The state of diabetes treatment coverage in 55 low-income and middle-income countries: a cross-sectional study of nationally representative, individual-level data in 680 102 adults

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Summary

Background Approximately 80% of the 463 million adults worldwide with diabetes live in low-income and middle-income countries (LMICs). A major obstacle to designing evidence-based policies to improve diabetes outcomes in LMICs is the scarce availability of nationally representative data on the current patterns of treatment coverage. The objectives of this study were to estimate the proportion of adults with diabetes in LMICs who receive coverage of recommended pharmacological and non-pharmacological diabetes treatment; and to describe country-level and individual-level characteristics that are associated with treatment.

Methods We did a cross-sectional analysis of pooled, individual data from 55 nationally representative surveys in LMICs. Our primary outcome of self-reported diabetes treatment coverage was based on population-level monitoring indicators recommended in the 2020 WHO Package of Essential Noncommunicable Disease Interventions. Surveys were included if they were done in 2008 or after in an LMIC, as classified by the World Bank in the year the survey was done; were nationally representative; had individual-level data; contained a diabetes biomarker (fasting glucose, random glucose, or glycated haemoglobin); and had data on one or more diabetes treatments. Our sample included non-pregnant individuals with an available diabetes biomarker who were at least 25 years of age. We assessed coverage of three pharmacological and three non-pharmacological treatments among people with diabetes. At the country level, we estimated the proportion of individuals reporting coverage by per-capita gross national income and geographical region. At the individual level, we used logistic regression models to assess coverage along several key individual characteristics including sex, age, body-mass index, wealth quintile, and educational attainment. In the primary analysis, we scaled sample weights such that countries were weighted equally.

Findings The final pooled sample from the 55 LMICs included 680 102 total individuals and 37 094 individuals with diabetes. Using equal weights for each country, diabetes prevalence was 9·0% (95% CI 8·7–9·4), with 43·9% (41·9–45·9) reporting a previous diabetes diagnosis. Overall, 4·6% (3·9–5·4) of individuals with diabetes self-reported meeting need for all treatments recommended for them. Coverage of glucose-lowering medication was 50·5% (48·6–52·5); antihypertensive medication was 41·3% (39·3–43·3); cholesterol-lowering medication was 6·3% (5·5–7·2); diet counselling was 32·2% (30·7–33·7); exercise counselling was 28·2% (26·6–29·8); and weight-loss counselling was 31·5% (29·3–33·7). Countries at higher-income levels tended to have greater coverage. Female sex and higher age, body-mass index, educational attainment, and household wealth were also associated with greater coverage.

Interpretation Fewer than one in ten people with diabetes in LMICs receive coverage of guideline-based comprehensive diabetes treatment. Scaling up the capacity of health systems to deliver treatment not only to lower glucose but also to address cardiovascular disease risk factors, such as hypertension and high cholesterol, are urgent global diabetes priorities.

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See **Comment** page e306

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Research in context

Evidence before this study

We searched PubMed on Jan 5, 2021, without language or date restrictions using the search terms "diabetes" and ("low- and middle-income countries" or "developing countries") and ("met need" or "treatment" or "coverage") in the title or abstract. We identified two large studies assessing levels of diabetes treatment using individual data from multiple low-income and middle-income countries (LMICs). One study reported estimates of glycaemic care (proportion tested, diagnosed, treated, and controlled) among individuals with diabetes in 28 LMICs but did not explore other components of comprehensive diabetes care such as medication treatment for hypertension or elevated cholesterol. A second study, the Prospective Urban Rural Epidemiology study, reported individual-level data on use of diabetes, hypertension, and cardiovascular disease medicines in LMICs. However, the PURE study is not nationally representative, includes fewer than 20 LMICs, and, to our knowledge, has not assessed the use of non-pharmacological interventions for diabetes.

Added value of this study

To our knowledge, this study is the largest assessment of comprehensive diabetes treatment using individual-level data from nationally representative samples of adults across LMICs of diverse income groups and geographical regions. This study makes three valuable additions to the existing literature. First, we found that fewer than one in ten people with diabetes in LMICs receive comprehensive diabetes treatment as recommended by WHO. Our findings are essential for policy makers as we identify pharmacological treatment of hypertension and elevated cholesterol as key drivers of low self-reported treatment. Second, we make cross-country estimates of diabetes treatment that could be used by health systems in LMICs to benchmark current and future performance. Third, we report individual characteristics such as young age and lower body-mass index that are associated with low coverage of diabetes treatment; these individual-level findings can be used by health systems to direct care to underserved groups.

Implications of all the available evidence

Although there are differences in the proportion of people receiving diabetes treatment both between and within countries, overall, there is need to scale up comprehensive diabetes treatment in LMICs. Our findings suggest that improving access to comprehensive treatment not only to lower glucose but also to address cardiovascular disease risk factors such as hypertension and elevated cholesterol are global diabetes priorities. Global initiatives such as the WHO HEARTS Technical Package and Global Diabetes Compact represent important opportunities to address the implementation and economic challenges of this approach

Introduction

The global burden of disability-adjusted life-years attributable to diabetes and elevated fasting glucose has more than doubled from 1990 to 2019.[1] Approximately 80% of the estimated 463 million adults with diabetes worldwide live in low-income and middle-income countries (LMICs).[2] The limitations of health systems in LMICs to deliver treatment for non-communicable diseases (NCDs) such as diabetes leads to substantial excess mortality.[3,4] Expanding access to diabetes treatment is crucial for many countries to meet Sustainable Development Goal 3.4 (reduce premature mortality from NCDs by a third by 2030).[5]

WHO recommends a comprehensive approach to clinical care of type 2 diabetes consisting of pharmacological and non-pharmacological treatment targeting glycaemic control and key cardiovascular disease (CVD) risk factors such as hypertension, elevated cholesterol, and obesity.[6,7] This approach is supported by randomised clinical trials and high-quality cohort studies showing the benefit of multiple risk factor reduction among people with diabetes.[3,8,9] Within this paradigm, the pharmacological treatments shown to be most effective in improving diabetes outcomes include glucose-lowering medications, antihypertensive medications, and cholesterol-lowering medications.[10] Non-pharmacological treatments such as counselling on diet, exercise, and weight loss are widely recommended in guidelines, although their role is less well defined given a paucity of data supporting long-term effectiveness, especially in LMICs.[10–12]

Overall, there are few nationally representative data on the performance of health systems in LMICs in delivering comprehensive diabetes treatment.[13] A previous study[14] assessing diabetes care cascades using individual data from 28 nationally representative surveys in LMICs showed substantial gaps in glycaemic care, but this study did not explore other components of diabetes treatment such as use of antihypertensive or cholesterol-lowering medication. National and regional strategies to treat the growing number of people with diabetes in LMICs should be shaped by the best available evidence on the coverage and quality of diabetes treatment.[15]

The objectives of this study are to estimate the proportion of adults with diabetes in LMICs who receive coverage of recommended pharmacological and non-pharmacological diabetes treatment; and to describe country-level and individual-level characteristics that are associated with treatment. Our estimates can be used by policy makers in LMICs to prioritise resources, target interventions, and benchmark progress in scaling up comprehensive diabetes treatment.

	Glucose-lowering medication	Antihypertensive medication	Cholesterol-lowering medication	Diet counselling	Exercise counselling	Weight-loss counselling
Number of countries	55	52	46	49	48	48
Numerator	Individuals self-reporting use of an oral glucose-lowering medication or insulin	Individuals self-reporting use of an antihypertensive medication	Individuals self-reporting use of a cholesterol-lowering medication	Individuals self-reporting dietary counselling	Individuals self-reporting exercise counselling	Individuals self-reporting weight-loss counselling
Denominator	Individuals with diabetes not reaching the glycaemic target or self-reporting use of a glucose-lowering medication	Individuals with diabetes and hypertension	Individuals with diabetes aged ≥40 years	Individuals with diabetes	Individuals with diabetes	Individuals with diabetes and body-mass index ≥25 kg/m²

Outcome definitions are consistent with recommended population-level monitoring indicators and clinical treatment guidelines in the 2020 World Health Package of Essential Noncommunicable Disease Interventions.[6]

Table 1: **Definitions of outcomes**

Methods

Study design

We did a cross-sectional analysis of pooled, individual-level data from 55 nationally representative surveys in LMICs. Surveys were included if they were done in 2008 or after in an LMIC, as classified by the World Bank in the year the survey was done; were nationally representative; had individual-level data; contained a diabetes biomarker (fasting glucose, random glucose, or glycated haemoglobin [HbA_{1c}]); and had data on one or more diabetes treatments as defined later in this section.

