The state of hypertension care in 44 low-income and middle-income countries: A cross-sectional study of nationally representative individual-level data from 1.1 million adults

The state of hypertension care in 44 low-income and middle-income countries: a cross-sectional study of nationally representative individual-level data from 1·1 million adults

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See Editorial page 611

See Comment page 613

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Summary

Background Evidence from nationally representative studies in low-income and middle-income countries (LMICs) on where in the hypertension care continuum patients are lost to care is sparse. This information, however, is essential for effective targeting of interventions by health services and monitoring progress in improving hypertension care. We aimed to determine the cascade of hypertension care in 44 LMICs—and its variation between countries and population groups—by dividing the progression in the care process, from need of care to successful treatment, into discrete stages and measuring the losses at each stage.

Methods In this cross-sectional study, we pooled individual-level population-based data from 44 LMICs. We first searched for nationally representative datasets from the WHO Stepwise Approach to Surveillance (STEPS) from 2005 or later. If a STEPS dataset was not available for a LMIC (or we could not gain access to it), we conducted a systematic search for survey datasets; the inclusion criteria in these searches were that the survey was done in 2005 or later, was nationally representative for at least three 10-year age groups older than 15 years, included measured blood pressure data, and contained data on at least two hypertension care cascade steps. Hypertension was defined as a systolic blood pressure of at least 140 mm Hg, diastolic blood pressure of at least 90 mm Hg, or reported use of medication for hypertension. Among those with hypertension, we calculated the proportion of individuals who had ever had their blood pressure measured; had been diagnosed with hypertension; had been treated for hypertension; and had achieved control of their hypertension. We weighted countries proportionally to their population size when determining this hypertension care cascade at the global and regional level. We disaggregated the hypertension care cascade by age, sex, education, household wealth quintile, body-mass index, smoking status, country, and region. We used linear regression to predict, separately for each cascade step, a country's performance based on gross domestic product (GDP) per capita, allowing us to identify countries whose performance fell outside of the 95% prediction interval.

Findings Our pooled dataset included 1 100 507 participants, of whom 192 441 (17·5%) had hypertension. Among those with hypertension, 73·6% of participants (95% CI 72·9–74·3) had ever had their blood pressure measured, 39·2% of participants (38·2–40·3) had been diagnosed with hypertension, 29·9% of participants (28·6–31·3) received treatment, and 10·3% of participants (9·6–11·0) achieved control of their hypertension. Countries in Latin America and the Caribbean generally achieved the best performance relative to their predicted performance based on GDP per capita, whereas countries in sub-Saharan Africa performed worst. Bangladesh, Brazil, Costa Rica, Ecuador, Kyrgyzstan, and Peru performed significantly better on all care cascade steps than predicted based on GDP per capita. Being a woman, older, more educated, wealthier, and not being a current smoker were all positively associated with attaining each of the four steps of the care cascade.

Interpretation Our study provides important evidence for the design and targeting of health policies and service interventions for hypertension in LMICs. We show at what steps and for whom there are gaps in the hypertension care process in each of the 44 countries in our study. We also identified countries in each world region that perform better than expected from their economic development, which can direct policy makers to important policy lessons. Given the high disease burden caused by hypertension in LMICs, nationally representative hypertension care cascades, as constructed in this study, are an important measure of progress towards achieving universal health coverage.

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Research in context

Evidence before this study

We searched MEDLINE for work published between Jan 1, 1966, and Jan 31, 2019, with variations of the search terms "hypertension", "screened", "aware", "treated", and "controlled" in the title or abstract. To date, the largest study of individual-level data to compare hypertension awareness, treatment, and control between low-income and middle-income countries (LMICs) was the Prospective Urban Rural Epidemiology (PURE) study. The PURE study also examined how the hypertension care cascade varied among population groups within countries. However, this study was based on a convenience sample rather than a random sample of communities, used data from 2003 to 2009, and only included 14 LMICs.

Added value of this study

To our knowledge, this is the largest study to date that analyses individual-level data from nationally representative samples of adults in LMICs to determine at which stages in the hypertension care process patients are lost, and how these losses vary between and within countries. We make four key additions to the current evidence base. First, for each of 44 LMICs, we quantified the loss of individuals with hypertension at each step of the hypertension care cascade; these data can be used to guide national policy makers in deciding whether to prioritise efforts to improve screening, diagnosis, initiation of treatment, or medication adherence and care retention. Second, we examined how the hypertension care cascade varies between different population groups within LMICs, providing important information on possible target groups for relevant interventions. Third, by benchmarking countries' performance against their gross domestic product per capita, our analysis identifies countries that performed better than expected based on their wealth and thus likely hold valuable policy lessons for countries at a similar level of economic development. Finally, our study provides a benchmark of health system performance for managing hypertension in LMICs against which future progress can be compared.

Implications of all the available evidence

Although the proportion of adults who achieved control of their hypertension was low in all four world regions that we examined, countries in Latin America and the Caribbean showed, on average, the best care cascade performance, whereas countries in sub-Saharan Africa tended to show the poorest performance. Well designed and well targeted interventions to improve hypertension care in LMICs are urgently needed. More research is required to understand why some LMICs achieve substantially better hypertension care cascade indicators than others and how the hypertension care cascade can be improved most effectively in different settings.

Introduction

Hypertension is a major risk factor for several common non-communicable diseases (NCDs), particularly stroke, heart disease, and chronic kidney disease.[1] The prevalence of hypertension is increasing rapidly in low-income and middle-income countries (LMICs).[2] The regions with the highest prevalence of hypertension are thought to be sub-Saharan Africa, south Asia, and central and eastern Europe, all regions largely comprised of LMICs.[2]

Evidence regarding where in the hypertension care continuum patients stop progressing and how these patterns vary between and within countries, is essential to designing effective interventions to improve hypertension control. Additionally, assessing the success of health systems in managing important—yet inexpensively treatable—NCD risk factors, such as hypertension,[3] would be a useful measure of health system performance that could be tracked as part of national and international targets, such as universal health coverage.[4] Specifically, as LMICs undergo the epidemiological transition, such a measure of health system performance could help track countries' progress in shifting health services away from mainly providing episodic care for acute communicable conditions towards furnishing long-term, person-centred care for chronic non-communicable conditions.

Estimates of health system performance regarding hypertension from nationally representative studies in LMICs are sparse.[5] This dearth of evidence, along with the projected rapid rise in the number of people with hypertension in these settings,[6] is the main reason for our focus on LMICs, rather than high-income countries. To inform the design of interventions in health services and to provide a cross-country comparison of health system performance for managing hypertension, we aimed to determine where patients in LMICs are lost to care along the hypertension management continuum and how these patterns vary among countries and population groups within these countries.

