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

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Abstract

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

Methods: We pooled individual-level population-based data collected between 2005 and 2016 from 44 LMICs. Hypertension was defined as systolic blood pressure (BP) ≥140 mmHg or diastolic BP ≥90 mmHg or reporting use of medication for hypertension. Among those with hypertension, we calculated the proportion who had i) ever had their BP measured, ii) been diagnosed, iii) been treated, and iv) achieved control. 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: 1,100,507 participants were included of whom 192,441 (17.5%) had hypertension. 73.6% (95% CI, 72.9 – 74.3) of those with hypertension ever had their BP measured, 39.2% (95% CI, 38.2 – 40.3) were diagnosed, 29.9% (95% CI, 28.6 - 31.3) received treatment, and 10.3% (95% CI, 9.6 – 11.0) achieved control. Countries in Latin America and the Caribbean generally achieved the highest performance, while those 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 a current smoker were all positively associated with reaching each of the four steps of the care cascade.

Interpretation: This study provides critical evidence for the design and targeting of health policies and service interventions for hypertension in LMICs by detailing at what step and for whom there are gaps in the care process in each study country. In addition, we have identified countries that perform better than expected based on their economic development in a diversity of world regions, which can guide policy decisions. Given the high disease burden caused by hypertension in LMICs, nationally representative hypertension care cascades as constructed in this study could be used as an important tracer of effective universal health coverage.

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Research in context

Evidence before this study: We searched MEDLINE from January 1966 until January 2019 for studies with variations of the words '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- and middle-income countries (LMICs) – and examine how these indicators vary among population groups within countries – was the Prospective Urban Rural Epidemiology (PURE) Study. However, the PURE study was based on a convenience – rather than random – sample of communities, used data from 2003 to 2009, and included only 14 LMICs.

Added value of this study: This is the first study based on nationally representative samples of adults in LMICs to determine where in the hypertension care process patients are lost, and how this varies between and within countries. We make four key additions to the current evidence base. First, we quantify for each of 44 LMICs the loss of individuals with hypertension at each step of the hypertension care cascade, which can guide national policy makers in whether to prioritise efforts to improve screening, diagnosis, initiation of treatment, or medication adherence and care retention. Second, we examine how the hypertension care cascade varies within LMICs between different population groups, providing important information on possible target groups for relevant interventions. Third, by benchmarking countries' performance against their Gross Domestic Product (GDP) per capita, this 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. Lastly, this 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: The proportion of adults with hypertension lost at each step of the hypertension care cascade varied widely between countries, with male, younger, less educated, less wealthy, and currently smoking adults generally being less likely to reach each cascade step. While the proportion who achieved control was low in all four regions examined, countries in Latin America and the Caribbean had, on average, the best care cascade indicators whereas countries in sub-Saharan Africa tended to have the lowest performance. Well-designed and 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) in low- and middle-income countries (LMICs), particularly stroke, heart disease, and chronic kidney disease.[1] The prevalence of hypertension is increasing dramatically in LMICs.[2] In fact, the world regions with the highest hypertension prevalence are now thought to be sub-Saharan Africa, South Asia, and Central and Eastern Europe – all regions that are largely comprised of LMICs.[2]

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

Estimates of health system performance for hypertension from population-based 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] – was the main reason for this collaboration's focus on LMICs rather than high-income countries. In an effort to inform the design of health services interventions and provide a cross-country comparison of health system performance for managing hypertension, this study aimed to i) determine where patients in LMICs are lost to care along the hypertension management continuum, and ii) how these patterns vary among countries and population groups within countries.

Methods

Data sources:

We requested access to the most recent nationally representative World Health Organisation (WHO) Stepwise Approach to Surveillance (STEPS) survey conducted since 2005 for all countries that were, as per the World Bank, a LMIC at the time of the survey. This search led to access to the individual-level data of 22 surveys (**Figure S1**). We preferred STEPS surveys because they use the same standardised questionnaire, tend to sample a wide age range of adults, and are the official method developed by the WHO for monitoring NCD risk factors at the population level.[7] For LMICs for which we were unable to acquire an eligible STEPS survey, we conducted a systematic search (**Text S1**), which led to the inclusion of an additional 22 survey datasets (**Figure S2**). Detailed information on the sampling strategy of each survey is provided in **Text S2**. Forty countries measured BP using a digital upper arm meter, two using a digital wrist meter, and two using a manual mercury sphygmomanometer (**Table S1**). Thirty-five countries measured BP three times, five two times, three two times with a third measurement if the first two differed by a pre-defined margin, and one (the Seychelles) five times.

Definition of hypertension:

Hypertension was defined as systolic BP ≥140mmHg or diastolic BP ≥90mmHg or reporting use of medications for hypertension. For participants with three BP measurements, we used the mean of the last two measurements (last four for the Seychelles); for participants with only two measurements, we computed the mean of both available measurements.

Constructing the hypertension care cascade:

We computed the percentage of all those with hypertension who had ever received a BP measurement ('ever measured' [step 1]), had been diagnosed with hypertension by a healthcare provider ('diagnosed' [step 2]), were currently taking anti-hypertensive medication ('treated' [step 3]), and had a normal BP (systolic BP <140mmHg and a diastolic BP <90mmHg) plus reported to have received relevant lifestyle advice and/or to be taking anti-hypertensive medication ('controlled' [step 4]). In supplementary analyses, we show all results when defining 'treated' as having received relevant lifestyle advice or taking anti-hypertensive medication. More detail on the computation of the care cascade is provided in **Text S3**.