Our two-step process for pooling surveys has been previously described.[16] First, we identified all LMICs in which a WHO Stepwise Approach to Surveillance (STEPS) survey had been done. Before 2019, we requested each STEPS survey from a list maintained on the WHO website. Beginning in 2019, we downloaded STEPS surveys from the WHO Central Data Catalog. Second, for countries in which no eligible STEPS survey was available or accessible, we did a systematic Google search in April, 2020, to identify non-STEPS surveys. In total, we included STEPS surveys from 44 countries and non-STEPS surveys from 11 countries. The appendix (pp 3–35) has further information on our search process, a map of included countries, and details of included surveys.

Our use of de-identified survey data was determined not to be human participant research by the institutional review board of the University of Michigan.

Sample and definitions

Our sample included non-pregnant individuals with an available diabetes biomarker who were at least 25 years of age. We excluded people younger than 25 years as this was the minimum age for inclusion in many surveys.

Diabetes status was defined by self-reported use of a glucose-lowering medication (oral glucose-lowering medication or insulin) or biochemical evidence of diabetes using the WHO definition: fasting plasma glucose (FPG) of 7·0 mmol/L (126 mg/dL) or higher, random plasma glucose of 11·1 mmol/L (200 mg/dL) or higher, or an HbA_{1c} measurement of 6·5% or higher.[6] The diabetes biomarker used for diagnosis was a point-of-care fasting capillary glucose in 44 surveys, a laboratory-based fasting plasma glucose in seven surveys, and HbA_{1c} in four surveys. In countries with capillary glucose measurements, we converted values to plasma glucose by multiplying by a factor of 1·11 based on research showing that capillary glucose underestimates plasma concentrations.[17] Where fasting status was missing, with one exception, we assumed that the glucose measurement was fasting in accordance with survey protocols. The exception was India where random blood glucose was the primary diabetes biomarker.

Hypertensive status was defined as systolic blood pressure of 140 mm Hg or higher, diastolic blood pressure of 90 mm Hg or higher, or self-reported use of an antihypertensive medication.[6] For respondents with three blood pressure measurements, values were averaged over the final two readings. For respondents with two blood pressure measurements, we used the mean of the two values. The appendix (pp 36–40) has additional, country-specific information on diabetes biomarker and blood pressure measurements.

Outcomes

Our primary outcome of diabetes treatment coverage was based on population-level monitoring indicators recommended in the 2020 WHO Package of Essential Noncommunicable Disease Interventions (WHO PEN).[6] Consistent with WHO PEN, we defined diabetes treatment coverage as the "proportion of eligible persons receiving drug therapy and counselling (including glycaemic control) to prevent heart attacks and strokes" in population-based data sources such as STEPS surveys.[6] We estimated self-reported coverage for six core type 2 diabetes clinical treatments recommended in WHO PEN.[6] The first group consisted of three pharmacological treatments: glucose-lowering, antihypertensive, and cholesterol-lowering medication. The second group

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See **Online** for appendix

	Year	Response rate	Sample size*	Sample median age, years*	Sample age range, years	Women	Sample with diabetes*	Diabetes†	Diagnosed†
Low-income countries									
Bangladesh	2011	95·0%	7305	48 (41–60)	35–96	49·7%	785	10·1%	42·5%
Benin	2015	98·6%	4041	39 (31–49)	25–69	52·1%	276	6·5%	9·4%
Burkina Faso	2013	98·7%	3945	37 (29–47)	25–64	50·7%	99	2·7%	8·3%
Cambodia	2010	96·3%	5026	43 (34–52)	25–64	64·4%	152	2·4%	52·6%
Comoros	2011	96·5%	2295	40 (32–50)	25–64	73·9%	98	4·3%	57·1%
Eritrea	2010	97·0%	5360	43 (33–55)	25–74	70·9%	203	3·7%	53·9%
Liberia	2011	87·1%	1543	35 (29–44)	25–64	53·7%	204	13·2%	5·9%
Nepal	2013	89·8%	3286	42 (35–54)	25–69	68·3%	192	5·4%	44·4%
Rwanda	2012	98·8%	5078	38 (31–48)	25–64	62·2%	85	1·6%	14·8%
Tanzania‡	2012	94·7%	4628	41 (33–50)	25–64	52·2%	142	2·8%	39·1%
Togo	2010	91·0%	2582	38 (30–47)	25–64	50·5%	82	3·3%	21·7%
Uganda	2014	92·2%	2633	38 (30–48)	25–69	59·2%	37	1·8%	30·7%
Zanzibar‡	2011	91·0%	2174	40 (32–50)	25–64	61·3%	95	3·6%	37·2%
Lower-middle-income countries									
Bhutan	2014	96·9%	2408	41 (33–51)	25–69	60·1%	72	2·5%	38·7%
Eswatini	2014	81·8%	2044	42 (32–54)	25–71	67·2%	154	6·7%	42·6%
Georgia	2016	75·7%	2973	53 (42–61)	25–70	72·4%	262	6·4%	66·6%
India	2015–16	96·0%	491 512	35 (30–42)	25–54	85·2%	19 086	5·1%	44·9%
Indonesia	2014	83·0%	5350	48 (34–62)	25–101	55·8%	476	8·2%	22·6%
Kenya	2015	95·0%	3325	39 (31–50)	25–69	59·5%	105	2·4%	29·7%
Kiribati	2015	55·0%	992	41 (32–51)	25–69	55·6%	209	19·9%	38·0%
Kyrgyzstan	2013	100·0%	2482	44 (35–53)	25–64	63·1%	153	5·4%	47·4%
Laos	2013	98·8%	2084	42 (33–50)	25–65	59·9%	127	5·7%	54·8%
Lesotho	2012	80·0%	1971	42 (32–54)	25–64	65·8%	82	2·8%	41·8%
Moldova	2013	83·5%	3371	51 (38–59)	25–69	63·5%	314	6·9%	48·6%
Mongolia	2013	97·4%	1866	40 (32–50)	25–64	56·3%	98	4·8%	52·2%
Morocco	2017	89·0%	4207	47 (37–59)	25–100	65·0%	663	13·6%	53·0%
Myanmar	2014	90·0%	7758	45 (36–54)	25–64)	65·1%	614	6·4%	47·0%
Samoa	2013	64·0%	1306	43 (34–52)	25–64	60·3%	331	24·6%	15·3%
São Tomé and Príncipe	2009	95·0%	1995	38 (30–48)	25–64	56·1%	59	3·0%	44·6%
Solomon Islands	2015	58·4%	1482	42 (34–51)	25–71	54·3%	94	5·4%	12·2%
Sudan	2015	88·0%	5311	40 (32–50)	25–69	63·0%	525	8·3%	52·5%
Tajikistan	2016	94·0%	2173	42 (33–52)	25–70	58·5%	202	5·5%	29·4%
Timor-Leste	2014	96·3%	2021	43 (34–54)	25–69	56·5%	60	3·0%	11·7%
Vanuatu	2011	94·0%	4444	40 (32–50)	25–64	49·1%	470	9·7%	18·4%
Vietnam	2015	79·8%	2768	45 (37–55)	25–69	57·2%	108	3·1%	53·1%
Zambia	2017	74·3%	2565	40 (32–50)	25–69	61·1%	231	8·2%	14·5%

(Table 2 continues on next page)

consisted of three non-pharmacological treatments counselling on: diet, exercise, and weight loss.