Methods

Data sources

In this cross-sectional study, we requested access to the most recent nationally representative WHO Stepwise Approach to Surveillance (STEPS) survey done since 2005, for all countries that were defined by the World Bank as a LMIC at the time of the survey.[7] We selected STEPS surveys because they use the same standardised questionnaire, sample a wide age range of adults, and are the official approach developed by WHO for monitoring NCD risk factors at the population level.[8] If an eligible STEPS dataset was not available for a LMIC, or we could not gain access to it, we conducted a systematic search with Google, to identify the most recent nationally representative household survey from the LMIC that was conducted in 2005 or later, collected data on at least three 10-year age groups older than 15 years, measured blood pressure in participants twice or more, and asked

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See Online for appendix

questions on at least two steps in the hypertension care cascade.

This study was designated "not human subjects research" and was thus deemed not to require additional ethical approval by the institutional review board of the Harvard T H Chan School of Public Health on May 9, 2018.

Definitions of hypertension and the cascade of care

Hypertension was defined as systolic blood pressure of at least 140 mm Hg or diastolic blood pressure of at least 90 mm Hg or reported use of medication for hypertension. For participants with three blood pressure measurements, we used the mean of the last two measurements; for participants with only two measurements, we computed the mean of both available measurements.

We calculated the proportion of all those with hypertension who had ever received a blood pressure measurement (designated ever measured), had been diagnosed with hypertension by a health-care provider (designated diagnosed), were currently taking antihypertensive medication (designated treated), and had been treated (or had received relevant lifestyle advice) and had a systolic blood pressure of less than 140 mm Hg and a diastolic blood pressure of less than 90 mm Hg (designated controlled). In additional analyses, we also evaluated these proportions when defining treated as having received relevant lifestyle advice or taking antihypertensive medication (appendix). Further details on the computation of the care cascade are shown in the appendix.

Statistical analysis

None of the analyses were prespecified. Countries were categorised according to the regional groupings of the WHO regional offices; however, the European and eastern Mediterranean regions and the southeast Asia and western Pacific regions were merged to avoid only having two countries with data in a region. All analyses accounted for the multi-stage cluster random sampling of the surveys by use of sampling weights. In our primary analyses, we weighted each country relative to its population size in 2015, when computing the hypertension care cascade at the global and regional level.[9] We also did additional analyses that assigned the same weight to each country (appendix).

We plotted the proportion of participants with hypertension who reached each step of the care cascade in each country against the country's gross domestic product (GDP) per capita (in constant 2011 international dollars, as estimated by the World Bank)[10] in the year of survey data collection, to ascertain health system performance relative to a country's wealth. For each cascade step, we also regressed the proportion of participants with hypertension who reached the given step on sex, 10-year age group, education, household wealth quintile, body-mass index (BMI) group (in which a BMI <18·5 kg/m² was defined as underweight; a BMI of ≥18·5 kg/m² but <25·0 kg/m² was defined as a healthy weight; a BMI of ≥25·0 kg/m² but <30·0 kg/m² was defined as overweight; and a BMI of ≥30·0 kg/m² was defined as obese), and a binary indicator for current tobacco smoking. Specifically, we fitted univariable and multivariable Poisson regressions with country-level fixed effects, adjusting standard errors for clustering at the level of the primary sampling unit. In 20 countries, household wealth quintiles were calculated based on a principal component analysis of participants' answers to several questions on key household dwelling characteristics and household ownership of durable goods (ie, goods that are not completely consumed in one use). In 14 countries these questions were not asked, but we did have data on household income in these countries, which we used instead to approximate household wealth quintiles in these surveys. More detail on the computation of the household wealth quintiles is shown in the appendix. Household wealth data were not available for ten countries, smoking data were not available for six countries, and BMI data were not available for five countries (appendix). These countries were therefore removed from the regressions that included these as independent variables. All analyses were complete case analyses.

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. The corresponding author had full access to the data and had final responsibility for the decision to submit for publication.

Results

We attained individual-level STEPS survey data from 22 LMICs and, from our systematic search, we included survey datasets from an additional 22 LMICs (appendix). 40 countries measured blood pressure with a digital upper arm meter, two countries with a digital wrist meter, and two countries with a manual mercury sphygmomanometer (appendix). 35 countries measured blood pressure three times, five countries twice, and one country (the Seychelles) five times. Three countries measured blood pressure twice, with a third measurement if the first two measurements differed by more than a predefined margin (appendix). We performed our analyses on these survey data between May 12, 2018, and March 5, 2019.

The survey-level median response rate was 90·9% (IQR 81·5–95·6; table 1). Among those interviewed, the proportion of participants with a missing outcome (blood pressure or questionnaire response to whether the participant has ever had their blood pressure measured) ranged from 0% in Belize, Romania, and the Seychelles to 30·2% in Mexico, and the survey-level median proportion of participants with missing outcome data was 2·3% (0·6–8·6). 1 100 507 participants with outcome data were included in the analysis. The survey-level median age among these participants was