Statistical analysis:

None of the analyses presented in this manuscript were pre-specified. Countries were categorised according to the regional groupings of the WHO regional offices whereby the European and Eastern Mediterranean Region as well as the South-East Asia and Western Pacific Region were merged to avoid having only two countries with data in a region. All analyses accounted for the complex survey design using sampling weights. Our primary analyses weighted each country proportional to its population size in 2015.[8] In supplementary analyses, we show all results when assigning the same weight to each country.

We plotted the proportion of participants with hypertension in a country who reached each step of the care cascade against countries' Gross Domestic Product (GDP) per capita (in constant 2011 international dollars as estimated by the World Bank[9]) in the year of data collection for the survey to ascertain health system performance relative to a country's wealth. In addition, we regressed – separately for each cascade step – the proportion of participants with hypertension who reached the given step on sex, ten-year age group, education, household wealth quintile, BMI group (BMI<18.5kg/m^2 [underweight], 18.5≤BMI<25.0kg/m^2 [normal weight], 25.0≤BMI<30.0kgm^2 [overweight], and BMI≥30.0kg/m^2 [obese]), and a binary indicator for current tobacco smoking. Specifically, we fitted uni- and multi-variable Poisson regressions with a country-level fixed effect adjusting standard errors for clustering at the level of the primary sampling unit. In 20 countries, household wealth quintile was computed based on a principal component analysis of participants' answers to a suite of questions on key household dwelling characteristics and household ownership of durable goods. Fourteen countries did not have these data but did have data on household income, which we used instead to create household wealth quintiles for these surveys. More detail is provided in **Text S4**. Household wealth, smoking, and BMI data was not available for ten, six, and five countries, respectively (**Table S4**). These countries were therefore removed from those regressions that included these variables as independent variables. All analyses were complete case analyses.

Ethics:

This study received a determination of "not human subjects research" by the institutional review board of the Harvard T.H. Chan School of Public Health on 9 May 2018.

Role of the funding source:

The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report. PG and LMJ had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Sample characteristics:

The survey-level median response rate was 90.9% (interquartile range [IQR]: 81.5 – 95.6) (**Table 1**). Among those interviewed, the percentage of participants with a missing outcome (BP or response to the first cascade step) ranged from 0.0% in Belize, Romania, and the Seychelles to 30.2% in Mexico, whereby the survey-level median was 2.3% (IQR: 0.6 – 8.6). 1,100,507 participants with a non-missing outcome were included in the analysis. The survey-level median age among these participants was 39.5 years (IQR: 34.8 – 44.5). 192,441 (17.5%) participants had hypertension. Detailed sample characteristics are shown in **Table S2-4**.

The hypertension care cascade by country and region:

The prevalence of hypertension and undiagnosed hypertension by country and ten-year age group is shown in **Table S5**. Among those with hypertension, 73.6% (95% CI, 72.9 – 74.3) ever had their BP measured, 39.2% (95% CI, 38.2 – 40.3) had been diagnosed prior to the survey, 29.9% (95% CI, 28.6 - 31.3) were treated, and 10.3% (95% CI, 9.6 – 11.0) had achieved control of their hypertension (**Figure S3**). 31.7% (95% CI, 30.6 – 32.7) of those with hypertension had received relevant lifestyle or took anti-hypertensive medication (**Figure S4**). The estimates for each cascade step were similar when assigning an equal weight to each country (**Figure S5-6**).

Figure S7-10 shows the care cascade disaggregated by ten-year age group. The hypertension care cascade for each country is shown in **Figure S11-12**.

Out of the four world regions examined, Latin America and the Caribbean had the best care cascade indicators, while sub-Saharan Africa had the worst (**Figure 1** and **Table S6-7**). Fewer than five percent of those with hypertension had achieved control in ten of 16 countries (63%) in sub-Saharan Africa, compared to three of eight (38%) in South-East Asia and the Western Pacific, one of ten (10%) in Europe and the Eastern Mediterranean, and zero of 10 countries (0%) in Latin America and the Caribbean (**Table S8**). Within regions, there was substantial variation among countries with Costa Rica being the best-performing country for each cascade step in Latin America and the Caribbean. Other high-performing countries – relative to other countries in their region – were Bangladesh, Namibia, and Romania. The relative differences between regions and countries were similar when defining treatment as receiving lifestyle advice or taking anti-hypertensive medication (**Figure S13**), weighting countries equally (**Figure S14-15**), and disaggregating the care cascade in each region by ten-year age group (**Figure S16-17**).

The hypertension care cascade by Gross Domestic Product per capita:

GDP per capita was positively associated with a country's performance for each cascade step (**Figure 2**). Countries that performed substantially better on all cascade steps than predicted based on their GDP per capita in the year of the survey were Bangladesh, Brazil (excluding the first step as the 95% prediction interval at Brazil's GDP per capita included perfect performance for 'ever measured'), Costa Rica, Ecuador, Kyrgyzstan, and Peru ('ever measured' was not assessed in Kyrgyzstan and Peru). Countries that performed significantly worse on all cascade steps than expected based on GDP per capita were Albania (‘ever measured’ was not assessed), Indonesia (‘ever measured’ was not assessed), Tanzania, Uganda, and South Africa. These results were similar when defining treatment as receiving lifestyle advice or taking anti-hypertensive medications (**Figure S18**), and when examining hypertension care cascade indicators by GDP per capita separately for each ten-year age group (**Figure S19-22**).

