based on different diabetes definitions. Differences in diabetes prevalence and proportions diagnosed, treated (among diagnosed), and controlled (among diagnosed) between the diagnosis-based and treatment-based diabetes definitions by country. The dotted purple lines indicate 80%-targets for diabetes diagnosis (target 1) and control (target 2) set in the World Health Organization Global Diabetes Compact. STP, São Tomé and Príncipe.

treatment-based diabetes definition led to lower estimates of the proportion of people with diabetes who are diagnosed, higher estimates of those who are treated, and lower estimates of those whose diabetes is controlled. Here, policymakers might decide against programs aimed at increasing access to diabetes treatments, and instead focus on diabetes screening and strengthening care quality (28). Particularly in low-resource settings, scarce resources for diabetes care must be allocated efficiently to avoid straining health budgets, while ensuring investments are directed toward interventions with the greatest potential health gains. Specific policy decisions depend on many contextual factors and likely entail a range of strategies. In some countries, differences between estimates will be too small to affect policy decisions altogether. However, across countries, the choice of either of the two approaches for deriving care cascades will skew diabetes control policies in predictable ways and have tangible implications for resource allocation.

Examining potential errors in biomarker measurement, diagnosis self-reports, and treatment self-reports can help to determine which diabetes definition yields more accurate care cascade estimates. As definitions differ only by inclusion of group E, we focus on errors that can lead to *1*) false-negative biomarkers, *2*) false-positive diagnosis reports, and *3*) false-

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negative treatment reports (Supplementary Table 9). On the one hand, individuals in group E may truly have diabetes—supporting their inclusion in care cascade estimates—but happen to have normal biomarkers due to random measurement error. False-negative test results are common when screening for diabetes using a single biomarker at a single point in time. Hence, outside of epidemiological studies, repeated glycemic measurements are needed to clinically diagnose diabetes (29). Compared with combined oral glucose tolerance testing, ∼30–40% of diabetes patients falsely test negative based on FPG alone with a cutoff of 7 mmol/L (30,31). Similarly, due to low sensitivity, more than half of individuals with diabetes may yield false-negative test results in HbA_{1c} assays with a cutoff of 6.5% (30,32). Next, individuals in group E might have attained glycemic control through other treatment modalities, such as behavioral modification or traditional medicine. In descriptive analyses, we found that individuals in group E more frequently had received lifestyle advice from a clinician and reported higher physical activity levels compared with the remaining individuals with diabetes. Behavioral modification might also explain why, under the diagnosis-based diabetes definition, the number of patients with glycemic control was slightly higher than the number of patients receiving medication. In contrast, traditional medicine use was less common in group E compared with other groups. Lastly, individuals in group E may use glucose-lowering medication without being aware that it is intended for diabetes, although evidence on the prevalence of this misclassification is scarce (33). The errors described in this paragraph would be mitigated by the diagnosis-based diabetes definition.

On the other hand, normoglycemic individuals reporting a diabetes diagnosis and no medication use may truly not have diabetes, implying that they should not be included in care cascade estimates. This could be the case if these individuals, labeled as group E, previously received an incorrect diagnosis from a health care worker, for example, due to transient hyperglycemia. However, the specificity of both FPG and HbA_{1c} for type 2 diabetes is high, so <5% of individuals without diabetes receive a false-positive test result (30). Similarly, <5% of patients with biomarker levels above the diabetes threshold regress to normal levels upon repeat measurement (34). Next, individuals in group E may have reported a diabetes diagnosis they never actually received. Studies that verified population-based diabetes surveys against medical records found that ∼5–10% of individuals with self-reported diabetes in cross-sectional data did not actually have diabetes (35,36). The observation that individuals in group E were more educated and younger compared with remaining individuals with diabetes might make the hypothesized influence of such recall bias less likely (37). The two errors in self-reported diabetes diagnosis described in this paragraph would be mitigated by the treatment-based diabetes definition.