	Years of data collection	Response rate, %	Missing outcomes, %	Sample size	Hypertensive, n (%)	Median age, years	Age range, years	Female, %	GDP per capita, international $	Population in 2015, thousands
Europe and the eastern Mediterranean										
Albania	2008	95·4%	4·3%	6380	1494 (23·4%)	33	15–49	55·2%	9154	2923
Azerbaijan	2006	83·3%	0·4%	10 486	1712 (16·3%)	32	15–59	75·9%	10 711	9617
Egypt	2015	95·0%	0·5%	14 790	2476 (16·7%)	33	15–59	53·0%	10 096	93 778
Georgia	2016	75·7%	4·2%	4034	1800 (44·6%)	50	17–70	70·4%	9277	3952
Kazakhstan	2012	93·0%	13·8%	10 901	2995 (27·5%)	43	15–90	57·3%	21 987	17 750
Kyrgyzstan	2012	96·5%	2·5%	9422	852 (9·0%)	29	15–49	75·5%	2870	5865
Lebanon	2008–09	62·0%	1·2%	2800	841 (30·0%)	37	18–95	52·9%	15 193	5851
Romania	2015–16	69·1%	0	1970	611 (31·0%)	47	18–80	52·5%	21 080	19 877
Russia	2007–08	61·4%	2·7%	4209	2696 (64·1%)	62	18–100	64·2%	24 006	143 888
Ukraine	2007	81·5%	17·9%	7932	2013 (25·4%)	33	15–49	68·4%	8497	44 658
Latin America and the Caribbean										
Belize	2005–06	92·6%	0	2434	695 (28·6%)	44	20–97	59·0%	7947	359
Brazil	2013	86·0%	10·6%	57 466	17 517 (30·5%)	41	18–101	56·5%	15 430	205 962
Chile	2009–10	85·0%	8·4%	4851	1497 (30·9%)	46	15–100	59·8%	18 995	17 763
Costa Rica	2010	87·8%	0·6%	3607	1291 (35·8%)	47	18–110	72·0%	13 000	4808
Ecuador	2012	81·5%	19·8%	29 659	2834 (9·6%)	34	20–59	58·7%	10 322	16 144
Grenada	2011–12	67·8%	2·8%	1097	460 (41·9%)	44	24–64	59·9%	11 249	107
Guyana	2016	66·7%	0·6%	2640	776 (29·4%)	40	18–69	59·9%	7266	769
Mexico	2009–12	90·0%	30·2%	20 946	5066 (24·2%)	35	15–99	56·6%	15 668	125 891
Peru	2012	94·3%	5·3%	29 415	7771 (26·4%)	54	40–96	52·6%	10 944	31 377
Saint Vincent and the Grenadines	2013	67·8%	0·4%	3457	1056 (30·5%)	42	18–70	55·9%	10 193	109
Southeast Asia and the western Pacific										
Bangladesh	2011	95·0%	10·4%	7593	2052 (27·0%)	48	35–96	49·5%	2571	161 201
Bhutan	2014	96·9%	0·2%	2814	1107 (39·3%)	39	18–69	61·9%	7366	787
China	2009	88·0%	9·3%	9752	2842 (29·1%)	50	15–99	52·5%	8652	1 397 029
India	2015–16	96·0%	2·0%	742 838	98 451 (13·3%)	30	15–54	85·6%	5924	1 309 054
Indonesia	2014	83·0%	0·7%	32 492	7882 (24·3%)	35	15–110	53·2%	10 003	258 162
Mongolia	2009	95·0%	0·4%	5420	1719 (31·7%)	36	15–65	40·8%	7368	2977
Nepal	2013	98·6%	0·5%	4124	1211 (29·4%)	40	15–69	67·8%	2164	28 656
Timor-Leste	2014	96·3%	1·6%	2568	713 (27·8%)	40	18–69	58·5%	1888	1241
Sub-Saharan Africa										
Benin	2008	99·0%	0·3%	3799	1218 (32·1%)	42	15–65	51·5%	1841	10 576
Burkina Faso	2013	97·8%	15·1%	3993	713 (17·9%)	36	25–64	53·9%	1562	18 111
Comoros	2011	96·5%	1·4%	5381	1443 (26·8%)	39	25–64	71·2%	1415	777
eSwatini	2014	81·8%	9·9%	3183	948 (29·8%)	33	15–70	65·1%	7871	1319
Ghana	2007–08	79·4%	9·6%	5030	2677 (53·2%)	60	18–110	46·7%	2760	27 583
Kenya	2015	95·0%	1·4%	4408	1188 (27·0%)	35	18–69	60·2%	2836	47 236
Lesotho	2014	90·8%	3·9%	5690	989 (17·4%)	27	15–59	52·6%	2677	2175
Liberia	2011	87·1%	1·7%	2482	719 (29·0%)	36	24–64	57·9%	734	4500
Mozambique	2005	98·3%	7·0%	3073	1102 (35·9%)	38	25–64	58·4%	742	28 011
Namibia	2013	96·9%	17·9%	3617	1543 (42·7%)	46	35–64	57·6%	9256	2426
Seychelles	2013	73·0%	0	1240	413 (33·3%)	47	25–64	57·2%	24 791	94
South Africa	2012	39·8%	3·6%	6317	2644 (41·9%)	39	15–98	64·9%	12 215	55 291
Tanzania	2012	94·7%	1·2%	5636	1737 (30·8%)	40	23–65	53·8%	2228	53 880
Togo	2010	91·0%	3·7%	4190	846 (20·2%)	32	15–64	52·0%	1208	7417
Uganda	2014	99·0%	2·1%	3904	983 (25·2%)	33	18–69	59·8%	1637	40 145
Zanzibar	2011	91·0%	0·7%	2467	848 (34·4%)	40	24–64	61·6%	1318	1441

(Table 1 continues on next page)

	Years of data collection	Response rate, %	Missing outcomes, %	Sample size	Hypertensive, n (%)	Median age, years	Age range, years	Female, %	GDP per capita, international $	Population in 2015, thousands
(Continued from previous page)										
World (all data)										
Survey-level median (IQR)	NA	90·9% (81·5–95·6)	2·3% (0·6–8·6)	1 100 507*	192 441 (29·3% †)*	39·5 (34·8–44·5)	NA	58·2% (53·2–62·5)	8222 (2651–11 491)	4 177 630*

Data are not weighted with sampling weights. Except for the missing outcome variable, all values were calculated in those with outcome data (ie, no missing blood pressure measurements or questionnaire answer needed to calculate the first step of the country's hypertension care cascade). The response rate includes both the household and the individual response rate. The proportion with a missing outcome is the percentage of participants with missing blood pressure measurements or survey response for the question ascertaining whether the participant had reached the first step of the country's hypertension care cascade. GDP per capita data are shown in constant 2011 international dollars (as estimated by the World Bank[9]) for the year in which data was collected for the survey. Response rate in Peru is in women only because men's response rate was not available. Response rate in China is from the 2006 wave of the China Health and Nutrition Survey (the most recent wave with a published response rate). GDP per capita in Zanzibar is shown in constant 2007 international dollars by use of data from the Office of the Chief Government Statistician of Zanzibar.[29] The population estimate for Zanzibar was taken from the Tanzania Population Projection Report 2013–35.[30] GDP=gross domestic product. NA=not applicable. *Total across all countries. †Percentage is the survey-level median.