Individual-level predictors of cascade progression:

Being a woman, in an older age group, and in a higher household wealth quintile were all associated with a higher probability of reaching each cascade step in both uni- and multi-variable regressions (**Table 2**). In addition, except for the controlled step in the multi-variable regression, being overweight or obese was associated with a higher probability of reaching each cascade step in all regressions. Furthermore, we found that i) higher educational attainment was positively associated with reaching each cascade step once adjusted for age and sex; ii) current smokers had a lower probability of reaching each cascade step than those who did not currently smoke; and iii) being obese was associated with a higher RR of reaching each cascade step (with the exception of the controlled step in the multi-variable regression) than being overweight. The positive associations with education were strongest in low-income countries and weakest in upper middle-income countries (**Table S9**). By region, these positive associations with education were generally strongest in sub-Saharan Africa, and did not exist – or were significant in the negative direction in some regression models – in the Europe and Eastern Mediterranean region (**Table S10**). All regression results were similar when assigning the same weight to each country (**Table S11-13**).

Stratifying the percent of participants with hypertension who reached each cascade step by sex, age group, and education (**Figure 3**) demonstrates that i) the proportion achieving control was less than 20% in all age and education group combinations; ii) in each educational attainment category, less than half were diagnosed in age groups below 55 years; and iii) women had a higher probability of reaching each cascade step than men in virtually all age and education group combinations.

Discussion

Overall, the performance of health systems in LMICs for managing hypertension was poor, with less than half of those with hypertension having been diagnosed, less than a third taking anti-hypertensive medications, and only one in ten achieving control. However, there was a large degree of variation among regions and countries. Regionally, Latin America and the Caribbean performed best and sub-Saharan Africa fared worst. Relative to GDP per capita, several countries in Latin America and the Caribbean (Brazil, Costa Rica, Ecuador, and Peru) as well as 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 may be due to multiple factors, such as a focus of primary healthcare services on maternal and child health, gender norms concerning care-seeking, and healthcare 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.[10] In addition, given our finding that those who were smokers and with overweight or obesity did generally not have a higher probability of completing the hypertension cascade, it will be important for hypertension services in LMICs to more consistently reach and retain those at the highest CVD risk. Lastly, we observed that individuals with lower education and household wealth were generally more likely to be lost to care prior to completion of the cascade. This finding is especially concerning given that those of a lower socioeconomic status are likely less able to access high-quality care for, and more likely to experience catastrophic healthcare expenditures from, CVD events.[11] 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, countries that performed particularly well in our analysis included Costa Rica, Kyrgyzstan, and Bangladesh, implying that important lessons could be learned from the approaches adopted by these health systems. We briefly outline three possible reasons that may partially explain these countries' comparatively strong performance. First, they have all established primary healthcare system structures at a highly local geographic level. Costa Rica's EBAIS clinics each serve a population of 4,000 people and offer a full range of primary care and health promotion services.[12] Similarly, Kyrgyzstan has established family group practices that provide comprehensive primary healthcare, with each practice serving a village of at least 2,000 inhabitants.[13] Bangladesh has invested since 2009 in the establishment of approximately 14,000 community clinics, which are tasked with providing hypertension and diabetes screening.[14] In addition, it has an extensive presence of informal providers, licensed and unlicensed drug stores, and non-governmental organisations throughout the country,[15] which are likely also playing an important role in meeting the population's demand for NCD care at a 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 (CHW) who measures BP during home visits and follows up at home with patients lost from care.[16,17] In addition, CHWs in Costa Rica hold health promotion sessions – including on CVD prevention – in community settings, which can help in the generation of demand for care. Kyrgyzstan has established village health committees, which consist of volunteers who were trained by primary healthcare staff to provide basic health promotion and care services, including for hypertension.[13] While Bangladesh has several large-scale CHW programmes,[18] these mostly do not yet focus on NCDs.[18] However, moving forward, the existence of these large-scale CHW programmes presents an important opportunity for the country to further improve hypertension and NCD care. Third, anti-hypertensive 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 widely available at primary care facilities.[17] In Kyrgyzstan, a 2015 survey found that key anti-hypertensive medications were widely available and generally affordable to the local population.[20] Similarly, in Bangladesh, the PURE study found that calcium-channel blockers and ß-blockers were available in 43 and 49 of 55 communities, respectively, and only 7% of sampled households were unable to afford at least one type of anti-hypertensive medication.[21]

While 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. Perhaps most importantly, the probability of reaching each of the care cascade steps likely is affected by individuals' socioeconomic 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 a lower educational attainment may be less well-equipped to engage with relevant health promotion messages and to actively negotiate an effective treatment plan with healthcare providers. In addition to socioeconomic circumstances, epidemiological factors may affect the hypertension care cascade. For instance, adults living in populations that are exposed to a high risk of a fatal non-CVD event, such as through infectious diseases, may be less willing to invest time, effort, and money into the prevention of CVD events. Similarly, even though hypertension control can be achieved solely through medications, social and environmental factors that affect BP – such as sodium content of the food supply,[23] air pollution,[24] conduciveness of the physical environment to physical activity,[23] and social norms to diet, excess weight, and exercise – likely also have an impact on the probability that individuals achieve hypertension control, especially among adults with low medication adherence.