We used WHO PEN to define the numerator and denominator for each outcome (table 1 and appendix pp 41–44).[6] Glucose-lowering medication use was quantified among individuals not having glycaemic targets or self-reporting use of an oral glucose-lowering medication or insulin. We set glycaemic targets of HbA_{1c} as less than 7·0% (equivalent to FPG <8·0 mmol/L)[18] in people younger than 65 years of age and less than 8·0% (FPG <9·2 mmol/L) in people 65 years or older. Antihypertensive medication use was quantified among people with both diabetes and hypertension. Cholesterol-lowering medication use was quantified among individuals with diabetes aged older than 40 years; we did not assess serum cholesterol levels as lipid measurements are not required to guide cholesterol-lowering therapy according to the WHO PEN guidelines. Counselling on diet and exercise was quantified among all people with diabetes. Counselling on weight-loss was quantified among individuals with diabetes and body-mass index (BMI) of at least 25 kg/m^2 or greater.

Statistical analysis

We estimated the proportion of individuals self-reporting coverage of each diabetes treatment alone and in

	Year	Response rate	Sample size*	Sample median age, years*	Sample age range, years	Women	Sample with diabetes*	Diabetes†	Diagnosed†
(Continued from previous page)									
Upper-middle-income countries									
Algeria	2016	93·8%	5162	43 (35–53)	25–69	54·9%	683	11·6%	64·1%
Azerbaijan	2017	97·3%	2394	49 (37–57)	25–69	59·6%	263	8·2%	55·9%
Belarus	2016	87·1%	4423	49 (39–58)	25–69	58·5%	262	5·2%	72·8%
Botswana	2014	64·0%	2574	39 (31–51)	25–69	68·9%	117	3·8%	40·3%
Chile	2009–10	85·0%	4149	50 (38–63)	25–100	60·5%	540	11·8%	66·3%
China	2009	88·0%	8120	52 (42–62)	25–99	53·2%	643	7·9%	36·1%
Costa Rica	2010	87·8%	2433	50 (39–62)	25–110	73·1%	375	12·0%	77·0%
Fiji	2009	80·0%	1344	54 (47–63)	40–90	57·1%	581	43·2%	33·9%
Guyana	2016	66·7%	702	45 (35–56)	25–69	63·2%	127	16·7%	66·9%
Iran	2016	~99%	19 248	46 (35–58)	25–100	53·5%	1740	9·6%	77·6%
Iraq	2015	98·8%	3187	43 (34–55)	25–102	60·2%	648	18·9%	70·3%
Lebanon	2017	65·9%	1106	49 (40–56)	25–69	62·6%	175	13·3%	47·9%
Mexico	2009–12	90·0%	7559	53 (45–64)	25–99	54·8%	2539	35·3%	44·2%
Namibia	2013	96·9%	3244	46 (40–53)	35–64	58·1%	218	6·1%	44·9%
Romania	2015–16	69·1%	1774	50 (39–65)	25–80	52·5%	250	14·1%	76·8%
Seychelles	2013	73·0%	1240	47 (36–55)	25–64	57·2%	179	11·7%	60·3%
South Africa	2012	39·8%	3390	48 (36–60)	25–97	65·2%	575	13·3%	46·6%
Saint Vincent and the Grenadines	2013	67·8%	889	47 (37–55)	25–70	60·7%	115	11·1%	79·4%
Tuvalu	2015	76·0%	860	47 (34–56)	25–69	54·8%	119	12·8%	59·5%
Overall total	..	..	680 102	..	..	52·7§	37 094	9·0%	43·9%

Data are year, %, n, median (IQR), or range. Country income groups are classified according to the World Bank in the year the survey was done. *The sample includes non-pregnant participants aged ≥25 years with a non-missing diabetes biomarker. †Values account for survey design and are weighted equally by country in the overall total. ‡Zanzibar is a semi-autonomous region of Tanzania. §Value accounts for survey design and is weighted equally by country.

Table 2: **Survey characteristics**

combination. We also estimated coverage by country per-capita gross national income (GNI) and geographical region adapted from the classification scheme of the NCD Risk Factor Collaboration.[19] A country's GNI was included both as a continuous variable and in categories defined by the World Bank in the year the survey was done.

We then assessed coverage along several key individual-level characteristics. Specifically, we constructed univariable and multivariable logistic regression models with country-level fixed effects and individual-level covariates of sex, age, BMI, wealth quintile, and educational attainment. Age and BMI were included as continuous variables using restricted cubic splines with five knots at 5%, 27·5%, 50%, 72·5%, and 95%. Household wealth quintiles were based on asset indices or income depending on the available data in each survey (appendix p 45). Survey weighting and clustering at the country level were accounted for in all analyses. We used the sample weights for the diabetes biomarker when available. Given that our main interest was at the level of the health system, we scaled sample weights such that countries were weighted equally; the India survey, therefore, contributes equally to other countries despite its large sample size. We used a complete case analysis in the models. We report model outputs as predicted probabilities. Analyses were done in Stata (version 16.1).

We did multiple sensitivity analyses. First, we restricted the sample to individuals reporting a previous diabetes diagnosis. Second, we weighted each country in proportion to its 2015 population size. Third, given differences in the upper age limit of surveys, we limited the analysis to individuals aged 25–64 years. Fourth, the WHO recommends using CVD risk scores to guide treatment with cholesterol-lowering medications when it is infeasible to treat all people with diabetes aged older than 40 years.[7] Therefore, we estimated coverage of cholesterol-lowering medication among people with diabetes who have a 10-year predicted CVD risk of at least 20% using the 2019 WHO non-laboratory risk equations.[20] Finally, we re-specified the multivariable logistic regressions as multilevel models using random effects at the country level.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

The final pooled sample from the 55 LMICs included 680 102 total individuals and 37 094 individuals with

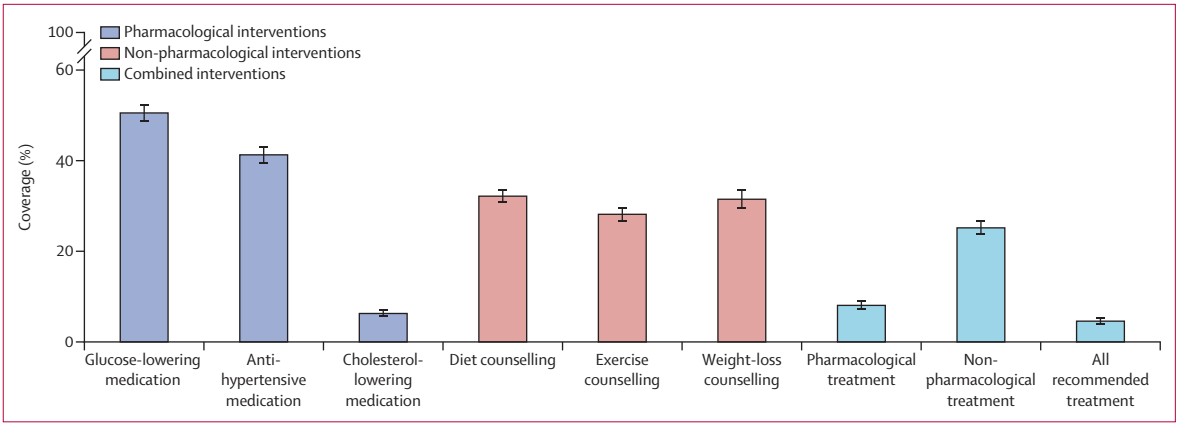

Figure 1: **Diabetes treatment coverage in 55 low-income and middle-income countries**
Coverage, or the proportion of eligible individuals receiving diabetes treatment, in 55 low-income and middle-income countries. Each treatment is a core recommendation for people with type 2 diabetes in the 2020 WHO Package of Essential Noncommunicable Disease Interventions. For the combined interventions, the denominator was all individuals who needed coverage for at least one treatment within the category; the numerator was the number of individuals self-reporting coverage for all treatments indicated for that individual within the category. For example, if an individual was defined to need glucose-lowering medication but not antihypertensive or cholesterol-lowering medication, the individual would be classified as having coverage for the pharmacological treatments if they self-reported use of the glucose-lowering medication (ie, one out of only one indicated treatment). Conversely, if an individual was defined to need both glucose-lowering therapy and antihypertensive therapy, the individuals would not be classified as having coverage for the pharmacological treatments if the individual only self-reported use of the glucose-lowering medication (ie, one out of two indicated interventions). Estimates account for clustering at the country level and equal weights by country. Error bars indicate 95% CIs.