Table 1: **Survey characteristics by region**

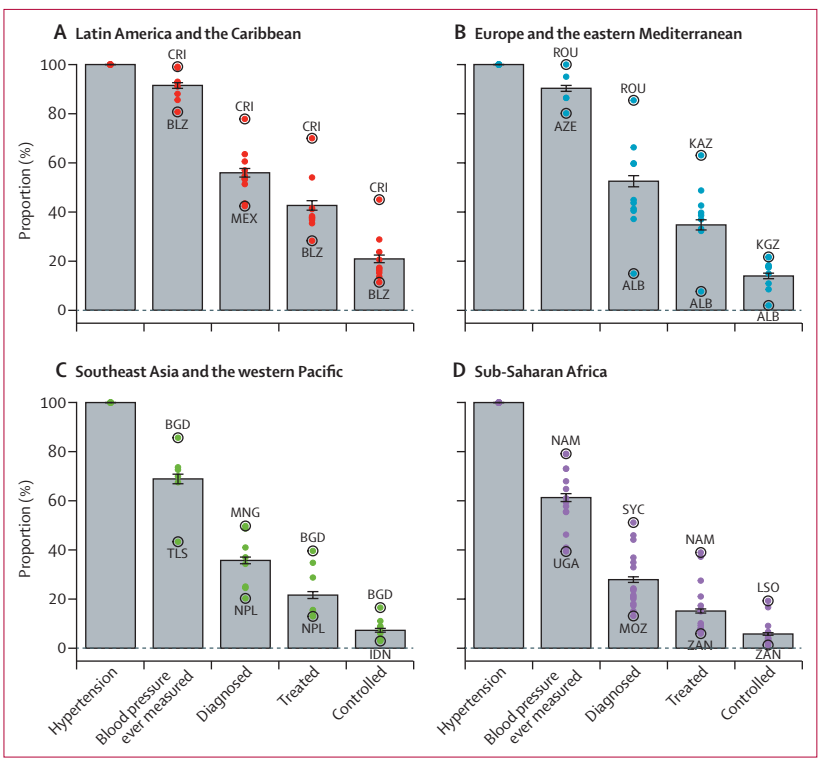

Figure 1: **The hypertension care cascade by region**

Data are percentages with 95% CIs. Individual points depict the point estimate for each country. ALB=Albania. AZE=Azerbaijan. BGD=Bangladesh. BLZ=Belize. CRI=Costa Rica. IDN=Indonesia. KAZ=Kazakhstan. KGZ=Kyrgyzstan. LSO=Lesotho. MEX=Mexico. MNG=Mongolia. MOZ=Mozambique. NAM=Namibia. NPL=Nepal. ROU=Romania. SYC=Seychelles. TLS=Timor-Leste. UGA=Uganda. ZAN=Zanzibar.

39·5 years (34·8–44·5). 192 441 (17·5%) participants had hypertension. Detailed sample characteristics are shown in the appendix.

The prevalence of hypertension and undiagnosed hypertension by country and 10-year age group is shown in the appendix. Using sampling weights that weighted countries in proportion to their population size, we estimated that, among those with hypertension, 73·6% of participants (95% CI 72·9–74·3) had ever had their blood pressure measured, 39·2% of participants (38·2–40·3) had been diagnosed with hypertension before the survey, 29·9% of participants (28·6–31·3) had been treated, and 10·3% of participants (9·6–11·0) had achieved control of their hypertension.

Of the four world regions examined, Latin America and the Caribbean had the highest proportion of individuals reaching each stage of the care cascade, whereas sub-Saharan Africa had the lowest (figure 1; appendix). Fewer than 5% of those with hypertension had achieved control of their condition in ten (63%) of 16 countries in sub-Saharan Africa, versus three (38%) of eight countries in southeast Asia and the western Pacific, one (10%) of ten countries in Europe and the eastern Mediterranean, and none (0%) of the ten countries in Latin America and the Caribbean (appendix). Within regions, there was substantial variation among countries in the proportion of individuals with hypertension attaining each cascade step. Costa Rica was the best-performing country regarding the proportion of people reaching each cascade step in Latin America and the Caribbean (figure 1). Other high-performing countries, relative to other countries in their region, were Bangladesh, Namibia, and Romania.

GDP per capita was positively associated with a country's performance for each cascade step (figure 2). Countries that performed substantially better on all measured cascade steps than predicted based on their GDP per capita in the year of the survey were Bangladesh, Brazil, Costa Rica, Ecuador, Kyrgyzstan, and Peru. Countries that performed significantly worse on all measured cascade steps than expected based on their GDP per capita were Albania, Indonesia, Tanzania, Uganda, and South Africa.

Those who were female, older, did not currently smoke, and who were in higher quintiles for household wealth were more likely to reach each step of the cascade in both univariable and multivariable regressions (table 2). Additionally, being overweight or obese was associated with a higher probability of reaching each cascade step in all regressions except for the last step, from treatment to control of blood pressure. Furthermore, we found that educational attainment was positively associated with reaching each cascade step in the multivariable regressions,

and people who were obese had a higher probability of reaching each cascade step than people who were overweight (with the exception of the last cascade step in the multivariable regression). The positive associations between attainment of each cascade step and education were strongest in low-income countries and weakest in upper middle-income countries (appendix). By region, the associations with education were strongly positive in sub-Saharan Africa and did not exist, or they were negative in the Europe and eastern Mediterranean region.

A stratification of the proportion of participants with hypertension who reached each cascade step by sex, age group, and education demonstrated that the proportion achieving control was less than 20% in all age and education group combinations; in each educational attainment category, less than half of individuals were diagnosed in age groups younger than 55 years; and women had a higher probability of reaching each cascade step than men in almost all age and education group combinations (figure 3).

The care cascade disaggregated by 10-year age group and the hypertension care cascade for each country are shown in the appendix. The relative differences between regions and countries regarding the proportion of people reaching each cascade step were similar to the primary results when defining treatment as receiving lifestyle advice or taking antihypertensive medication, when weighting countries equally, and when disaggregating the care cascade in each region by 10-year age group. Performance relative to GDP per capita-based estimates were also similar to the primary