This study has several limitations. First and foremost, while many surveys used the same WHO STEPS questionnaire to enquire about hypertension care and employed a similar approach to measuring BP, there were some differences in how questions were phrased and translated into local languages, and in how BP was measured (e.g., the exact model of BP meter). This may 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 minimized potential bias from this data constraint by showing each figure that compares countries or regions separately for each ten-year age group (see **Figure S7-10, S16-17, and S19-22**). Third, while – to our knowledge – this 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[8]) 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 may be a sign of a country's commitment to hypertension care. Fourth, the surveys were conducted at different time points. 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 median percentage across countries of missing values for the variables needed to ascertain the hypertension care cascade was only 2.3%, some countries had a substantially higher proportion of participants with a missing outcome variable, which could have resulted in selection bias. Sixth, due to data constraints, we used the same threshold in each survey to define a BP 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 anti-hypertensive medications differently, such as based on a global CVD risk or target-organ damage. Lastly, because we did not include a previous hypertension diagnosis in our definition of hypertension, we may have falsely excluded some participants with hypertension from our care cascade analysis. Our hypertension definition, however, is the same as was used in other studies of hypertension care,[25-28] and yields conservative estimates for the care cascade under the assumption that some of those who reported a previous hypertension diagnosis, but had a normal BP and did not report to be on treatment, did, in fact, not have hypertension.

This study identified important variation in the hypertension care cascade between and within countries, which can guide governments with regards to the design – such as whether to prioritise efforts to improve screening, diagnosis, treatment initiation, or medication adherence – and target groups of appropriate interventions and reforms. 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] the hypertension care cascade could be used as an important tracer of health system performance in LMICs. Improving hypertension care, however, will be a formidable undertaking requiring strong political will and financial commitments.

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Contributors

PG, JMG, JID, TB, RA, SV, and LMJ co-conceived the study. PG, JMG, MEM, CE, JID, TB, RA, SV, and LMJ led the data collation. PG, JMG, and LMJ led the data analysis. PG wrote the first draft of the manuscript and all authors provided critical inputs on multiple iterations. All authors have approved the final version. PG is the guarantor of the work.

Declaration of interests

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

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References

1. GBD 2017 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 2018; 392(10159):1923-1994.

2. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in blood pressure from 1975 to 2015: a pooled analysis of 1479 population-based measurement studies with 19.1 million participants. Lancet 2017; 389(10064): 37-55.

3. Prabhakaran D, Anand S, Watkins D, et al. Cardiovascular, respiratory, and related disorders: key messages from Disease Control Priorities, 3rd edition. Lancet 2018; 391(10126): 1224-36.

4. Hogan DR, Stevens GA, Hosseinpoor AR, Boerma T. Monitoring universal health coverage within the Sustainable Development Goals: development and baseline data for an index of essential health services. Lancet Global Health 2018; 6(2): e152-e68.

5. Ikeda N, Sapienza D, Guerrero R, et al. Control of hypertension with medication: a comparative analysis of national surveys in 20 countries. Bulletin of the World Health Organization 2014; 92(1): 10-9c.

6. Sudharsanan N, Geldsetzer P. Impact of Coming Demographic Changes on the Number of Adults in Need of Care for Hypertension in Brazil, China, India, Indonesia, Mexico, and South Africa. Hypertension 2019; 73(4):770-776.

7. Riley L, Guthold R, Cowan M, et al. The World Health Organization STEPwise Approach to Noncommunicable Disease Risk-Factor Surveillance: Methods, Challenges, and Opportunities. American Journal of Public Health 2016; 106(1): 74-8.

8. United Nations Population Division. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. New York, NY: United Nations, 2017.
9. The World Bank. GDP per capita, PPP (constant 2011 international $). 2018. https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD (accessed May 22 2018).
10. World Health Organisation. World Health Statistics 2018: Monitoring health for the SDGs. Geneva, Switzerland: World Health Organisation, 2018.
11. Jan S, Laba TL, Essue BM, et al. Action to address the household economic burden of non-communicable diseases. Lancet 2018; 391(10134): 2047-58.
12. Organisation for Economic Co-operation and Development. Costa Rica - Evaluación y recommendaciones. San José, Costa Rica: Ministry of Health of the Republic of Costa Rica and Organisation for Economic Co-operation and Development, 2019.
13. Ibraimova A, Akkazieva B, Ibraimov A, Manzhieva E, Rechel B. Kyrgyzstan Health System Review. Copenhagen, Denmark: World Health Organization, 2011.
14. Ministry of Health and Family Welfare of the People's Republic of Bangladesh. Community-based health care 2019. http://www.communityclinic.gov.bd/index.php?id=14 (accessed March 4th 2019).
15. Ahmed SM, Evans TG, Standing H, Mahmud S. Harnessing pluralism for better health in Bangladesh. Lancet 2013; 382(9906): 1746-55.
16. Pesec M, Ratcliffe HL, Karlage A, Hirschhorn LR, Gawande A, Bitton A. Primary Health Care That Works: The Costa Rican Experience. Health Affairs (Millwood) 2017; 36(3): 531-8.
17. Pesec M, Ratcliffe HL, Bitton A. Building a thriving primary health care system: The story of Costa Rica. Boston, MA: Ariadne Labs, 2017.