diabetes (table 2; detailed sample characteristics are reported in appendix p 52). Overall, 7·9% of participants were missing data on at least one individual-level characteristic (appendix pp 46–51). Using equal weights for each country, diabetes prevalence by self-report of a glucose-lowering medication or biomarker was 9·0% (95% CI 8·7–9·4), with 43·9% (41·9–45·9) reporting a previous diabetes diagnosis. Diabetes prevalence and the proportion of diagnosed diabetes tended to be greater in countries in higher World Bank income categories (appendix pp 53–55). Among geographical regions, Oceania had the highest diabetes prevalence (19·3%, 95% CI 18·0–20·7) and lowest proportion diagnosed (29·7%, 23·7–36·6). Latin America and the Caribbean had the next highest diabetes prevalence (17·4%, 95% CI 16·1–18·8) but had the highest proportion diagnosed (66·8%, 62·9–70·5).

Coverage varied by treatment (figure 1 and appendix p 56). Among pharmacological treatments, coverage of glucose-lowering medication was 50·5% (95% CI 48·6–52·5); antihypertensive medication was 41·3% (39·3–43·3); and cholesterol-lowering medication was 6·3% (5·5–7·2). Among non-pharmacological treatments, coverage of diet counselling was 32·2% (30·7–33·7); exercise counselling was 28·2% (26·6–29·8); and weight-loss counselling was 31·5% (29·3–33·7). In the combined analysis, coverage of pharmacological treatment was 8·1% (7·1–9·1) and coverage of non-pharmacological treatment was 25·2% (23·7–26·7). Overall, 4·6% (3·9–5·4) of individuals with diabetes self-reported meeting need for all treatments defined in this study that were recommended for them in WHO PEN.

There were substantial differences in coverage by country stratifications of income and geographical region (figure 2 and appendix pp 56–59). Countries in higher-income groups generally had higher coverage across all treatments. For example, coverage of glucose-lowering medication was 40·3% (95% CI 36·4–44·3) in low-income countries, 45·1% (42·0–48·2) in lower-middle-income countries, and 64·1% (60·3–67·7) in upper-middle-income countries. Regionally, coverage was generally highest in Latin America and the Caribbean and lowest in Oceania followed by sub-Saharan Africa. Across all income and geographical stratifications, coverage of glucose-lowering and hypertension medication was higher than coverage of non-pharmacological treatment of diet, exercise, and weight-loss counselling. Antihypertensive medication coverage also was higher than cholesterol-lowering medication coverage across income groups and regions.

The positive association between country income and coverage also was observed when countries' per-capita GNI was included as a continuous variable among individuals aged 25–64 years (figure 3 and appendix pp 68–69). Countries that generally had higher diabetes treatment coverage than predicted based on income included Bangladesh, Costa Rica, Cambodia, Eritrea, Guyana, Iran, and Saint Vincent and the Grenadines. Countries that generally had lower diabetes treatment coverage than predicted based on income included Benin, Fiji, Indonesia, Rwanda, and Solomon Islands.

Predicted probabilities of coverage from the multivariable logistic regression models are shown in table 3. Full model details and univariate logistic regression models are

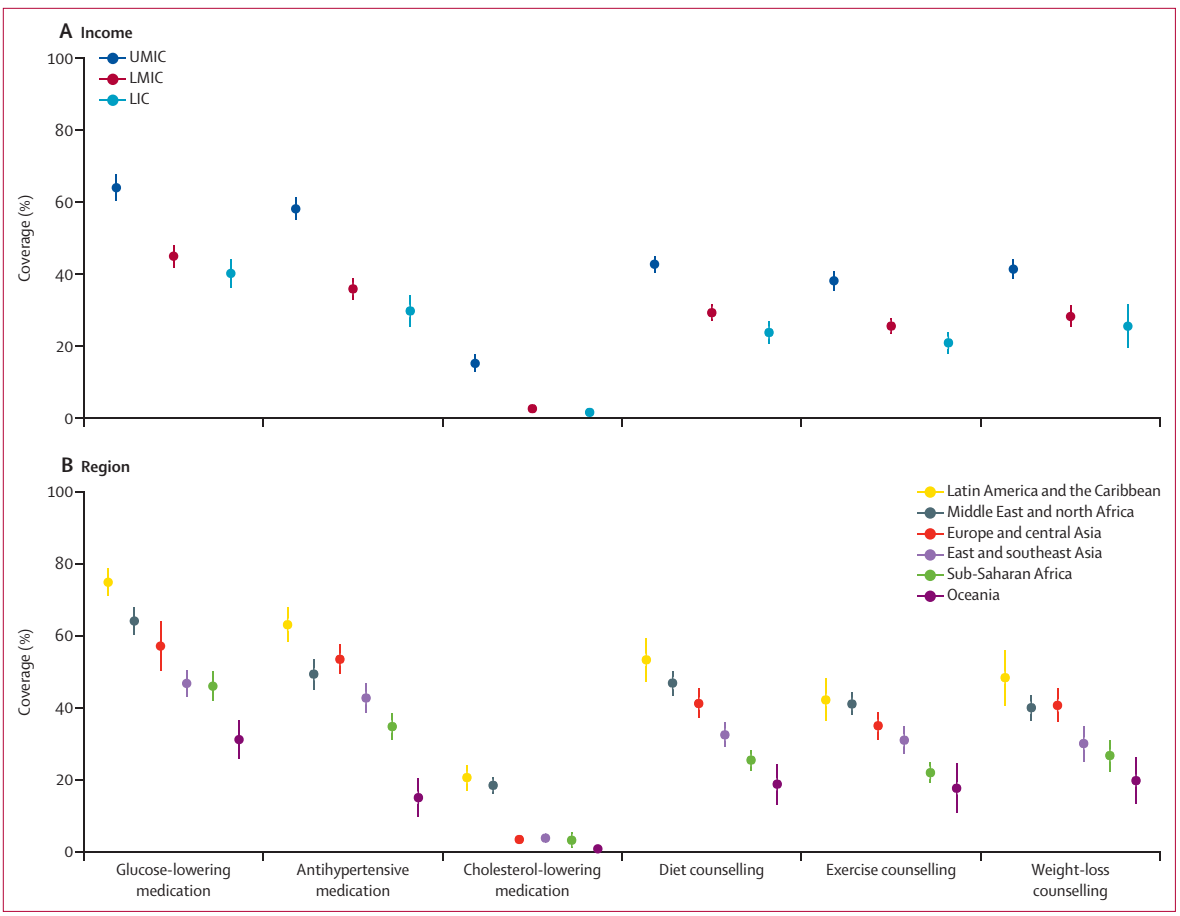

Figure 2: **Diabetes treatment coverage by country income group and geographical regions**
Data are percentages with 95% CIs accounting for clustering at the country level and equal weights by country. Income categories represent the World Bank's classification in the year the survey was conducted. Geographical regions were categorised according to the Non-Communicable Disease Risk Factor Collaboration.[19] LIC=low-income country. LMIC=lower-middle-income country. UMIC=upper-middle-income country

available in the appendix (pp 60–64). Women had greater coverage than men for multiple treatments. There also tended to be a gradient of greater coverage with increasing age and BMI, higher levels of educational attainment, and, to a lesser extent, household wealth.