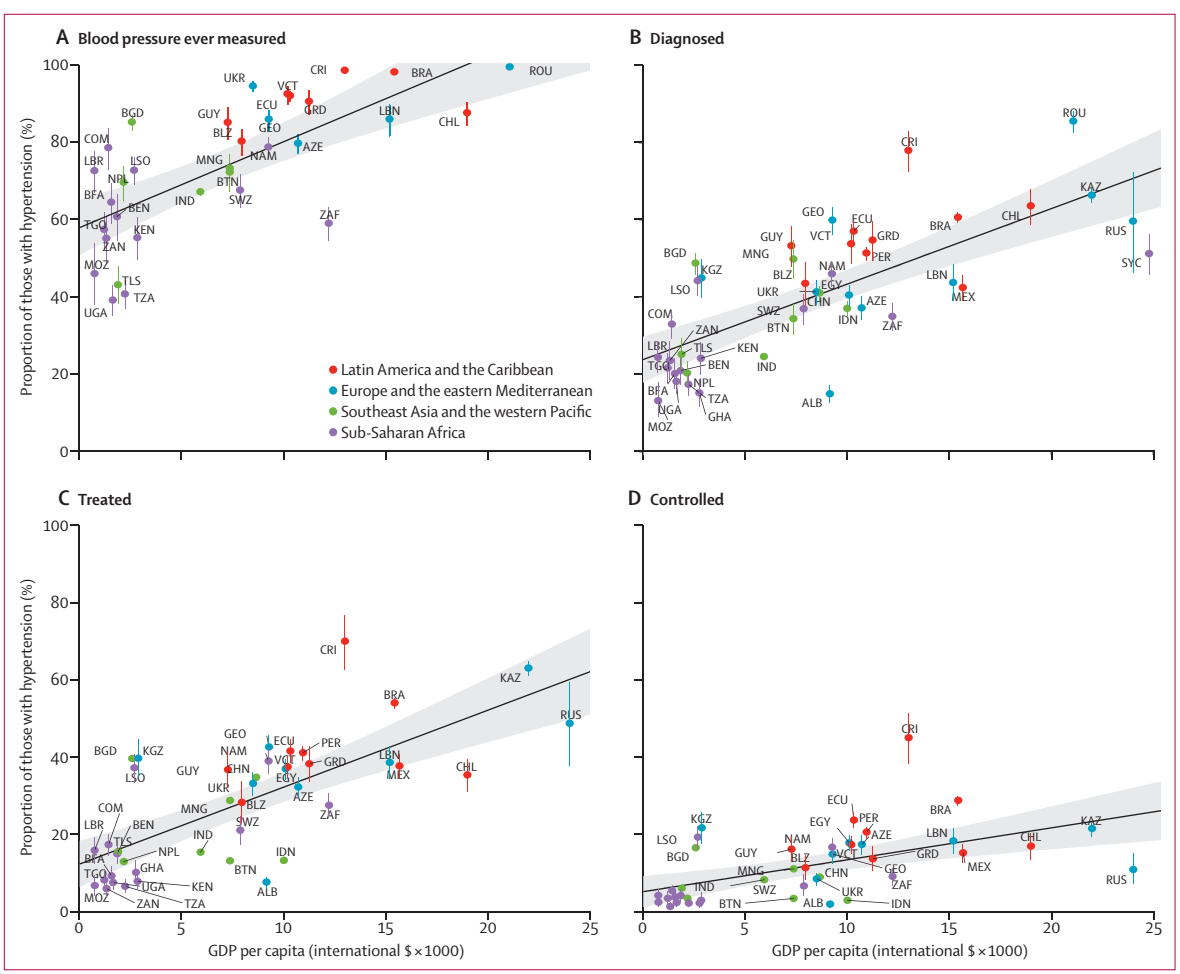

Figure 2: **Hypertension care cascade indicators by GDP per capita**
GDP per capita is in constant 2011 international dollars for the year in which the survey was done. The grey boundary shows the point-wise 95% prediction interval, and the vertical bars are 95% CIs around point estimates. The p values for the coefficients of the linear regressions of each cascade step onto GDP per capita (with each country having the same weight) were <0·001, except for the last cascade step, from treated to controlled blood pressure (p=0·0014). Country labels are not shown in the controlled plot to avoid visual overcrowding for Benin, Burkina Faso, Comoros, Ghana, Kenya, Liberia, Mozambique, Nepal, Tanzania, Timor-Leste, Togo, and Uganda. The figure is broken down for each 10-year age group in the appendix. ALB=Albania. AZE=Azerbaijan. BEN=Benin. BFA=Burkina Faso. BGD=Bangladesh. BLZ=Belize. BRA=Brazil. BTN=Bhutan. CHL=Chile. CHN=China. COM=Comoros. CRI=Costa Rica. ECU=Ecuador. EGY=Egypt. GDP=Gross Domestic Product. GEO=Georgia. GHA=Ghana. GRD=Grenada. GUY=Guyana. IDN=Indonesia. IND=India. KAZ=Kazakhstan. KEN=Kenya. KGZ=Kyrgyzstan. LBN=Lebanon. LBR=Liberia. LSO=Lesotho. MEX=Mexico. MNG=Mongolia. MOZ=Mozambique. NAM=Namibia. NPL=Nepal. PER=Peru. ROU=Romania. RUS=Russia. SWZ=eSwatini. SYC=Seychelles. TGO=Togo. TLS=Timor-Leste. TZA=Tanzania. UGA=Uganda. UKR=Ukraine. VCT=Saint Vincent and the Grenadines. ZAF=South Africa. ZAN=Zanzibar.

results when defining treatment as receiving lifestyle advice or taking antihypertensive medications, and when examining hypertension care cascade indicators by GDP per capita separately for each 10-year age group.

Discussion

Overall, the performance of health systems in LMICs regarding the management of hypertension was poor: less than half of those with hypertension were diagnosed, less