18. El Arifeen S, Christou A, Reichenbach L, et al. Community-based approaches and partnerships: innovations in health-service delivery in Bangladesh. Lancet 2013; 382(9909): 2012-26.

19. Wirtz VJ, Kaplan WA, Kwan GF, Laing RO. Access to Medications for Cardiovascular Diseases in Low- and Middle-Income Countries. Circulation 2016; 133(21): 2076-85.

20. Medicines Transparency Alliance. Medicine Prices, Availability, Affordability in Kyrgyz Republic. Bishkek, Kyrgyz Republic: Medicines Transparency Alliance, 2015.

21. Attaei MW, Khatib R, McKee M, et al. Availability and affordability of blood pressure-lowering medicines and the effect on blood pressure control in high-income, middle-income, and low-income countries: an analysis of the PURE study data. Lancet Public Health 2017; 2(9): e411-e9.

22. Chimbindi N, Bor J, Newell ML, et al. Time and money: the true costs of health care utilization for patients receiving 'free' HIV/TB care and treatment in rural KwaZulu-Natal. Journal of Acquired Immune Deficiency Syndromes 2015; 70(2): e52-60.

23. Olsen MH, Angell SY, Asma S, et al. A call to action and a lifecourse strategy to address the global burden of raised blood pressure on current and future generations: the Lancet Commission on hypertension. Lancet 2016; 388(10060): 2665-712.

24. Brook RD, Weder AB, Rajagopalan S. “Environmental hypertensionology” – the effects of environmental factors on blood pressure in clinical practice and research. The Journal of Clinical Hypertension 2011; 13(11): 836-42.

25. Chow CK, Teo KK, Rangarajan S, et al. Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. JAMA 2013; 310(9): 959-68.

26. Lu J, Lu Y, Wang X, et al. Prevalence, awareness, treatment, and control of hypertension in China: data from 1.7 million adults in a population-based screening study (China PEACE Million Persons Project). Lancet 2017; 390(10112): 2549-58.

27. Falaschetti E, Mindell J, Knott C, Poulter N. Hypertension management in England: a serial cross-sectional study from 1994 to 2011. Lancet 2014; 383(9932): 1912-9.

28. Wozniak G, Khan T, Gillespie C, et al. Hypertension Control Cascade: A Framework to Improve Hypertension Awareness, Treatment, and Control. Journal of Clinical Hypertension (Greenwich) 2016; 18(3): 232-9.

29. Office of Chief Government Statistician Zanzibar. Gross Domestic Product (GDP). 2018. http://www.ocgs.go.tz/profile.php (accessed July 11 2018).

30. National Bureau of Statistics, Ministry of Finance and Planning. National Population Projections. Dar es Salaam, Tanzania: Office of the Chief Government Statistician, 2018.

Figure legends

Figure 1. The hypertension care cascade by region[1,2]

[1] Vertical error bars are 95% confidence intervals.

[2] Individual points depict the point estimate for each country.

Abbreviations: S.E. Asia=South-East Asia; W. Pacific = Western Pacific; ALB=Albania; AZE=Azerbaijan; BGD=Bangladesh; BLZ=Belize; CRI=Costa Rica; IDN=Indonesia; KAZ=Kazakhstan; KGZ=Kyrgyz Republic; LSO=Lesotho; MEX=Mexico; MNG=Mongolia MOZ=Mozambique; NAM=Namibia; NPL=Nepal; PER=Peru; ROU=Romania; SYC=Seychelles; TLS=Timor-Leste; UGA=Uganda; ZAN=Zanzibar

Figure 2. Hypertension care cascade indicators by GDP per capita[1,2,3,4,5,6]

[1] Gross Domestic Product per capita is shown in constant 2011 international dollars for the year in which the survey was carried out.

[2] The grey ribbon depicts the point-wise 95% prediction interval.

[3] The vertical bars depict 95% confidence intervals.

[4] 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 'Controlled' (p=0.0014)

[5] Country labels are not shown for the following countries in the "controlled" plot to avoid over-crowding: Benin, Burkina Faso, Comoros, Ghana, Kenya, Liberia, Mozambique, Nepal, Tanzania, Timor-Leste, Togo, and Uganda.

[6] The figure is shown separately for each ten-year age group in Figure S19-22.

Abbreviations: 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; int=international; 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=Russian Federation; SWZ=Swaziland; SYC=Seychelles; TGO=Togo; TLS=Timor-Leste; TZA=Tanzania; UGA=Uganda; UKR=Ukraine; VCT=St. Vincent & the Grenadines; ZAF=South Africa; ZAN=Zanzibar

Figure 3. The percent of participants with hypertension reaching each cascade step stratified by sex, age group, and education.[1,2,3]

[1] The colour gradient and the numbers in each cell of the figure display the same point estimates.

[2] 'Primary school' refers to having received some primary schooling or having completed primary school.