In the sensitivity analysis restricting the sample to individuals reporting a previous diabetes diagnosis (appendix p 65), coverage of glucose-lowering medication was 85·0% (95% CI 82·3–87·4); antihypertensive medication was 57·0% (53·9–60·0); cholesterol-lowering medication was 9·2% (7·7–10·9); diet counselling was 73·9% (71·4–76·3); exercise counselling was 65·3% (62·8–67·8); and weight-loss counselling was 62·8% (59·3–66·1). In this scenario, the combined coverage of pharmacological treatment was 14·3% (12·2–16·8); non-pharmacological treatment, 56·2% (53·6–58·8); and all recommended treatments, 10·1% (8·2–12·5). In the sensitivity analysis weighting each country in proportion to its 2015 population size (appendix p 66), the overall coverage was similar for antihypertensive medication (40·5%, 95% CI 38·0–43·1), cholesterol-lowering medication (7·9%, 95% CI 6·8–9·1), and exercise counselling (27·8%, 24·4–31·5); however, coverage was lower for glucose-lowering medication (45·6%, 42·0–49·2), diet counselling (23·5%, 21·2–26·0), and weight-loss counselling (19·0%, 16·3–21·9). Results from the sensitivity analysis restricted to the sample of individuals aged 25–64 years is shown in figure 3 and the appendix (pp 67–70). In the sensitivity analysis among people with diabetes who had a 10-year predicted CVD risk of at least 20% (appendix p 71), coverage of cholesterol-lowering medication was 7·6% (95% CI 5·4–10·6). Finally, results from the sensitivity analysis with multivariable logistic regression models using random effects at the country level were generally consistent with the primary analysis (appendix p 72).

Discussion

In this pooled analysis of nationally representative, individual-level data from 55 LMICs, we found that fewer than one in ten people with diabetes had a composite indicator of coverage for up to six clinical treatments

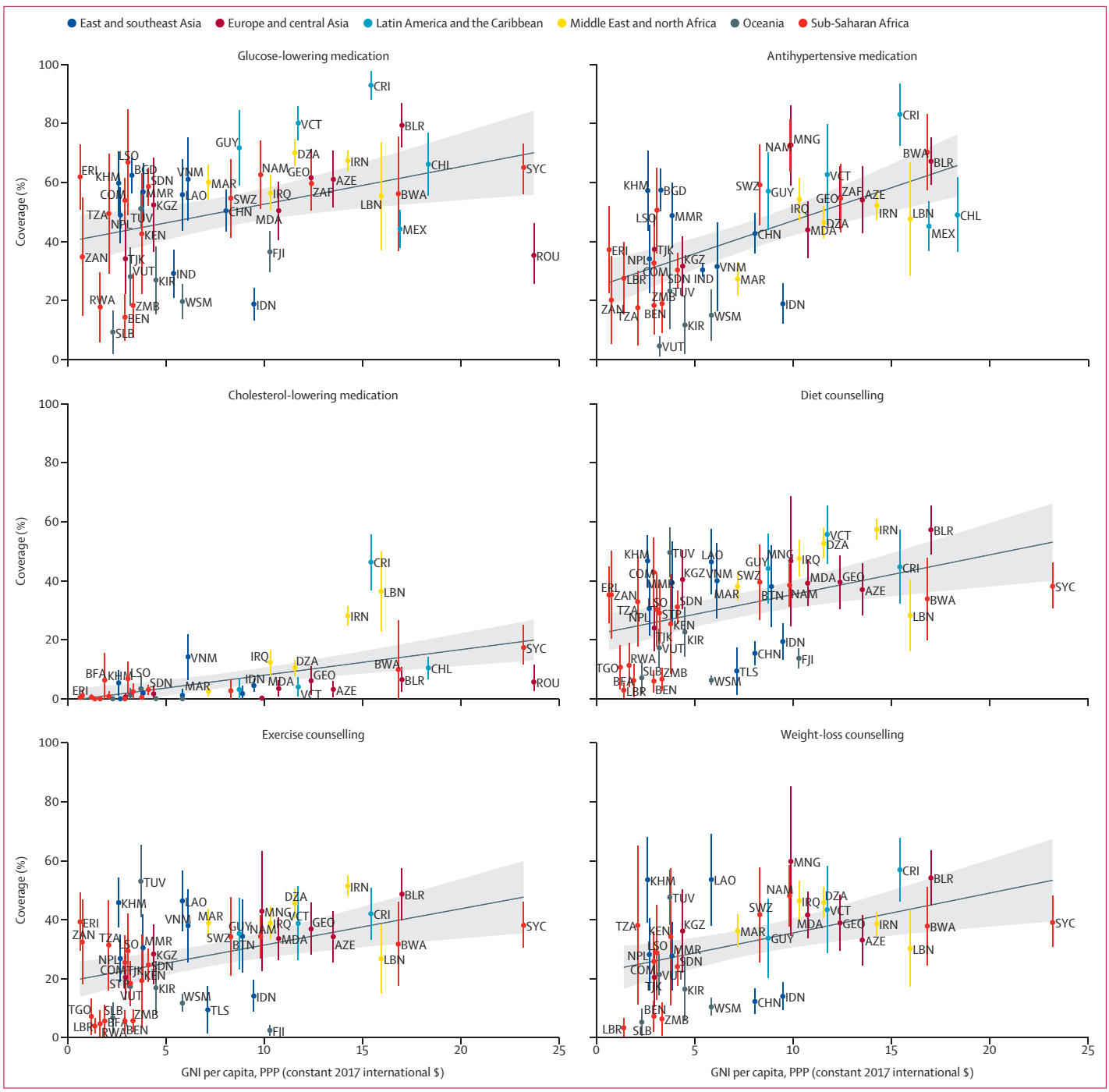

Figure 3: **Diabetes treatment coverage by per capita GNI among individuals aged 25–64 years**

The grey shaded area represents the 95% linear prediction interval. The vertical bars represent 95% CIs around point estimates for a given country. The estimates account for weighting and survey design. Only countries with at least 50 individuals are included in this plot; results for all countries are depicted in the appendix (pp 68–70). GNI per capita is in constant 2017 international dollars as calculated by the World Bank for the year in which the survey was done. For countries with unavailable GNI data in the survey year, we used per-capita gross domestic product in constant 2017 international dollars. For Eritrea, we used per-capita gross domestic product at current prices in 2011. For Zanzibar, we used estimates using constant 2015 international dollars as published by the Office of the Chief Government Statistician of Zanzibar. Some labels in the cholesterol-lowering medication plot are omitted due to space limitations. AZE=Azerbaijan. BEN=Benin. BFA=Burkina Faso. BGD=Bangladesh. BLR=Belarus. BTN=Bhutan. BWA=Botswana. CHL=Chile. CHN=China. COM=Comoros. CRI=Costa Rica. DZA=Algeria. ERI=Eritrea. FJI=Fiji. GEO=Georgia. GNI=gross national income. GUY=Guyana. IDN=Indonesia. IND=India. IRN=Iran. IRQ=Iraq. KEN=Kenya. KGZ=Kyrgyzstan. KHM=Cambodia. KIR=Kiribati. LAO=Laos. LBN=Lebanon. LBR=Liberia. LSO=Lesotho. MAR=Morocco. MDA=Moldova. MEX=Mexico. MMR=Myanmar. MNG=Mongolia. NAM=Namibia. NPL=Nepal. PPP=purchasing power parity. ROU=Romania. RWA=Rwanda. SDN=Sudan. SLB=Solomon Islands. STP=São Tomé and Príncipe. SWZ=Eswatini. SYC=Seychelles. TGO=Togo. TJK=Tajikistan. TLS=Timor-Leste. TUV=Tuvalu. TZA=Tanzania. UGA=Uganda. VCT=St Vincent and the Grenadines. VNM=Vietnam. VUT=Vanuatu. WSM=Samoa. ZAF=South Africa. ZAN=Zanzibar. ZMB=Zambia.