	Blood pressure ever measured		Diagnosed		Treated		Controlled	
	RR	p value	RR	p value	RR	p value	RR	p value
Univariable regressions*								
Sex								
Male	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Female	1·16 (1·14–1·18)	<0·0001	1·39 (1·33–1·46)	<0·0001	1·50 (1·41–1·58)	<0·0001	1·69 (1·53–1·87)	<0·0001
Age, years								
15–24	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
25–34	1·39 (1·33–1·46)	<0·0001	1·51 (1·30–1·74)	<0·0001	1·47 (1·22–1·77)	<0·0001	1·09 (0·88–1·36)	0·426
35–44	1·52 (1·46–1·60)	<0·0001	2·18 (1·93–2·47)	<0·0001	2·24 (1·94–2·57)	<0·0001	1·27 (1·09–1·48)	0·002
45–54	1·57 (1·50–1·65)	<0·0001	3·14 (2·79–3·52)	<0·0001	3·51 (3·08–4·00)	<0·0001	1·67 (1·44–1·92)	<0·0001
55–64	1·57 (1·50–1·64)	<0·0001	3·87 (3·43–4·36)	<0·0001	4·78 (4·17–5·49)	<0·0001	2·15 (1·81–2·55)	<0·0001
≥65	1·56 (1·48–1·64)	<0·0001	4·21 (3·72–4·76)	<0·0001	5·42 (4·72–6·22)	<0·0001	2·10 (1·76–2·51)	<0·0001
Education								
No schooling	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Primary education	1·08 (1·05–1·10)	<0·0001	0·97 (0·91–1·04)	0·454	0·97 (0·89–1·06)	0·462	1·02 (0·86–1·22)	0·807
Secondary education or further	1·13 (1·11–1·16)	<0·0001	0·92 (0·86–0·98)	0·014	0·88 (0·81–0·96)	0·003	1·08 (0·92–1·27)	0·322
Household wealth quintile								
1 (poorest)	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
2	1·12 (1·09–1·14)	<0·0001	1·12 (1·02–1·23)	0·021	1·14 (1·02–1·29)	0·024	1·19 (0·98–1·44)	0·075
3	1·18 (1·15–1·21)	<0·0001	1·10 (1·00–1·20)	0·053	1·12 (1·00–1·26)	0·049	1·05 (0·87–1·27)	0·596
4	1·26 (1·23–1·30)	<0·0001	1·19 (1·10–1·29)	<0·0001	1·25 (1·13–1·39)	<0·0001	1·23 (1·02–1·49)	0·026
5 (richest)	1·36 (1·32–1·40)	<0·0001	1·31 (1·20–1·44)	<0·0001	1·42 (1·27–1·58)	<0·0001	1·65 (1·38–1·98)	<0·0001
Body-mass index group								
Underweight	0·82 (0·78–0·85)	<0·0001	0·85 (0·75–0·96)	0·009	0·86 (0·72–1·02)	0·085	0·89 (0·72–1·10)	0·265
Healthy weight	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Overweight	1·16 (1·14–1·18)	<0·0001	1·21 (1·15–1·28)	<0·0001	1·22 (1·14–1·31)	<0·0001	1·02 (0·89–1·17)	0·730
Obese	1·25 (1·22–1·28)	<0·0001	1·54 (1·43–1·66)	<0·0001	1·66 (1·52–1·81)	<0·0001	1·21 (1·05–1·40)	0·007
Tobacco smoking								
Not currently smoking	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Currently smoking	0·88 (0·86–0·90)	<0·0001	0·76 (0·71–0·81)	<0·0001	0·68 (0·62–0·74)	<0·0001	0·59 (0·51–0·69)	<0·0001
Multivariable regression with age group, sex, and education†								
Sex								
Male	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Female	1·20 (1·18–1·23)	<0·0001	1·40 (1·33–1·47)	<0·0001	1·50 (1·42–1·59)	<0·0001	1·78 (1·61–1·98)	<0·0001
Age, years								
15–24	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
25–34	1·42 (1·36–1·49)	<0·0001	1·50 (1·30–1·73)	<0·0001	1·46 (1·22–1·76)	<0·0001	1·08 (0·87–1·35)	0·468
35–44	1·57 (1·50–1·65)	<0·0001	2·12 (1·87–2·41)	<0·0001	2·15 (1·87–2·48)	<0·0001	1·23 (1·05–1·43)	0·010
45–54	1·66 (1·58–1·74)	<0·0001	3·14 (2·79–3·54)	<0·0001	3·49 (3·06–3·99)	<0·0001	1·68 (1·45–1·95)	<0·0001
55–64	1·66 (1·58–1·74)	<0·0001	3·95 (3·48–4·48)	<0·0001	4·86 (4·22–5·60)	<0·0001	2·22 (1·85–2·66)	<0·0001
≥65	1·68 (1·59–1·77)	<0·0001	4·45 (3·90–5·08)	<0·0001	5·74 (4·96–6·64)	<0·0001	2·31 (1·90–2·82)	<0·0001
Education								
No schooling	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Primary education	1·14 (1·11–1·17)	<0·0001	1·14 (1·06–1·23)	0·0002	1·18 (1·08–1·29)	0·0002	1·22 (1·03–1·46)	0·024
Secondary education or further	1·26 (1·23–1·30)	<0·0001	1·33 (1·24–1·42)	<0·0001	1·39 (1·27–1·51)	<0·0001	1·59 (1·34–1·88)	<0·0001

(Table 2 continues on next page)

	Blood pressure ever measured		Diagnosed		Treated		Controlled	
	RR	p value	RR	p value	RR	p value	RR	p value
(Continued from previous page)								
Multivariable regressions with all predictor variables‡								
Sex								
Male	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Female	1·16 (1·14–1·18)	<0·0001	1·26 (1·19–1·34)	<0·0001	1·31 (1·22–1·42)	<0·0001	1·54 (1·35–1·76)	<0·0001
Age, years								
15–24	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
25–34	1·33 (1·27–1·39)	<0·0001	1·29 (1·09–1·53)	0·003	1·16 (0·93–1·44)	0·187	0·95 (0·73–1·23)	0·698
35–44	1·42 (1·36–1·49)	<0·0001	1·73 (1·49–2·01)	<0·0001	1·61 (1·37–1·89)	<0·0001	1·03 (0·85–1·23)	0·790
45–54	1·50 (1·44–1·57)	<0·0001	2·61 (2·27–3·01)	<0·0001	2·67 (2·30–3·10)	<0·0001	1·40 (1·18–1·67)	<0·0001
55–64	1·47 (1·40–1·54)	<0·0001	3·46 (2·96–4·06)	<0·0001	3·92 (3·31–4·64)	<0·0001	2·01 (1·60–2·53)	<0·0001
≥65	1·47 (1·40–1·54)	<0·0001	4·02 (3·42–4·73)	<0·0001	4·76 (4·01–5·63)	<0·0001	2·11 (1·65–2·69)	<0·0001
Education								
No schooling	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Primary education	1·08 (1·05–1·11)	<0·0001	1·06 (0·97–1·16)	0·179	1·09 (0·98–1·21)	0·128	1·13 (0·90–1·43)	0·279
Secondary education or further	1·11 (1·09–1·14)	<0·0001	1·16 (1·06–1·27)	0·001	1·17 (1·05–1·31)	0·005	1·33 (1·06–1·66)	0·013
Household wealth quintile								
1 (poorest)	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
2	1·09 (1·06–1·12)	<0·0001	1·11 (1·00–1·23)	0·051	1·13 (1·00–1·27)	0·054	1·15 (0·91–1·44)	0·242
3	1·14 (1·11–1·18)	<0·0001	1·08 (0·98–1·19)	0·119	1·12 (0·99–1·26)	0·071	1·00 (0·80–1·26)	0·993
4	1·20 (1·16–1·24)	<0·0001	1·18 (1·07–1·30)	0·001	1·25 (1·11–1·41)	0·0003	1·17 (0·93–1·48)	0·186
5 (richest)	1·27 (1·23–1·31)	<0·0001	1·28 (1·16–1·41)	<0·0001	1·36 (1·21–1·53)	<0·0001	1·56 (1·23–1·96)	0·0002
Body-mass index group								
Underweight	0·88 (0·84–0·91)	<0·0001	0·84 (0·72–0·98)	0·030	0·83 (0·68–1·01)	0·057	0·87 (0·69–1·11)	0·263
Healthy weight	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Overweight	1·08 (1·06–1·10)	<0·0001	1·19 (1·12–1·27)	<0·0001	1·20 (1·11–1·30)	<0·0001	0·97 (0·83–1·13)	0·655
Obese	1·11 (1·09–1·13)	<0·0001	1·47 (1·37–1·59)	<0·0001	1·58 (1·45–1·72)	<0·0001	1·01 (0·86–1·20)	0·873
Tobacco smoking								
Not currently smoking	1 (ref)	..	1 (ref)	..	1 (ref)	..	1 (ref)	..
Currently smoking	0·94 (0·92–0·97)	<0·0001	0·93 (0·86–1·00)	0·048	0·87 (0·79–0·96)	0·006	0·74 (0·62–0·89)	0·001

RRs are shown with 95% CIs, which are adjusted for clustering at the level of the primary sampling unit. Schooling categories are defined as having attended (but not necessarily completed) the indicated level of education. RR=risk ratio. *Included only one of the variables shown in the table and a binary indicator for each country (country-level fixed effects). †Included sex, age group, education, and a binary indicator for each country (country-level fixed effects). ‡Included sex, age group, education, household wealth quintile, body-mass index, tobacco smoking, and a binary indicator for each country (country-level fixed effects).