Furthermore, although not a measurement error, higher levels of glycemic control under the diagnosis-based diabetes definition might be driven by individuals with early dysglycemia. In this scenario, comparatively high diabetes control levels would not necessarily reflect better health system performance but overall less severe cases.

To guide policymakers and researchers, we summarized key diabetes monitoring priorities—corresponding to the measurement errors described above—that would favor one diabetes definition over the other (Supplementary Table 10). Existing studies on diabetes care cascades rarely justify their choice of diabetes definition (7,9–19). In future research, we recommend that cascade estimates resulting from both approaches should be reported. Similarly, policy briefs should present ranges for each step of the care cascade that can be calculated from the two different approaches. Such ranges are more likely to capture true values and can help avoiding biased or one-sided policy recommendations. As a final suggestion, studies may consider defining the control stage of the diabetes care cascade using all individuals with treated diabetes as the denominator, in addition to calculating this estimate relative to all individuals with diagnosed diabetes. Estimates of controlled diabetes (WHO GDC target 2) did not differ across the two disease definitions when the treatment stage was used as the denominator. One important drawback of this approach is that it can only capture individuals who attain glycemic control through medication use.

Further methodological considerations during data collection can influence care cascade estimates and may help mitigate some of the measurement and classification errors described above. For instance, different diabetes biomarkers identify subgroups of individuals with diabetes that overlap only partly (38). The highest sensitivity would result from using both HbA_{1c} and FPG in health surveys, although resource constraints might render this approach infeasible in many low- and middle-income countries. Next, the reliability of health surveys could benefit from verification of self-reported diagnosis and treatment data using medical records (39), although this might not be feasible in settings without electronic health record systems. Lastly, relying on cross-sectional survey data collected at intervals of several years to estimate diabetes care cascades—although widely used—remains a stopgap solution. For a timely health system response, a robust disease monitoring surveillance infrastructure that provides data on health system performance for diabetes in near real-time would be optimal. Similarly, diabetes control targets should not exclusively focus on glycemic control but also consider other important intermediary health outcomes that affect the risk of complications, such as blood pressure control or lipid management (6).

Changing data ecosystems and treatment algorithms may influence how diabetes performance metrics will evolve in future years. Previously, three medication classes (metformin, sulfonylureas, and insulin) dominated treatment regimens and were specific to diabetes. However, two newer major medication classes (sodium–glucose cotransporter 2 inhibitors and glucagon-like peptide 1 receptor agonists) increasingly shape diabetes treatments, which are also widely used for indications other than diabetes, such as obesity, chronic kidney disease, or cardiovascular diseases (40). Hence, defining diabetes status in national performance metrics based on self-reported treatment might become increasingly inaccurate, particularly when using administrative rather than survey data.

Leveraging harmonized nationally representative data from a large and diverse set of countries and individuals, our study highlights potential opportunities for improving diabetes surveillance globally. Yet, some limitations should be considered.

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First, we could not quantify errors in self-reported data on diagnosis and treatment status that may lead to misclassification. Future studies are needed that—by linking health survey data with health records—quantify the relative magnitude of random and systematic errors in measuring diabetes diagnosis and treatment. Such quantitative bias analyses may help in generating definitive answers on how to adequately define diabetes and care cascades in cross-sectional survey data. Second, we could not distinguish between type 1 and type 2 diabetes, although >95% of individuals with diabetes globally have type 2 (1). Third, compared with HbA_{1c}, FPG is less reliable for assessing attainment of glycemic control targets in individuals with diabetes (25). However, care cascade estimates and differences between diabetes definitions were mostly similar when using HbA_{1c} as the sole biomarker in a subsample of 14 countries with available data.

In conclusion, we found substantial differences across current approaches to quantify and compare health system performance for diabetes. Harmonizing disease definitions across studies will be a prerequisite to reliably monitor progress toward WHO GDC targets. Enhanced accuracy in diabetes control indicators will facilitate evidence-based policymaking, which is urgently needed to meet the health care needs of 828 million individuals living with diabetes globally (19).

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