	Glucose-lowering medication	Antihypertensive medication	Cholesterol-lowering medication	Diet counselling	Exercise counselling	Weight-loss counselling
Sex						
Male	44·9% (41·9–47·9)	34·4% (31·2–37·6)	7·0% (5·3–8·7)	31·3% (28·9–33·6)	27·7% (25·3–25·3)	28·8% (25·7–32·0)
Female	52·2% (49·9–54·5)	44·6% (41·8–47·3)	6·7% (5·5–7·9)	33·5% (31·4–35·6)	29·8% (27·8–31·8)	34·3% (31·5–37·1)
Age, years						
30	24·0% (18·4–29·6)	20·6% (13·4–27·8)	..	13·1% (9·7–16·5)	12·1% (8·8–15·5)	17·2% (11·3–23·2)
40	38·6% (34·8–42·4)	29·4% (23·8–35·0)	3·7% (1·5–5·8)	25·5% (22·4–28·6)	22·7% (19·6–25·7)	27·9% (23·8–32·0)
50	50·2% (46·7–53·6)	38·2% (34·2–42·1)	6·6% (5·0–8·3)	34·3% (31·5–37·1)	30·4% (27·6–33·3)	32·7% (29·2–36·3)
60	60·1% (56·6–63·7)	49·1% (45·4–52·7)	7·9% (6·0–9·8)	41·6% (38·8–44·4)	36·7% (34·0–39·4)	38·8% (35·4–42·2)
Body-mass index, kg/m²						
20	45·6% (41·2–50·0)	30·7% (25·3–36·1)	3·5% (1·8–5·2)	23·0% (19·8–26·1)	18·7% (15·7–21·7)	..
25	48·7% (45·4–52·0)	36·6% (33·4–39·9)	6·5% (3·9–9·1)	31·2% (28·3–34·0)	28·3% (25·5–31·1)	28·2% (19·5–36·9)
30	50·3% (47·5–53·1)	42·9% (39·8–46·1)	6·9% (5·2–8·6)	35·2% (32·5–37·9)	30·9% (28·2–33·5)	32·1% (28·2–36·0)
35	51·7% (47·7–55·7)	47·3% (43·0–51·6)	8·2% (6·4–10·0)	40·3% (36·4–44·2)	35·6% (31·8–39·3)	37·6% (33·4–41·7)
Education						
None	37·7% (32·9–42·6)	34·6% (30·4–38·7)	6·6% (4·5–8·8)	25·0% (21·4–28·7)	19·8% (16·2–23·4)	23·8% (18·5–29·1)
Primary	49·0% (45·8–52·2)	40·9% (37·2–44·6)	7·2% (5·8–8·6)	33·3% (30·5–36·0)	28·2% (25·5–30·9)	32·6% (29·0–36·3)
Secondary or higher	53·0% (49·9–56·0)	42·4% (39·0–45·7)	6·6% (4·6–8·5)	34·7% (32·0–37·5)	32·9% (30·1–35·7)	34·6% (31·2–37·9)
Wealth quintile						
1 (poorest)	47·8% (44·0–51·7)	40·4% (36·1–44·8)	7·2% (5·3–9·1)	29·7% (26·2–33·2)	25·5% (22·0–28·9)	27·6% (23·1–32·1)
2	44·9% (41·2–48·6)	39·7% (35·2–44·1)	6·5% (4·0–9·1)	27·8% (24·7–30·9)	25·3% (22·0–28·6)	26·9% (22·8–31·1)
3	45·6% (41·6–49·6)	41·6% (36·7–46·4)	5·1% (3·8–6·3)	29·4% (26·2–32·6)	27·0% (23·8–30·1)	30·1% (25·9–34·2)
4	50·8% (47·2–54·4)	40·4% (36·3–44·5)	7·2% (5·3–9·1)	35·7% (32·0–39·4)	30·2% (26·4–34·0)	33·2% (28·6–37·9)
5 (richest)	54·5% (50·3–58·7)	39·6% (35·1–44·2)	8·5% (5·1–12·0)	38·7% (34·9–42·5)	35·3% (31·7–38·9)	39·7% (35·0–44·4)

Data are % (95% CI). Predicted probabilities of coverage with 95% CIs are reported from multivariable logistic regression models. Predicted probabilities were generated as average adjusted predictions for categorical variables (sex, educational attainment, and wealth) and adjusted predictions at representative values for continuous variables (age and body-mass index). Wealth quintile was not available in seven surveys (appendix p 45). Each column represents a diabetes treatment that serves as the model's dependent variable. The covariates in the model include all row variables and country-fixed effects. Illustrative values for age and body-mass index are presented; these variables were included as continuous variables in the models using restricted cubic splines at knots of 5%, 27·5%, 50%, 72·5%, and 95%. Survey weighting and clustering at the country level were accounted for in the models.

Table 3: **Predicted probabilities of diabetes treatment coverage from multivariable logistic regression models**

recommended in WHO guidelines. Moreover, less than 15% of people with previously diagnosed diabetes had reached the composite indicator. Coverage of glucose-lowering medication was modestly higher than antihypertensive medication and substantially higher than cholesterol-lowering medication. Among all people with diabetes, approximately one in three people self-reported receiving recommended non-pharmacological treatment in the form of counselling about diet, exercise, or weight loss.

Additionally, we found that countries in higher-income categories tended to reach greater coverage across treatments. We also identified countries that generally had higher coverage than would be predicted based on per-capita income. Costa Rica emerged as an example of one such well performing country, a result that has been attributed to the country's commitment to universal health coverage.[21] Other countries that outperformed predicted coverage based on per-capita income included Bangladesh, Cambodia, Eritrea, Guyana, Iran, and Saint Vincent and the Grenadines. When countries were analysed by geographical region, countries in Oceania tended to have the lowest coverage across treatments despite having the highest overall prevalence of diabetes. Previous research on diabetes among people of this region suggests that high diabetes prevalence and limited implementation of diabetes care results from complex structural forces.[22] The region of Latin America and the Caribbean had the second-to-highest diabetes prevalence, but this region also consistently had among the highest levels of coverage across treatments.

At the individual level, we found that women had greater coverage across multiple treatments. This finding is consistent with the broad global literature detailing lower use of primary health care services among men in low-resource settings.[23] Greater coverage also was associated with higher age, BMI, educational attainment, and household wealth. The results for age and BMI suggest that health systems in LMICs are reaching more people with diabetes who have traditional risk factors such as older age and high BMI. These findings are crucial given that there is a high proportion of individuals with diabetes in LMICs who are normal weight according to clinically defined BMI categories,[24] and adequate

diabetes treatment in a young person might confer health and economic benefits throughout the lifespan.

A strength of our study is that, in our primary analysis, we define diabetes using an individual's diabetes biomarker or use of a glucose-lowering medication, rather than limiting the analysis only to individuals reporting a previous diabetes diagnosis. Given substantial differences in the proportion of people diagnosed between countries, we believe that our approach is the most valid method to compare performance of health systems in delivering diabetes treatment with the overall population in need, which was our study's main objective. In the sensitivity analysis, we restrict the sample to those reporting a diabetes diagnosis and find that large differences persist in diabetes treatment coverage among the three pharmacological treatments and also between pharmacological versus non-pharmacological treatments. As a high-income country comparison among people previously diagnosed with diabetes, in the 2007–12 US National Health and Nutrition Examination (NHANES) survey,[25] the proportion of eligible adults with diabetes who self-reported use of an antihypertensive medication for hypertension and statin use for primary CVD prevention was approximately 90% and 52%, respectively,[25] rates which are substantially higher than the results from the LMICs included in our study. However, the prevalence of self-reported exercise, diet, and weight-loss counselling among people with diagnosed diabetes in the 2011–16 US NHANES survey was approximately 70%,[26] rates which are similar to our results. In a pooled study[27] of health examination surveys from 12 high-income countries, overall treatment of hypertension (among all hypertensive individuals) ranged from 40% to 80%, whereas in our study we found that 41·3% (95% CI 39·3–43·3) of people with diabetes were treated in the sample of countries. In the 2013–17 Japan National Health and Nutrition Surveys,[28] coverage for glucose-lowering was 79·9% and for antihypertensive therapy was 46·3% among those in need of treatment.[28] The PURE study[3] in 21 countries also has shown markedly higher diabetes medication use and lower CVD mortality among people with diabetes in high-income countries compared with LMICs.