[3] 'High school or above' refers to having received some secondary schooling, having completed secondary school, or having received some type of tertiary education.

Table 1. Survey characteristics by region[1,2]

Country	Year[3]	Response rate (%)[4]	Missing outcome[5] (%)	Sample size	Hypertensive, n (%)	Median age (y)	Age range (y)	Female (%)	GDP per capita[6]	Population in 2015 (thousands)
Latin America and the Caribbean										
Belize	2005/06	92.6	0.0	2,434	695 (28.6)	44	20-97	59.0	7,947	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	4,851	1,497 (30.9)	46	15-100	59.8	18,995	17,763
Costa Rica	2010	87.8	0.6	3,607	1,291 (35.8)	47	18-110	72.0	13,000	4,808
Ecuador	2012	81.5	19.8	29,659	2,834 (9.6)	34	20-59	58.7	10,322	16,144
Grenada	2011/12	67.8	2.8	1,097	460 (41.9)	44	24-64	59.9	11,249	107
Guyana	2016	66.7	0.6	2,640	776 (29.4)	40	18-69	59.9	7,266	769
Mexico	2009-12	90.0	30.2	20,946	5,066 (24.2)	35	15-99	56.6	15,668	125,891
Peru	2012	94.3[7]	5.3	29,415	7,771 (26.4)	54	40-96	52.6	10,944	31,377
St. Vincent & the Grenadines	2013	67.8	0.4	3,457	1,056 (30.5)	42	18-70	55.9	10,193	109
Europe and the Eastern Mediterranean										
Albania	2008	95.4	4.3	6,380	1,494 (23.4)	33	15-49	55.2	9,154	2,923
Azerbaijan	2006	83.3	0.4	10,486	1,712 (16.3)	32	15-59	75.9	10,711	9,617
Egypt	2015	95.0	0.5	14,790	2,476 (16.7)	33	15-59	53.0	10,096	93,778
Georgia	2016	75.7	4.2	4,034	1,800 (44.6)	50	17-70	70.4	9,277	3,952
Kazakhstan	2012	93.0	13.8	10,901	2,995 (27.5)	43	15-90	57.3	21,987	17,750
Kyrgyzstan	2012	96.5	2.5	9,422	852 (9.0)	29	15-49	75.5	2,870	5,865
Lebanon	2008/09	62.0	1.2	2,800	841 (30.0)	37	18-95	52.9	15,193	5,851
Romania	2015/16	69.1	0.0	1,970	611 (31.0)	47	18-80	52.5	21,080	19,877
Russia	2007/08	61.4	2.7	4,209	2,696 (64.1)	62	18-100	64.2	24,006	143,888
Ukraine	2007	81.5	17.9	7,932	2,013 (25.4)	33	15-49	68.4	8,497	44,658
South-East Asia and the Western Pacific										
Bangladesh	2011	95.0	10.4	7,593	2,052 (27.0)	48	35-96	49.5	2,571	161,201
Bhutan	2014	96.9	0.2	2,814	1,107 (39.3)	39	18-69	61.9	7,366	787
China	2009	88.0[8]	9.3	9,752	2,842 (29.1)	50	15-99	52.5	8,652	1,397,029
India	2015/16	96.0	2.0	742,838	98,451 (13.3)	30	15-54	85.6	5,924	1,309,054
Indonesia	2014	83.0	0.7	32,492	7,882 (24.3)	35	15-110	53.2	10,003	258,162
Mongolia	2009	95.0	0.4	5,420	1,719 (31.7)	36	15-65	40.8	7,368	2,977
Nepal	2013	98.6	0.5	4,124	1,211 (29.4)	40	15-69	67.8	2,164	28,656

Timor-Leste	2014	96.3	1.6	2,568	713 (27.8)	40	18-69	58.5	1,888	1,241
Sub-Saharan Africa										
Benin	2008	99.0	0.3	3,799	1,218 (32.1)	42	15-65	51.5	1,841	10,576
Burkina Faso	2013	97.8	15.1	3,993	713 (17.9)	36	25-64	53.9	1,562	18,111
Comoros	2011	96.5	1.4	5,381	1,443 (26.8)	39	25-64	71.2	1,415	777
Ghana	2007/08	79.4	9.6	5,030	2,677 (53.2)	60	18-110	46.7	2,760	27,583
Kenya	2015	95.0	1.4	4,408	1,188 (27.0)	35	18-69	60.2	2,836	47,236
Lesotho	2014	90.8	3.9	5,690	989 (17.4)	27	15-59	52.6	2,677	2,175
Liberia	2011	87.1	1.7	2,482	719 (29.0)	36	24-64	57.9	734	4,500
Mozambique	2005	98.3	7.0	3,073	1,102 (35.9)	38	25-64	58.4	742	28,011
Namibia	2013	96.9	17.9	3,617	1,543 (42.7)	46	35-64	57.6	9,256	2,426
Seychelles	2013	73.0	0.0	1,240	413 (33.3)	47	25-64	57.2	24,791	94
South Africa	2012	39.8	3.6	6,317	2,644 (41.9)	39	15-98	64.9	12,215	55,291
Swaziland	2014	81.8	9.9	3,183	948 (29.8)	33	15-70	65.1	7,871	1,319
Tanzania	2012	94.7	1.2	5,636	1,737 (30.8)	40	23-65	53.8	2,228	53,880
Togo	2010	91.0	3.7	4,190	846 (20.2)	32	15-64	52.0	1,208	7,417
Uganda	2014	99.0	2.1	3,904	983 (25.2)	33	18-69	59.8	1,637	40,145
Zanzibar	2011	91.0	0.7	2,467	848 (34.4)	40	24-64	61.6	1,318[9]	1,441[10]
Total	-	90.9[11] (81.5 – 95.6)[12]	2.3[11] (0.6 – 8.6)[12]	1,100,507[13]	192,441[13] (29.3[11])	39.5[11] (34.8 – 44.5)[12]	-	58.2[11] (53.2 – 62.5)[12]	8,222[11] (2,651 – 11,491)[12]	4,177,630[13]