Table 2: **Univariable and multivariable regressions of each cascade step onto individual-level predictors**

than a third were taking antihypertensive medications, and only one in ten had control over their hypertension. However, there were large variations among regions and countries. Regionally, Latin America and the Caribbean performed the best and sub-Saharan Africa fared the worst regarding the proportion of individuals with hypertension attaining each step of the cascade of care. Relative to their GDP per capita, several countries in Latin America and the Caribbean (Brazil, Costa Rica, Ecuador, and Peru) and Bangladesh and Kyrgyzstan performed well. Together, these findings provide an important benchmark of health system performance for managing hypertension in LMICs against which future progress can be compared.

Within countries, we found that men were less likely to reach each step of the hypertension care cascade than women, which could be due to several factors, such as a focus of primary health-care services on maternal and child health, gender norms concerning care-seeking, and health-care facility opening hours. As hypertension care services are strengthened in LMICs, it will be crucial that health systems identify ways of engaging men in hypertension screening and care to avoid further widening the existing gender gap in life expectancy.[11] Additionally, given our finding that those who were smokers and who were overweight or obese generally did not have a higher probability of completing the hypertension cascade (ie, to control of their hypertension), it will be important for hypertension services in LMICs to more consistently reach and retain those at the highest risk of cardiovascular disease. Finally, we observed that individuals with lower education and household wealth were generally more likely to be lost to care before reaching the final cascade stage of blood pressure control. This finding is especially concerning given that those of a lower socioeconomic

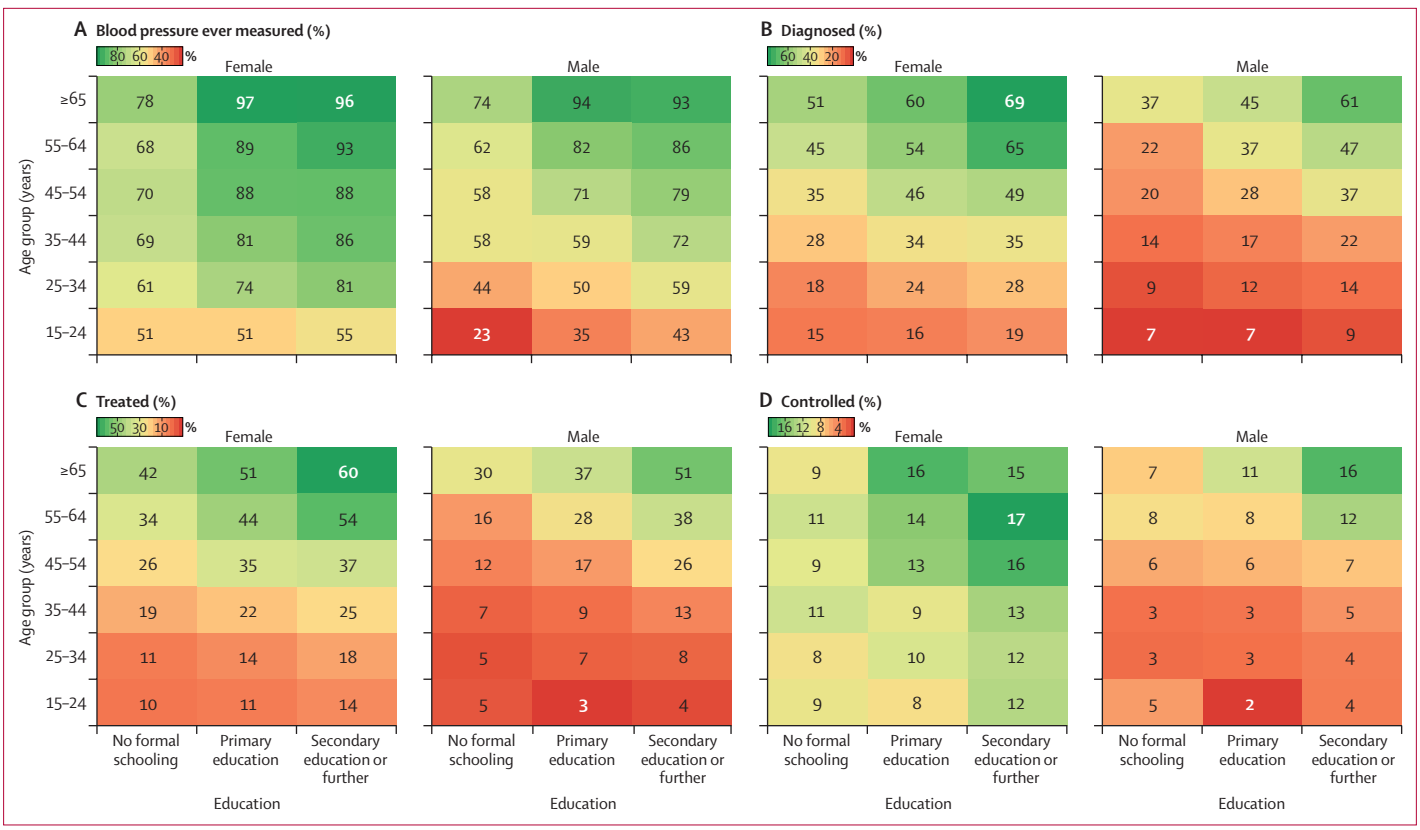

***Figure 3*: Proportion of participants with hypertension reaching each cascade step, stratified by sex, age group, and education**
Primary education refers to having received some primary education or having completed primary school. Secondary education or further refers to having received some secondary education, having completed secondary school, or having received some type of tertiary education.

status are likely less able to access high-quality care for cardiovascular disease events (such as heart attacks and strokes) and are more likely to have catastrophic health-care expenditures from use of the health care to which they do have access.[12] More optimistically, however, our findings also imply that well designed investments in improving hypertension care present an opportunity to reduce health inequalities between socioeconomic groups in LMICs.