Such comparisons between our results and previously published reports from high-income countries should be made cautiously, as there are likely to be differences in methods and definitions among surveys. Nevertheless, our findings suggest that antihypertensive and cholesterol-lowering medication are areas of diabetes treatment in which there is a sizeable gap between health systems in LMICs versus those in high-income countries. Randomised clinical trials show the high degree of absolute clinical benefit in addressing hypertension and elevated cholesterol among people with diabetes, as reflected in more favourable numbers needed to treat for antihypertensive and cholesterol-lowering medications (ie, statins) compared with intensive glucose-lowering therapy.[29] Non-pharmacological interventions for diabetes, although widely recommended, have less evidence for improvement in long-term outcomes.[11] Taken in this context, our results suggest that scaling up pharmacological treatment of CVD risk factors such as hypertension and elevated cholesterol are priorities for the management of diabetes in LMICs. Although modelling studies[30] and consensus reports such as the Disease Control Priorities 3rd edition[31] have pointed to the cost-effectiveness of this approach, implementation will require substantial investments in health systems in LMICs. Global initiatives such as the WHO HEARTS Technical Package[7]—which integrates management of diabetes within a CVD prevention package in primary health care—and the forthcoming WHO Global Diabetes Compact[32] represent important opportunities to address these implementation and economic challenges. In the recently published *Lancet* Commission[15] on diabetes, global experts highlighted the urgent need to scale up treatment of cardiometabolic risk factors among people with diabetes through a multifaceted health systems strengthening approach that includes deployment of non-physician health workers (ie, task sharing) within a team-based approach, ensuring access to affordable medications including insulin, and strengthened data systems to measure health system performance. Although there is also a need to develop prospective, longitudinal data sources such as patient registries in LMICs,[15] our study also shows the power of population-based surveys such as STEPS to benchmark health system performance for diabetes. Analysis of repeated surveys from the same country over time, although beyond the scope of the present work, would also aid in understanding temporal trends in health systems' ability to deliver diabetes treatment within and across countries.

To our knowledge, this study is the most comprehensive assessment of diabetes treatment using nationally representative data in LMICs of diverse income groups and geographical regions. Previous pooled studies of diabetes treatment in LMICs include the PURE study,[3] an analysis of diabetes and CVD risk factors in a total of seven countries including four LMICs,[33] and our group's analysis of diabetes care cascades in 28 LMICs.[14] The PURE study also reported minimal use of glucose-lowering, antihypertensive, and cholesterol-lowering medications in LMICs, but the study was limited by non-nationally representative samples, inclusion of fewer than 20 LMICs, and, to our knowledge, no estimates for non-pharmacological diabetes interventions.[3] Our group's previous work in 28 LMICs showed substantial gaps in the cascade of glycaemic care, especially at the step of diagnosis, but this study did not explore coverage of antihypertensive or cholesterol-lowering medication.[14] The present study makes a substantial contribution to the global diabetes literature by evaluating coverage of comprehensive diabetes treatment in a much larger sample of nationally representative country surveys in LMICs than has previously been available.

Our study has limitations. First, we define diabetes diagnosis based on a single diabetes biomarker, many of

which are capillary glucose measurements. Single measurements of capillary glucose are common in high-quality pooled diabetes surveys[19,34] although there are concerns about diagnostic misclassification and the need for conversion to plasma glucose.[35] In our study, misclassification could lead to both underdiagnosis and overdiagnosis. Underdiagnosis can occur as a single fasting glucose could fail to capture 30% or more of people with undiagnosed diabetes who would be detected using an oral glucose tolerance test.[36–38] Conversely, overdiagnosis can occur as the short-term variability of a single fasting glucose might inflate diagnoses by as much as 30%.[39,40] Second, variations in diabetes clinical guidelines between countries might account for some observed differences.[41] Additionally, in clinical practice, the decision to start or stop a pharmacological treatment could be related to patients' observed responses to non-pharmacological treatment. For example, in patients with modestly elevated blood glucose, clinicians might appropriately defer initiating glucose-lowering treatment while first focusing on lifestyle changes through counselling on diet, exercise, and weight loss. Although we acknowledge these nuances, we justify our outcomes as they are based on population-monitoring indicators and clinical treatment recommendations in WHO PEN, which is a widely cited global reference standard for NCD management in LMICs.[6] Third, differences among surveys regarding the year the survey was done, diabetes biomarker, age sample, and how surveys implemented the same question might account for some of the observed variation and affect cross-country comparisons. Despite these differences, to our knowledge, the included surveys represent the best available population-level data on diabetes treatment in LMICs. We include extensive information on the underlying surveys in our appendices, and we attempt to investigate these differences through a suite of sensitivity analyses. Fourth, as we define coverage using self-reported measures, our estimates might be impacted by recall bias or the potential for self-reports to overestimate coverage.[42] Fifth, the underlying surveys had incomplete inclusion of each outcome, and, in particular, there was an absence of non-pharmacological data from several large countries, such as Bangladesh, India, and Mexico. Similarly, due to unavailability of the relevant variables, we were unable to pool data on the coverage of smoking cessation counselling; this is a limitation as smoking is a major contributor to CVD risk among people with diabetes. Sixth, we do not consider the topic of diabetes prevention or the role of new drugs such as SGLT2 inhibitors and GLP-1 receptor agonists, which reduce mortality among diabetes patients at high CVD risk.[43] These are active priority areas for future research within our group. A final limitation is that our study focuses on treatment coverage and does not assess the quality of coverage or the adequacy of risk factor control. The *Lancet Global Health* Commission[44] on high quality health systems advocates for the use of effective coverage, a quality-corrected coverage metric, to benchmark health system performance.[44] Effective coverage accounts not only for coverage but also for the magnitude of health gain experienced by the individual receiving the treatment.[45] In cross-sectional data such as that used in this study, it is very challenging to estimate the health gains associated with treatment. Given these challenges, we define our coverage outcome to mirror the population-level monitoring indicators recommended in WHO PEN, which are in turn based on existing clinical evidence.[6] In future research, we plan to provide estimates of effective coverage of diabetes treatment.

In conclusion, we found that fewer than one in ten people with diabetes in LMICs receive coverage of guideline-based comprehensive diabetes treatment. Our findings suggest that delivering treatment not only to lower glucose but also to manage CVD risk factors such as hypertension and elevated cholesterol among people with diabetes are urgent global priorities. Policy efforts to achieve Sustainable Development Goal 3.4 should focus on filling these gaps in global diabetes care.

Contributors

DF, JAS, and JM-G conceived the idea for this study. JM-G, MT, MEM, RA, SV, TWB, JID, and PG led the data collation. GB, BN, MTM, MSG, KKA, DL, MDo, BKS, PB, JMAJ, DG, CH, GA-B, SQ-C, LS, FF, and SSM led the data acquisition. DF, JAS, and JM-G led the data analysis and verified the data. DF and JM-G wrote the first draft of the manuscript with substantial revisions from MDu, ST, DJW, PR, MR-Z, and MH. All authors provided crucial input on multiple iterations of the manuscript. DF and JM-G verified the underlying data. All authors had full access to the data and had the final responsibility to submit for publication.

Declaration of interests

DJW reports serving on a data-monitoring committee for Novo Nordisk. All other authors declare no competing interests.

Data sharing

This study includes individual-level data from 55 countries. Data are publicly available for 47 of these countries. For data that are not publicly accessible and for which we have arranged specific data-use agreements, we are unable to share these data given the terms of our agreements. The appendix (p 35) provides a complete list of web addresses and country-specific contacts regarding data access.

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References

1 Murray CJL, Aravkin AY, Zheng P, et al. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1223–49.

2 International Diabetes Federation. IDF Diabetes Atlas, 9th edn. Brussels: International Diabetes Federation, 2019.

3 Anjana RM, Mohan V, Rangarajan S, et al. Contrasting associations between diabetes and cardiovascular mortality rates in low-, middle-, and high-income countries: cohort study data from 143,567 individuals in 21 countries in the PURE study. *Diabetes Care* 2020; **43:** 3094–101.

4 Kruk ME, Gage AD, Joseph NT, Danaei G, García-Saisó S, Salomon JA. Mortality due to low-quality health systems in the universal health coverage era: a systematic analysis of amenable deaths in 137 countries. *Lancet* 2018; **392:** 2203–12.