Abbreviations: n=number; y=years; GDP=Gross Domestic Product.

[1] Values are unweighted (i.e., do not account for the complex survey design).

[2] Except for the percent missing, all values were calculated among those with a non-missing outcome variable (i.e., no missing BP measurement or questionnaire answer needed to calculate the hypertension cascade).

[3] Years in which the data collection for the survey was carried out.

[4] This includes both the household and the individual response rate.

[5] This is the percent of participants for whom the blood pressure measurement was missing or a who had a missing response for the survey question needed to ascertain whether the participant had reached the first step of the country's hypertension care cascade.

[6] This is the GDP per capita in constant 2011 international dollars (as estimated by the World Bank[9]) for the year in which data was collected for the survey.

[7] This is the response rate among women; the men's response rate in Peru was not available.

[8] This is the response rate for the 2006 wave of the survey (the most recent wave for which a response rate was published).

[9] This is the GDP per capita in constant 2007 international dollars using data from the Office of the Chief Government Statistician of Zanzibar.[29]

[10] The population estimate for Zanzibar was taken from the Tanzania Population Projection Report 2013-2035.[30]

[11] This is the median value with each country having the same weight.

[12] This is the interquartile range.

[13] This is the sum across all countries.

Table 2. Uni- and multi-variable regressions of each cascade step onto individual-level predictors[1]

	Ever BP measured		**Diagnosed**		**Treated**		**Controlled**	
	RR	*P*	*RR*	*P*	*RR*	*P*	*RR*	*P*
Uni-variable regressions[2]								
Sex								
Male	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Female	1.16 (1.14-1.18)	<0.001	1.39 (1.33-1.46)	<0.001	1.50 (1.41-1.58)	<0.001	1.69 (1.53-1.87)	<0.001
Age group								
15-24 years	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
25-34 years	1.39 (1.33-1.46)	<0.001	1.51 (1.30-1.74)	<0.001	1.47 (1.22-1.77)	<0.001	1.09 (0.88-1.36)	0.426
35-44 years	1.52 (1.46-1.60)	<0.001	2.18 (1.93-2.47)	<0.001	2.24 (1.94-2.57)	<0.001	1.27 (1.09-1.48)	0.002
45-54 years	1.57 (1.50-1.65)	<0.001	3.14 (2.79-3.52)	<0.001	3.51 (3.08-4.00)	<0.001	1.67 (1.44-1.92)	<0.001
55-64 years	1.57 (1.50-1.64)	<0.001	3.87 (3.43-4.36)	<0.001	4.78 (4.17-5.49)	<0.001	2.15 (1.81-2.55)	<0.001
≥65 years	1.56 (1.48-1.64)	<0.001	4.21 (3.72-4.76)	<0.001	5.42 (4.72-6.22)	<0.001	2.10 (1.76-2.51)	<0.001
Education								
No schooling	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Primary school[3]	1.08 (1.05-1.10)	<0.001	0.97 (0.91-1.04)	0.454	0.97 (0.89-1.06)	0.462	1.02 (0.86-1.22)	0.807
≥ High school[4]	1.13 (1.11-1.16)	<0.001	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)	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
2	1.12 (1.09-1.14)	<0.001	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)	<0.001	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)	<0.001	1.19 (1.10-1.29)	<0.001	1.25 (1.13-1.39)	<0.001	1.23 (1.02-1.49)	0.026
5 (richest)	1.36 (1.32-1.40)	<0.001	1.31 (1.20-1.44)	<0.001	1.42 (1.27-1.58)	<0.001	1.65 (1.38-1.98)	<0.001
BMI group								
Underweight	0.82 (0.78-0.85)	<0.001	0.85 (0.75-0.96)	0.009	0.86 (0.72-1.02)	0.085	0.89 (0.72-1.10)	0.265
Normal weight	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Overweight	1.16 (1.14-1.18)	<0.001	1.21 (1.15-1.28)	<0.001	1.22 (1.14-1.31)	<0.001	1.02 (0.89-1.17)	0.730
Obese	1.25 (1.22-1.28)	<0.001	1.54 (1.43-1.66)	<0.001	1.66 (1.52-1.81)	<0.001	1.21 (1.05-1.40)	0.007
Tobacco smoking								
Not currently smoking	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Currently smoking	0.88 (0.86-0.90)	<0.001	0.76 (0.71-0.81)	<0.001	0.68 (0.62-0.74)	<0.001	0.59 (0.51-0.69)	<0.001