Relative to their GDP per capita, Costa Rica, Kyrgyzstan, and Bangladesh performed well in our analysis of cascade step attainment, implying that important lessons could be learned by studying the health policies and systems of these countries. We briefly outline three possible reasons that could partially explain the comparatively strong performance of these countries. First, these countries all have established primary health-care system structures at the local level. Costa Rica's *Equipos Básicos de Atención Integral en Salud* clinics each serve a population of about 4000 people and offer a full range of primary care and health promotion services.[13] Similarly, Kyrgyzstan has established family group practices that provide comprehensive primary health care, with each practice serving a village of at least 2000 inhabitants.[14] Since 2009, Bangladesh has invested in the establishment of approximately 14 000 community clinics, which are tasked with providing screening for hypertension and diabetes. Bangladesh also has an extensive number of informal providers, licensed and unlicensed drug stores, and non-governmental organisations throughout the country,[15] which are likely to fulfil an important role in meeting the population's demand for NCD care at the local level. Second, the health systems of Costa Rica and Kyrgyzstan have implemented structures that allow for effective community outreach for NCDs. Each of Costa Rica's community clinics include at least one community health worker who measures blood pressure during home visits and follows up at the homes of patients lost to care.[16,17] Community health workers in Costa Rica also hold health promotion sessions in community settings, including on prevention of cardiovascular disease; these sessions likely help to generate demand for hypertension screening and care. Kyrgyzstan has established village health committees, which consist of volunteers who were trained by primary health-care staff to provide basic health promotion and care services, including for hypertension.[14] Although Bangladesh has several large-scale community health worker programmes, these mostly do not yet focus on NCDs.[18] However, moving forward, the existence of functional and substantial community health worker programmes presents an important opportunity for the

For more on **Community-based health care by the Bangladesh Government** see www.community.clinic.gov.bd

country to further improve hypertension and NCD care. Finally, antihypertensive medications are generally both available and affordable in all three countries, which is not the norm in many LMICs.[19] In Costa Rica, these medications are fully covered under the Costa Rican social security fund, and they are widely available at primary care facilities.[17] In Kyrgyzstan, a 2015 survey[20] found that key antihypertensive medications were widely available and generally affordable to the local population. Similarly, in Bangladesh, the PURE study[21] found that, of 55 communities, calcium-channel blockers were available in 43 communities and ß blockers were available in 49 communities, and only 7% of sampled households were unable to afford at least one type of antihypertensive medication.

Although the hypertension care cascade is a useful measure of health system performance in LMICs, there are important contextual factors beyond the health system that likely are responsible for some of the differences in the success of hypertension management that we observed between and within countries. As we show, the probability of reaching each of the care cascade steps likely is affected by individuals' economic circumstances which, in turn, vary widely between and within countries. For instance, even if care is provided free of charge, time lost from income-generating activities and transport costs can still pose a substantial obstacle to accessing care for those with little income and savings.[22] Likewise, individuals with lower educational attainment might be less well equipped to engage with relevant health promotion messages and to actively negotiate an effective treatment plan with health-care providers. In addition to these socioeconomic circumstances, epidemiological factors could affect the hypertension care cascade. For instance, adults living in populations that are exposed to a high risk of a fatal non-cardiovascular disease event, such as through infectious diseases, might be less willing to invest time, effort, and money into the prevention of a heart attack or stroke. Similarly, although hypertension control can be achieved solely through medications, social and environmental factors that affect blood pressure—such as sodium content of diets,[23] air pollution,[24] conduciveness of the physical environment to physical activity,[23] and social norms regarding diet, excess weight, and exercise—likely also have an effect on the probability that individuals achieve hypertension control, especially among adults with low medication adherence.

Our study of nationally representative surveys has several limitations. First and foremost, although many surveys used the same WHO STEPS questionnaire to elicit information about hypertension care and employed a similar approach to measuring blood pressure, there were some differences in how questions were phrased and translated into the local languages, and in how blood pressure was measured. These disparities might have affected our estimates and thus be responsible for some of the variation that we observed between countries and regions. Of note, however, is that the core elements of the questions asked about hypertension care were the same across surveys. Second, the age range sampled in each survey varied between countries. We have addressed this issue by controlling for age group in our multivariable regressions, and by providing figures showing the regional hypertension care cascades and the relationships between cascade attainment and GDP per capita separately for each 10-year age group (appendix). Third, although, to our knowledge, our study includes the largest set of LMICs of any study on this topic thus far, the 44 LMICs in this analysis (representing 67% of the population living in LMICs worldwide)[9] are not representative of all LMICs globally. Specifically, it is possible that LMICs included in this analysis had better hypertension care indicators because implementing a survey that was eligible for this study could be a sign of a country's commitment to hypertension care. Fourth, the surveys were done in different years. Each country's performance should thus be interpreted as the performance in the given survey year rather than as the country's current performance. To reduce bias from secular trends when comparing countries against each other, we benchmarked performance against each country's GDP per capita in the survey year (rather than current GDP per capita). Fifth, even though the survey-level median proportion of missing values regarding the variables needed to ascertain the hypertension care cascade was only 2·3%, some countries had a substantially higher proportion of participants with missing outcome data, which could have resulted in selection biases. Sixth, because of data constraints, we used the same threshold in each survey to define a blood pressure that requires treatment. This approach, thus, ignored that guidelines in use in some countries at the time of the survey may have defined eligibility for antihypertensive medications differently, such as based on a cardiovascular disease risk score or target organ damage. Finally, because we did not include a previous hypertension diagnosis in our definition of hypertension, we might have falsely excluded some participants with hypertension from our care cascade analysis. Our hypertension definition, however, is the same as that used in other studies[25–28] of hypertension care. Moreover, our definition yields conservative estimates for the loss of individuals with hypertension along the care cascade, under the assumption that some of those who reported a previous hypertension diagnosis but had a normal blood pressure and did not report to be on treatment, did, in fact, not have hypertension.

We have identified notable variation in the hypertension care cascade between and within countries, which can guide government decisions regarding future health policies and the design of appropriate interventions, such as who to target and whether to prioritise efforts to improve screening, diagnosis, treatment initiation, or medication adherence. Given that hypertension is a major risk factor for several of the most common causes of death in LMICs,[1] and that the condition can be effectively controlled at a low

cost,[3] monitoring the development of the hypertension care cascade over time would likely be a worthwhile investment, providing feedback on the effectiveness of policy and health system reforms that are aimed at addressing unmet needs for hypertension care in LMICs. The magnitude of the losses in the hypertension care cascade, which we have measured in this study, indicates that reducing the burden of hypertension through health system improvements will be a formidable undertaking requiring strong political will and financial commitments.

Contributors

PG, JM-G, JID, TB, RA, SV, and LMJ co-conceived the study. PG, JM-G, M-EM, CE, JID, TB, RA, SV, and LMJ led the data collation. PG, JM-G, and LMJ led the data analysis. PG wrote the first draft of the manuscript, and all authors provided crucial input on several iterations of the manuscript. All authors have approved the final version.

Declaration of interests

AS reports a research grant from Johnson & Johnson for work unrelated to this manuscript. All other authors declare no competing interests.

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