5 Countdown NCD. NCD Countdown 2030: pathways to achieving Sustainable Development Goal target 3.4. *Lancet* 2020; **396:** 918–34.

6 WHO. WHO package of essential noncommunicable (PEN) disease interventions for primary health care. Geneva: World Health Organization, 2020.

7 WHO. Diagnosis and management of type 2 diabetes (HEARTS-D). Geneva: World Health Organization, 2020.

8 Rawshani A, Rawshani A, Franzén S, et al. Risk factors, mortality, and cardiovascular outcomes in patients with type 2 diabetes. *N Engl J Med* 2018; **379:** 633–44.

9 Gaede P, Vedel P, Larsen N, Jensen GV, Parving HH, Pedersen O. Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. *N Engl J Med* 2003; **348:** 383–93.

10 Ali MK, Siegel KR, Chandrasekar E, et al. Diabetes: an update on the pandemic and potential solutions. In: Prabhakaran D, Anand S, Gaziano TA, Mbanya JC, Wu Y, Nugent R, eds. Cardiovascular, Respiratory, and Related Disorders. Washington, DC: World Bank, 2017.

11 Wing RR, Bolin P, Brancati FL, et al. Cardiovascular effects of intensive lifestyle intervention in type 2 diabetes. *N Engl J Med* 2013; **369:** 145–54.

12 Flood D, Hane J, Dunn M, 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:** e1003434.

13 Shivashankar R, Kirk K, Kim WC, et al. Quality of diabetes care in low- and middle-income Asian and Middle Eastern countries (1993-2012): 20-year systematic review. *Diabetes Res Clin Pract* 2015; **107:** 203–23.

14 Manne-Goehler J, Geldsetzer P, Agoudavi K, 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:** e1002751.

15 Chan JCN, Lim L-L, Wareham NJ, et al. The *Lancet* Commission on diabetes: using data to transform diabetes care and patient lives. *Lancet* 2020; **396:** 2019–082.

16 Seiglie JA, Marcus ME, Ebert C, et al. Diabetes prevalence and its relationship with education, wealth, and bmi in 29 low- and middle-income countries. *Diabetes Care* 2020; **43:** 767–75.

17 Sacks DB, Arnold M, Bakris GL, et al. Guidelines and recommendations for laboratory analysis in the diagnosis and management of diabetes mellitus. *Clin Chem* 2011; **57:** e1–47.

18 Wei N, Zheng H, Nathan DM. Empirically establishing blood glucose targets to achieve HbA1c goals. *Diabetes Care* 2014; **37:** 1048–51.

19 Zhou B, Lu Y, Hajifathalian K, et al. Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. *Lancet* 2016; **387:** 1513–30.

20 Kaptoge S, Pennells L, De Bacquer D, et al. World Health Organization cardiovascular disease risk charts: revised models to estimate risk in 21 global regions. *Lancet Glob Health* 2019; **7:** e1332–45.

21 Pesec M, Ratcliffe HL, Karlage A, Hirschhorn LR, Gawande A, Bitton A. Primary health care that works: the costa rican experience. *Health Aff (Millwood)* 2017; **36:** 531–38.

22 Foliaki S, Pearce N. Prevention and control of diabetes in Pacific people. *BMJ* 2003; **327:** 437–39.

23 Baker P, Shand T. Men's health: time for a new approach to policy and practice? *J Glob Health* 2017; **7:** 010306.

24 Gujral UP, Weber MB, Staimez LR, Narayan KMV. Diabetes among non-overweight individuals: an emerging public health challenge. *Curr Diab Rep* 2018; **18:** 60.

25 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:** 681–89.

26 Grabovac I, Smith L, Stefanac S, et al. Health care providers' advice on lifestyle modification in the US population: results from the NHANES 2011-2016. *Am J Med* 2019; **132:** 489–97.

27 Zhou B, Danaei G, Stevens GA, et al. Long-term and recent trends in hypertension awareness, treatment, and control in 12 high-income countries: an analysis of 123 nationally representative surveys. *Lancet* 2019; **394:** 639–51.

28 Ikeda N, Nishi N, Sugiyama T, Noda H, Noda M. Effective coverage of medical treatment for hypertension, diabetes and dyslipidaemia in Japan: an analysis of National Health and Nutrition Surveys 2003–2017. *J Health Serv Res Policy* 2021; **26:** 106–14.

29 Yudkin JS, Richter B, Gale EA. Intensified glucose lowering in type 2 diabetes: time for a reappraisal. *Diabetologia* 2010; **53:** 2079–85.

30 Basu S, Wagner RG, Sewpaul R, Reddy P, Davies J. Implications of scaling up cardiovascular disease treatment in South Africa: a microsimulation and cost-effectiveness analysis. *Lancet Glob Health* 2019; **7:** e270–80.

31 Prabhakaran D, Anand S, Watkins D, et al. Cardiovascular, respiratory, and related disorders: key messages from Disease Control Priorities, 3rd edition. *Lancet* 2018; **391:** 1224–36.

32 WHO. The WHO global diabetes compact: uniting around a common agenda for diabetes. 2020. https://www.who.int/docs/default-source/world-diabetes-day/global-diabetes-compact-final.pdf (accessed March 29, 2021).

33 Gakidou E, Mallinger L, Abbott-Klafter J, et al. Management of diabetes and associated cardiovascular risk factors in seven countries: a comparison of data from national health examination surveys. *Bull World Health Organ* 2011; **89:** 172–83.

34 Sarwar N, Gao P, Seshasai SR, et al. Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies. *Lancet* 2010; **375:** 2215–22.

35 Stauffer F, Viswanathan B, Jean M, Kinabo P, Bovet P. Comparison between capillary glucose measured with a Contour glucometer and plasma glucose in a population survey. *LaboratoriumsMedizin* 2016; **40:** 133–39.

36 WHO. Definition and diagnosis of diabetes mellitus and intermediate hyperglycaemia: report of a WHO/IDF consultation. Geneva: World Health Organization, 2006.

37 Zhou X, Pang Z, Gao W, et al. Performance of an A1C and fasting capillary blood glucose test for screening newly diagnosed diabetes and pre-diabetes defined by an oral glucose tolerance test in Qingdao, China. *Diabetes Care* 2010; **33:** 545–50.

38 Danaei G, Fahimi S, Lu Y, et al. Effects of diabetes definition on global surveillance of diabetes prevalence and diagnosis: a pooled analysis of 96 population-based studies with 331,288 participants. *Lancet Diabetes Endocrinol* 2015; **3:** 624–37.

39 Selvin E, Crainiceanu CM, Brancati FL, Coresh J. Short-term variability in measures of glycemia and implications for the classification of diabetes. *Arch Intern Med* 2007; **167:** 1545–51.

40 Schmidt MI, Bracco P, Canhada S, et al. Regression to the mean contributes to the apparent improvement in glycemia 3.8 years after screening: the ELSA-Brasil study. *Diabetes Care* 2021; **44:** 81–88.

41 Owolabi MO, Yaria JO, Daivadanam M, et al. Gaps in guidelines for the management of diabetes in low- and middle-income versus high-income countries-a systematic review. *Diabetes Care* 2018; **41:** 1097–105.

42 Stirratt MJ, Dunbar-Jacob J, Crane HM, et al. Self-report measures of medication adherence behavior: recommendations on optimal use. *Transl Behav Med* 2015; **5:** 470–82.

43 Tsapas A, Avgerinos I, Karagiannis T, et al. Comparative effectiveness of glucose-lowering drugs for type 2 diabetes: a systematic review and network meta-analysis. *Ann Intern Med* 2020; **173:** 278–86.

44 Kruk ME, Gage AD, Arsenault C, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. *Lancet Glob Health* 2018; **6:** e1196–252.

45 Ng M, Fullman N, Dieleman JL, Flaxman AD, Murray CJ, Lim SS. Effective coverage: a metric for monitoring Universal Health Coverage. *PLoS Med* 2014; **11:** e1001730.