Multi-variable regression with age group, sex, and education[5]								
Sex								
Male	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Female	1.20 (1.18-1.23)	<0.001	1.40 (1.33-1.47)	<0.001	1.50 (1.42-1.59)	<0.001	1.78 (1.61-1.98)	<0.001
Age group								
15-24 years	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
25-34 years	1.42 (1.36-1.49)	<0.001	1.50 (1.30-1.73)	<0.001	1.46 (1.22-1.76)	<0.001	1.08 (0.87-1.35)	0.468
35-44 years	1.57 (1.50-1.65)	<0.001	2.12 (1.87-2.41)	<0.001	2.15 (1.87-2.48)	<0.001	1.23 (1.05-1.43)	0.010
45-54 years	1.66 (1.58-1.74)	<0.001	3.14 (2.79-3.54)	<0.001	3.49 (3.06-3.99)	<0.001	1.68 (1.45-1.95)	<0.001
55-64 years	1.66 (1.58-1.74)	<0.001	3.95 (3.48-4.48)	<0.001	4.86 (4.22-5.60)	<0.001	2.22 (1.85-2.66)	<0.001
≥65 years	1.68 (1.59-1.77)	<0.001	4.45 (3.90-5.08)	<0.001	5.74 (4.96-6.64)	<0.001	2.31 (1.90-2.82)	<0.001
Education								
No schooling	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Primary school[3]	1.14 (1.11-1.17)	<0.001	1.14 (1.06-1.23)	<0.001	1.18 (1.08-1.29)	<0.001	1.22 (1.03-1.46)	0.024
≥ High school[4]	1.26 (1.23-1.30)	<0.001	1.33 (1.24-1.42)	<0.001	1.39 (1.27-1.51)	<0.001	1.59 (1.34-1.88)	<0.001
Multi-variable regressions with all predictor variables[6]								
Sex								
Male	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Female	1.16 (1.14-1.18)	<0.001	1.26 (1.19-1.34)	<0.001	1.31 (1.22-1.42)	<0.001	1.54 (1.35-1.76)	<0.001
Age group								
15-24 years	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
25-34 years	1.33 (1.27-1.39)	<0.001	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 years	1.42 (1.36-1.49)	<0.001	1.73 (1.49-2.01)	<0.001	1.61 (1.37-1.89)	<0.001	1.03 (0.85-1.23)	0.790
45-54 years	1.50 (1.44-1.57)	<0.001	2.61 (2.27-3.01)	<0.001	2.67 (2.30-3.10)	<0.001	1.40 (1.18-1.67)	<0.001
55-64 years	1.47 (1.40-1.54)	<0.001	3.46 (2.96-4.06)	<0.001	3.92 (3.31-4.64)	<0.001	2.01 (1.60-2.53)	<0.001
≥65 years	1.47 (1.40-1.54)	<0.001	4.02 (3.42-4.73)	<0.001	4.76 (4.01-5.63)	<0.001	2.11 (1.65-2.69)	<0.001
Education								
No schooling	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Primary school[3]	1.08 (1.05-1.11)	<0.001	1.06 (0.97-1.16)	0.179	1.09 (0.98-1.21)	0.128	1.13 (0.90-1.43)	0.279
≥ High school[4]	1.11 (1.09-1.14)	<0.001	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)	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
2	1.09 (1.06-1.12)	<0.001	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)	<0.001	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)	<0.001	1.18 (1.07-1.30)	0.001	1.25 (1.11-1.41)	<0.001	1.17 (0.93-1.48)	0.186
5 (richest)	1.27 (1.23-1.31)	<0.001	1.28 (1.16-1.41)	<0.001	1.36 (1.21-1.53)	<0.001	1.56 (1.23-1.96)	<0.001
BMI								
Underweight	0.88 (0.84-0.91)	<0.001	0.84 (0.72-0.98)	0.030	0.83 (0.68-1.01)	0.057	0.87 (0.69-1.11)	0.263

Normal weight	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Overweight	1.08 (1.06-1.10)	<0.001	1.19 (1.12-1.27)	<0.001	1.20 (1.11-1.30)	<0.001	0.97 (0.83-1.13)	0.655
Obese	1.11 (1.09-1.13)	<0.001	1.47 (1.37-1.59)	<0.001	1.58 (1.45-1.72)	<0.001	1.01 (0.86-1.20)	0.873
Tobacco smoking								
Not currently smoking	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	
Currently smoking	0.94 (0.92-0.97)	<0.001	0.93 (0.86-1.00)	0.048	0.87 (0.79-0.96)	0.006	0.74 (0.62-0.89)	0.001

Abbreviations: BP=blood pressure; RR=Risk Ratio; P=P-value; Ref.=reference category;

[1] Standard errors were adjusted for clustering at the level of the primary sampling unit.

[2] These regressions included only one of the variables shown in the table and a binary indicator for each country (country-level ‘fixed effects’).

[3] This refers to having received some primary schooling or having completed primary school.

[4] This refers to having received some secondary schooling, having completed secondary school, or having received some type of tertiary education.

[5] These regressions included sex, age group, education, and a binary indicator for each country (country-level ‘fixed effects’).

[6] These regressions included sex, age group, education, household wealth quintile, BMI, tobacco smoking, and a binary indicator for each country (country-level ‘fixed effects’).